The Effect of Population Growth on Economic Growth: A Meta-Regression Analysis of the Macroeconomic Literature

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A stylized fact in the macroeconomic literature on population growth is the absence of a robust effect of total population growth on economic growth (Birdsall 1988; Dasgupta 1995; Kelley 1988, 2003; McNicoll 1984; Srinivasan 1988; World Bank 1984). The earliest forays into this literature in the 1960s and 1970s generally concluded that aggregate population growth had no significant effect (or perhaps even some positive effect) on economic growth (Kuznets 1967). This result was in several respects counterintuitive: neo-Malthusian antinatalist arguments were widespread at the time, chiefly voiced by non-economists (Ehrlich 1971); and Coale and Hoover (1958) had identified several ways in which population growth was likely to constrain economic development. The 1980s witnessed a marked shift in the literature, however. For one thing, economists became more influential (Kelley 1988, 2001) and brought to the debate new ideas about how population growth might positively affect development (especially in the long run), as well as new empirical evidence on the subject. Furthermore, the decline in population growth among OECD countries appeared to be slowing economic growth in these countries rather than accelerating it. Yet by the late 1990s this relatively neutral "revisionist" position was also being qualified by a new wave of research on cross-country growth, the so-called new growth empirics. This literature increasingly identified adverse economic effects of high population growth in the less developed countries (LDCs) (Kelley 1988, 2001), but also uncovered considerable diversity in results, largely based on different methodologies.

The differences were related to the time frame of the analyses, the types of countries considered, the nature of the control variables included, the way in which population growth was measured, and the statistical methods employed. Somewhat surprisingly, however, no previous research has comprehensively explored the extent to which these methodological differences do indeed account for the diversity of results in this literature.[1] The use of meta-regression analysis (MRA), which we conduct below, is ideal in these circumstances for several reasons:

First, a large number of cross-country growth regression studies include some measure of population growth as an explanatory variable. Second, many of the economic growth studies include population growth as an incidental control variable, even though the authors' primary interest lies in testing other determinants of growth. These two characteristics suggest that: (a) our hypothesis tests will be supported by considerable statistical power; and (b) this literature may not be unduly influenced by researcher biases, which MRA is sometimes used to test indirectly.[2]

Following from (b), a second advantage of MRA is that the absence of major research biases may allow us to uncover legitimate diversity in the results from this literature, and some of these results might have indirect policy relevance. For example, our results may answer the question posed by Kling and Pritchett (1994): Where in the world is population growth bad? Moreover, our findings may also provide broad insights into the mechanisms through which population growth affects economic development. This is especially important given that the theoretical literature outlines both positive and negative effects of population growth.

Finally, unlike many other research areas in the study of development, many economists feel that macro-demographic studies have significant advantages over the microeconomic literature. The latter is usually incapable of capturing the positive and negative spillovers associated with population growth, precisely because these effects are economy-wide and only evolve over long periods of time (Dasgupta 1995).[3] That said, the empirical growth literature has been widely criticized for its lack of robustness (Durlauf, Johnson, and Temple 2005; Roodman 2004; Sala-i-Martin 1997; Sala-i-Martin, Doppelhofer, and Miller 2004), and the population growth literature appears to be no exception.[4] So meta-regression analysis also provides an ideal means of systematically exploring the hyper-sensitivity of the macroeconomic literature.[5]

Literature review and initial hypotheses

A review of the literature allows us to generate some clear hypotheses as to how findings on the effect of demographic change on economic growth can be expected to differ and why. More detailed reviews of this literature can be found elsewhere (Birdsall 1988; Dasgupta 1995; Kelley 1988; Kelley and Schmidt 2001; McNicoll 1984; Nagarajan 2007; National Research Council 1986; Srinivasan 1988).

The earliest economic theories of population growth extend back to the classical economists, especially Malthus and Ricardo. Their concern lay with a stagnant agricultural sector in which the supply of arable land was fixed and in which labor suffered from sharply diminishing returns. Malthus contended that if fertility rose with income, the economy could be caught in a vicious cycle of boom and bust, temporary plenty followed by inexorable famine. More recent neoclassical models that largely focus on savings and capital accumulation (Solow 1956) outline how population growth can have an adverse short-run effect on growth. Coale and Hoover (1958), for example, identify a labor-supply effect in which high fertility rates (especially those that exceed death rates) lead to a lower proportion of people in the labor force (i.e., a higher dependency ratio). This effect is expected to decrease GDP per capita, but not necessarily output per worker. However, Coale and Hoover also identify a resource-dilution effect whereby existing resources, such as physical capital, are spread thin by population growth. Underlying this effect are two important assumptions. First, additional labor growth may come from households whose net contribution to the capital stock is less than average. Very young workers, for example, may save less, or fertility rates may be higher among the poorer sections of society. Second, this growth in population has negligible demand-side effects, so that an increase in population does not induce domestic or foreign entrepreneurs to increase their rate of investment. Finally, Coale and Hoover outline a resource diversion or substitution effect. A shift toward a younger population may induce governments and households to shift resources from directly productive areas into health and education expenditures, which are likely to be productive only in the long run. Subsequent studies also emphasized the deleterious effects of rapid urbanization, domestic conflict, less effective health and education services (if the resource diversion is incomplete), and accelerated environmental degradation (NAS 1971).

Although these theories found a sympathetic audience from antinatalist thinkers outside of economics, economists generally found very little support for the Coale–Hoover hypotheses. Kuznets (1967), in a widely cited review, concluded that there was no clear evidence of a negative relationship between population growth and economic growth, and subsequent work regularly attacked the mechanisms of resource dilution and resource diversion.[6] Oddly, the skeptical conclusions reached by economists in the 1960s and 1970s played a minor role in the broader interdisciplinary debate of the time, in which the pessimistic predictions of antinatalists and neo-Malthusians clearly captured the public imagination. By the mid-1980s, however, economists were at the heart of a revisionist movement that adopted a far more neutral position on population growth (Kelley 2001).

The theoretical source of this neutral stance is a greater emphasis on the long-run feedback effects of population growth, which are more closely associated with endogenous growth processes. Boserup (1965, 1981), for example, had challenged the Malthusian assumption that technological growth in agriculture was stagnant and argued that population pressure induced technological change. The Green Revolution in Asia seemed consistent with her notions. Simon (1981) analogously argued that population growth was merely an increase in the human capital stock, which should also lead to faster technology growth. He likewise cited the higher returns to public investments and public goods in population-dense economies (Simon 1992). In addition, "new" endogenous growth theories began to emphasize increasing returns to scale (Kremer 1993; Romer 1986) and agglomeration externalities (Krugman 1991). Moreover, the emergence of neoclassical theories of the family suggested that economic growth—especially growth in women's wages—was the best way to curb fertility rates (Schultz 1997). This more neutral stance was embodied in the widely cited 1986 National Academy of Sciences report, *Population Growth and Economic Development*, and in the policies of the administration of US President Ronald Reagan, as well as in prominent reviews by Kelley (1988), McNicoll (1984), Srinivasan (1988), and Birdsall (1988).

These reviews also explicitly emphasized that population growth had adverse effects only in some countries, mainly those at lower levels of development, and in countries with ineffective or inappropriate policy or institutional environments. Kelley (2001) terms the latter the "variables versus constraints" hypothesis. For example, in countries where public spending and trade barriers discriminate against the labor-absorbing agricultural sector, population growth exacerbates the problem. However, population growth only affects economic growth by interacting with institutional and policy factors. Hereafter, then, we term this the "institutional interactions" hypothesis.

In the 1990s, the debate took a different turn, and again pitted economic evidence against the prevailing "neutral" or "revisionist" consensus. The catalysts for these new findings were twofold. First, new growth empirics—especially the neoclassical convergence model pioneered by Barro (1989, 1991)—provided new data and new techniques with which to test old theories. Second, economists increasingly focused on more nuanced theories and measures of population growth, particularly the demographic transition in which declines in mortality rates are followed by declines in fertility rates, but only with a substantial lag (see, for example, Bloom and Freeman 1988). This sizable literature is the subject of our meta-regression analysis. A number of key features of the literature can be identified. First, growth regressions adopt a variety of techniques: estimators vary between ordinary least squares (OLS), weighted least squares (WLS), instrumental variables (IV), fixed-effects panels, and dynamic panels; data structures vary between long- and short-run cross-sections, and between cross-sections and panels; samples vary over time and over countries; and control variables vary enormously over a range of factors, including measures of education, health, policy, institutional quality, geographic location, and demographic status. As we noted above, reviews of the generic growth literature have often concluded that these choices can make a substantial difference to key findings.

A second feature of the more recent literature is that population growth variables that focus on adverse stages or components of demographic transition (high rates of fertility or births, high age-dependency ratios) are expected to have adverse short-run effects on growth. In contrast, growth in the adult or working-age population is generally expected to have a positive or neutral effect on economic growth. Kelley and Schmidt (1995) suggested that these new findings are largely consistent with the pattern of demographic change, and subsequent work by Bloom and Williamson (1998) and Radelet, Sachs, and Lee (1997) also emphasized age-distribution patterns.

A final feature is that the association between population growth and economic growth seems to have become negative, often significantly so, since the early 1980s, although it is not clear why this is so (Blanchet 1991; Bloom and Freeman 1988; Brander and Dowrick 1994; Kelley and Schmidt 1994, 1995).

Our review of the literature suggests a number of explanations for the variety of observed effects of population growth on economic growth. We conclude this section by outlining a list of hypotheses and the ways in which meta-regression analysis might provide evidence on them.

1) Population growth variables that emphasize the relative growth of the young/dependent population (ages 0–14 years) should show a more adverse effect on economic growth than measures of growth in the total or working-age populations.

2) Population growth has a more adverse effect under conditions of land scarcity, at least in the short run.

3) The partial association between population growth and economic growth will be more positive (less negative) when the regression controls for investment (the resource-dilution effect).

4) The partial association between population growth and economic growth will be more positive (less negative) when the regression controls for education expenditure (the resource-diversion effect).

5) Since education and health can also affect fertility rates and promote economic growth, a regression model that excludes education and health variables may lead to a more negative effect of population growth on economic growth because of multicollinearity problems.

6) The partial association between population growth and economic growth will be more positive (less negative) when the regression controls for the quality of policies and institutions (the institutional interactions hypothesis).

7) The effect of population growth on economic growth has been more adverse since 1980.

8) The effect of population growth on economic growth is more adverse in developing countries because of greater resource-dilution and resource-diversion effects, as well as poorer policy environments. A confounding factor here is that regressions which focus on smaller samples may have less statistical power, and key variables—such as population growth and economic

growth—may provide insufficient variation, which influences the precision of the OLS estimator (Greene 2003).

9) Differences in econometric methods account for some of the diversity in results, but it is difficult to say in which direction. If economic growth partly causes population growth, then valid instrumental variables estimators and fixed-effects or dynamic-panel estimators may reduce the economic growth effect of population growth. However, weighted least squares and the structuring of data (from short panels to long cross-sections) may influence results in either direction, depending on measurement issues, multicollinearity, and the temporal distribution of population growth effects (i.e., short run versus long run).

Next we show how meta-regression analysis can be used to test these hypotheses.

The theory and practice of meta-regression analysis

Although not yet employed in the literature on demography and economic growth, meta-regression analysis has been increasingly applied to a range of literatures within economics,[7] including new growth empirics (Abreu, de Groot, and Florax 2005; Doucouliagos 2005; Doucouliagos and Paldam 2006). Stanley and Jarrell (2005) provide a good overview of the MRA literature; here we focus on some of the basics.

Suppose that a sufficiently large number of statistical regression tests exist in a literature and that they take a sufficiently common form.[8] In the population growth–economic growth context this form is typically:

$$g_i = \beta_0 + \beta_n n + \overline{\beta}_z \overline{Z} + \varepsilon, \qquad \text{(Model 1: Original regression)}$$

where g is economic growth, n is some measure of population growth, $\overline{Z}$ is a set of control variables, and ε is an error term. The main coefficient of interest is β_n, an estimate of the impact of population growth on economic growth. The usual test of interest relates to whether β_n is significantly different from zero (a two-sided t-test).

The key idea of MRA is that although this “original” model takes a common basic form, different researchers could derive substantially different estimates of the effect of population growth on economic growth by varying the specific methods that they use to uncover β_n. They could measure economic growth and population growth in different ways. They could vary the set of control variables. They could make different assumptions about the error term by assuming that it is heteroskedastic (warranting WLS) or correlated with n or an element of Z (warranting instrumental variables, fixed-effects, or dynamic-panel methods). Or they could select different countries and different time periods, or structure their data as a panel or cross-section. The rationale of MRA is that the effects of these alternative methods are unlikely to be random or neutral.

To conduct an MRA, we first need to construct a dataset that comprises the results and methods of the existing literature. This would consist of different estimates of the impact of population growth on economic growth (β_n), as well as a larger set of variables that describe the principal characteristics of the regression models that generated each of these estimates. Appendix A describes the search process by which we derive this dataset and provides a summary of the data and a list of the studies that make up the dataset. Our basic approach was analogous to the approach used in medicine (a field in which MRA is widely employed) in that we began by conducting a search of the main economic research database (ECONLIT) using relevant keywords. We then consulted the reference lists of these papers as well as some of the principal resources on economic growth research. We assessed each paper to determine its suitability and proceeded to record key data if it satisfied the general form of equation (1). Our final dataset consists of data that record the characteristics of 471 "original regressions."

We record the key characteristics of each regression: the estimated impact of the population growth variable on economic growth (β_n); the standard error of β_n (s_k) and its t-statistic (β_k/s_k); the type of demographic measure used to generate β_n; the type of indicator used to measure economic growth; the types of measures employed among the control variables (Z); the sample size and structure of the data (e.g., panel, cross-section); and various properties of the sample (countries and time periods covered). Let all these characteristics—which, for reasons outlined below, generally take the form of dummy variables—be denoted by D.

With the data organized in this manner we can then estimate a meta-regression that seeks to explain the variation in population growth effects from the existing literature (or from the "original regressions"). These meta-regressions take the form:

$$t\text{-}stat = \beta_n / s_n = \gamma_0 + \gamma_d D + u \qquad \text{(Model 2: Meta-regression)}$$

In regression (2), the dependent variable consists of the t-statistics of the slope coefficients from the original regressions, which are simply the ratios of the estimated effects from these regressions (β_n) divided by the estimated standard errors (s_n). These t-statistics are then explained by the methodological dummy variables (D) and the usual error term (u).

An advantage of Model 2 over alternative models is that the t-statistic is a standardized variable, so that we can ignore issues regarding the measurement scales of the economic growth and population growth variables. This allows us to include a range of measures of population growth, such as total population growth, working-age or labor force growth rates, crude birth rates, age-dependency ratios (the ratio of non-working-age to working-age populations), and crude fertility rates (the number of infants a woman can be expected to give birth to in her lifetime), although in practice we disaggregate our meta-regressions by different classes of demographic measures.

A disadvantage of Model 2 is that we do not explain differences in the size of the estimated demographic effects in the literature. But in defense of our approach, *t*-statistics are a function of size, and they are arguably more important in a scientific sense because they refer to statistical significance. Indeed, most econometric studies focus greater attention on significance than size (Ziliak and McCloskey 2004). In any case, Appendix B reports a fuller set of results that includes a variation on Model 2 in which the dependent variable is the slope coefficients rather than the *t*-statistics.

Finally, a word on interpretation. Clearly the slope coefficients in Model 2 (i.e., γ_D) are the parameters of primary interest, since these indicate whether the methodologies used in the literature influence the findings of that literature. Note, however, that the intercept term in Model 2 (i.e.,γ_0) also has an important interpretation in this context. Depending on how the methodological dummy variables (*D*) are defined—that is, what the base comparisons are—the intercept from Model 2 may be interpreted as a "baseline effect."[9] In this study we define the dummy variables in such a way that the baseline effects (or intercept terms) relate to the most common and unrestricted methodology: OLS estimates of a full cross-section of countries with no control variables. The slope parameters from Model 2 (γ_d) therefore indicate how different methodologies lead researchers to obtain results that are above or below these baseline effects.

Technique-based explanations of the heterogeneity in population effects

Using the methodology described above, we report the key results of our MRA analysis. We first focus on the basic characteristics of our MRA dataset, including the raw variation in the estimated effects of population growth on economic growth. We then address the crucial question of how different demographic measures influence the effects estimated by the literature, before gauging the influence of other methodological choices on demographic effects.

An overview of the MRA dataset

Although the 471 estimates of demographic effects on economic growth recorded in our MRA dataset are derived from a broadly similar literature,

TABLE 1 Number of original regression results by variable class of independent and dependent variables from "original" regressions

Independent demographic variables

Total sample size	Total population growth	Young population growth			Adult population growth	
		Birth rate	Age-dependency ratio	Fertility rate	Labor force	Working age
471	163	36	21	22	139	90

Dependent growth variables

Total sample size	GDP per capita	GDP per worker	GNP per capita
471	238	225	8

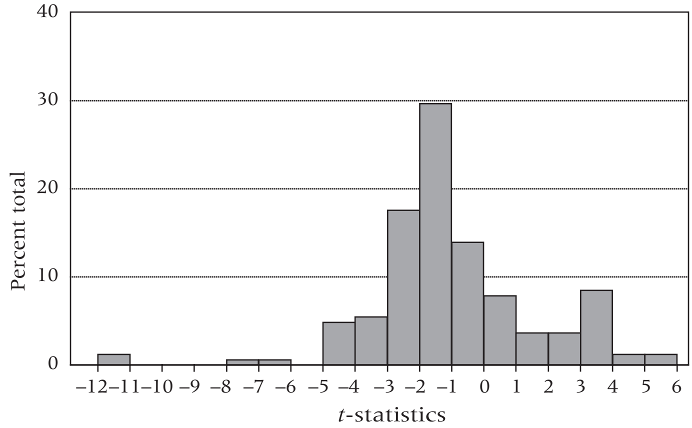
the first major difference among studies is the choice of how both population growth and economic growth are measured. Table 1 shows that economic measures are mostly evenly split between GDP per capita and GDP per worker (a handful of original regressions use GNP per capita). As for demographic measures, total population growth is the most common measure (N=163), followed by the two very similar measures of adult population growth (labor force growth, N=139; working-age growth, N=90), while three measures primarily relating to growth in the young (aged 0–14 years) population (fertility rates, birth rates, and the age-dependency ratio[10]) number only 79 observations.[11] Table B1 in Appendix B reports some simple correlations between these variables that confirm the above categorization.

The effects of alternative measures of population growth

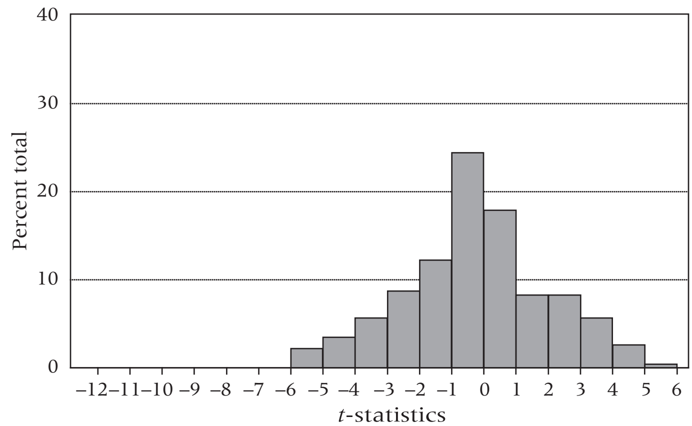
An initial question of interest is the extent to which the estimated effects of these three classes of demographic indicators vary across studies. The three panels in Figure 1 show the distribution of *t*-statistics for the effect estimates from the literature for our three types of population measures (we plot *t*-statistics rather than coefficients, because the former are scale-independent). In Panel A we observe that *t*-statistics associated with total population growth mostly vary from –5 to 5, and that many coefficients are insignificant at the 5 percent level (i.e., between –2 and +2). In Panel B the variation in measures of adult population growth similarly ranges from negative to positive values, although we find a larger portion of positive *t*-statistics, as expected. Panel C shows the distribution of coefficients for the three "young population" measures. As expected, these have typically far more negative values, and many of these are significant (less than –2). Indeed, only these young population growth measures are statistically significant on average, the mean *t*-statistic being –2.5. This may suggest that the negative effect of a fast-growing young population is stronger (larger in absolute size and more significant in a sta-

FIGURE 1 Distribution of *t*-statistics for measures of population growth in growth regressions

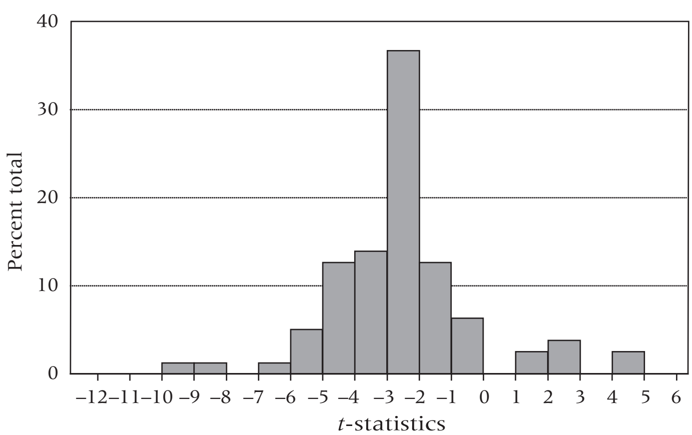
A. *t*-statistics for total population growth coefficients



B. *t*-statistics for working-age and labor force growth coefficients



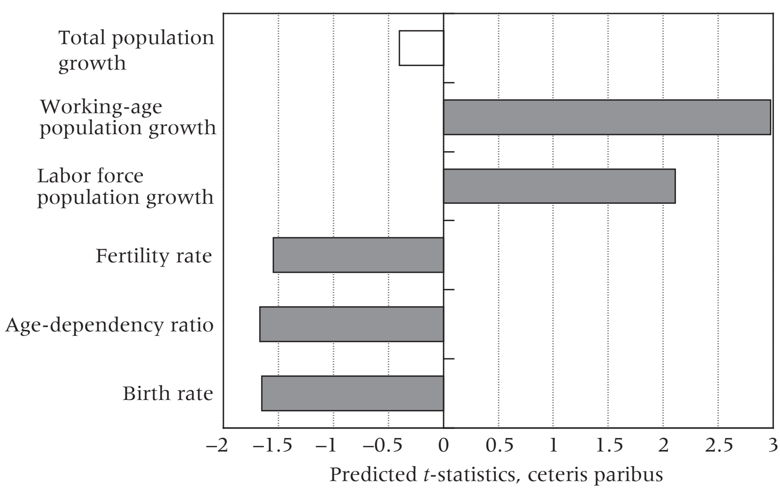
C. *t*-statistics associated with "young age" population change coefficients



tistical sense) than the positive effect of a fast-growing adult population. We discuss this possibility below.

The main finding we draw from Figure 1 is that there is a great deal of variation in the size and significance of population effects on economic growth. This clearly motivates our main research question: how much of this variation in population effects is explained by technical choices, and how much is actually substantive? To answer this question we test equation (2) for each of our three types of demographic measures. As we saw from the histograms in Figure 1, the distributions of *t*-statistics are by no means the same across these three classes of measures. Figure 2 presents predicted or "average" *t*-ratios for each type of measure after controlling for other methodological choices.[12] The figure indicates that the expected *t*-statistic for total population growth is less than one and therefore insignificant. Researchers who switched their demographic measure to working-age or labor force growth would expect to find a positive and significant effect of these variables on growth (i.e., *t*-statistics greater than 2). In contrast, switching to one of the three young-age population measures would lead to estimates of effects that were negative, although somewhat less statistically significant (significant at

FIGURE 2 Predicted *t*-statistics for alternative population growth measures



NOTES: These are predicted *t*-statistics from a regression with *t*-statistics from all population measures as the dependent variable. The set of explanatory variables includes all the dummies for alternative methods, including dummies for alternative population growth measures, with total population growth as the omitted category. Hence, the predicted value for total population growth in Figure 2 is simply the intercept term from this regression. The other predicted *t*-statistics are this intercept term plus the coefficient on the dummy variable for the alternative population growth measure in question. All the predicted *t*-statistics for these alternative measures are significantly different from the predicted *t*-statistic for total population growth (shaded bars), but the *t*-statistic for total population growth is not significantly different from zero (white bar).

the 10 percent level). Thus the choice of measure obviously makes a large difference to the results of population growth variables.

A second question is how to interpret these results. For example, if the growth of the young population has a negative effect now, but has a positive effect when the young population eventually reaches adulthood, then perhaps the overall effect of population growth is neutral, as the results above suggest. The literature offers no explicit means of testing this question since it does not include measures of the growth of the young population (0–14 years) versus the growth of the adult population (15 years and above). To offer preliminary insight into this question, we ran our own "original regression" using a sample of all large countries (developed and less developed), four ten-year periods from 1960 to 2000, and basic controls such as initial GDP per capita and three period dummies. We obtained a coefficient on young-age population growth of –1.07 that was highly significant, indicating that a one percentage point increase in young-age population growth reduces economic growth by just over one percentage point (a large effect). In contrast, the coefficient on working-age population growth was +0.55 but also highly significant.

These results suggest that, on average, the negative effect of young-age population growth is greater than the positive effect of working-age population growth, a result that we also confirmed with a formal statistical test.[13] Of course, these results might not be robust to the inclusion of additional control variables or to interactions between population growth and other variables.

The influence of alternative techniques

Although we tested numerous dummy variables representing the different techniques used in the literature, we confine our presentation to those variables that influenced results at the 10 percent significance level or higher. These are reported in Table 2, which disaggregates the results by the three classes of demographic measures and by whether the effect of each technique was to increase or decrease the original *t*-statistics. Asterisks alongside each indicator also indicate whether this technique had a strong effect on the *t*-statistics observed in the literature.

Beginning with population growth, which we previously observed to have insignificant effects on economic growth on average, three factors increased the *t*-statistics associated with total population growth. All of them relate to the control set (Z in Model 2): whether or not that set includes a health indicator, an income inequality indicator, or an investment indicator. These factors may account for important implicit interaction forces between population growth and other control variables. For example, Coale and Hoover (1958) emphasized a resource-dilution effect by which higher population growth reduces capital per worker. Controlling for capital via an investment term, for example, should purge the effect of population growth

TABLE 2 Summarizing the effects of methodological choices on the significance levels of demographic effects on economic growth

Demographic indicator	Factors that increase estimated effects	Factors that lower estimated effects
Total population (average effect is negative but close to zero)	Control set includes health indicator* Control set includes inequality* Control set includes investment*	Dependent variable is GDP per worker** Estimator is weighted least squares (WLS)** Data is 10-year panel structure** Time span mostly covers post-1980 period*** Control set includes coastal population density***
Adult population (average effect is positive)	Sample is developing countries rather than developed*** Sample is land-poor or population-dense** Time span covers 12–25 years*** Control set includes South Asia dummy*** Control set includes governance quality* Control set includes public education expenditure** Control set includes savings*	Time span mostly covers post-1980 period*** Control set includes East Asia dummy*** Control set includes health indicator*** Control set includes coastal population density* Control set includes education indicator*
Young population (average effect is negative)		Dependent variable is GDP per worker** Time span covers 12–25 years* Time span mostly covers post-1980 period** Control set includes public education expenditure**

NOTES: Table summarizes the results of three separate regressions—corresponding to the three demographic indicators listed above—of Model 2. (*), (**), and (***) indicate that the methodological dummy variable in question yielded a slope coefficient that was significant at the 10%, 5%, and 1% levels, respectively. The full results are listed in the tables presented in Appendix B.

on economic growth of this dilution effect. Similarly, faster population growth could be associated with poorer health conditions or higher inequality, so controlling for these factors tends to increase the *t*-statistic associated with population growth.

As for factors that have a negative association with *t*-statistics (meaning that these factors relate to significantly negative population change coefficients in the economic growth regression), several stand out as having substantial impacts. The most interesting result relates to the negative effect of using a time span that predominantly covers the post-1980 period, suggesting that the more adverse effect of population growth on economic growth after 1980 is a fairly robust stylized fact. The other variables relate primarily to techniques that have no obvious theoretical interpretation.

A large number of factors seem to influence the significance of the effect of adult population growth on economic growth. First, sampling developing countries, especially land-poor countries, seems to increase the significance of adult population growth, and the effects of sampling Asia and Africa are larger than those of sampling Latin America (full results are given in Appendix B). This result may be counterintuitive, but it could be related to the older population structure of richer countries. Some other positive effects are of interest: the inclusion of governance and public education indicators provides indirect support for the institutional interactions hypothesis; namely, that good education and labor market policies can better absorb surplus adult labor. Likewise, the inclusion of a savings variable offers indirect support to the resource-dilution hypothesis discussed above; however, this last effect is not very strong.

As for factors that reduce the effects of adult population growth, the inclusion of the post-1980 period again plays a significant role. However, control for education, health, and East Asian effects (which are also positively associated with growth) tends to reduce the estimated effect of adult population growth on economic growth. Given that an opposite result was found for public education expenditure, it is not clear how adult population growth and health and education factors interact. But our results do establish that the decision to include these indicators can have strong effects on the results of studies of demographic growth.

Finally, the typically negative effect of population growth at young ages is made even stronger by a small set of factors. First, using GDP per worker instead of GDP per capita again seems to reduce the estimated effects of population growth. Second, sampling a post-1980 period again pulls the estimated effects downward, or, in this case, more sharply negative. Third, including public education expenditure is associated with more negative effects of young population growth, in contrast to the adult population measures in which the inclusion of public education expenditure increased the positive effects. This finding may be related to a resource-dilution effect: faster growth of the young population draws resources away from directly productive investment and into education expenditure, which only bears fruit many years later when children join the labor force.

Conclusions

In this final section we revisit our initial hypotheses and summarize our findings. We conclude with a discussion of the theoretical and methodological implications of these findings.

Hypothesis 1. The age pattern of population growth matters. Although this is an unsurprising result, our meta-regression analysis allowed us to estimate the differences in t-statistics between alternative measures of population growth, after controlling for other methodological approaches. While total population growth appeared to have effects that are typically insignificantly different from zero, adult population growth had an expected positive and significant effect on economic growth, and measures of young population growth had the expected significant negative effects. Whether these contrary young-age and adult population growth effects cancel each other out is a question warranting further research. Running our own "original regressions," we found evidence that the adverse effects of young-age population growth tend to be larger than the positive effects of adult population growth. In keeping with other evidence, however, it may be that the effects of adult population growth are more dependent upon policies and institutions (see below).

Hypothesis 2. Population growth has a more adverse effect in conditions of land scarcity. In one instance—measures of adult population growth—we found that controlling for population density tended to increase the generally positive impacts of adult population growth. These findings are arguably consistent with Malthus's theory, but should not be construed as a direct test of that theory.[14] We also note that the few regressions which control for coastal population density greatly increase the adverse effect of total population growth, suggesting heterogeneity in the effect of population density on the relationship between population growth and economic growth.

Hypothesis 3. The partial association between population growth and economic growth will be more positive (less negative) when the regression controls for investment (the resource-dilution effect). In several meta-regressions for total and adult population growth, we found evidence consistent with dilution effects, namely an increase in population growth coefficients or t-statistics after controlling for investment or savings. Often the effect was weak, however.

Hypothesis 4. The partial association between population growth and economic growth will be more positive (less negative) when the regression controls for education expenditure (the resource-diversion effect). Controlling for public education expenditure modestly decreased the t-statistics associated with young-age population growth, but increased the coefficients associated with adult population growth. This suggests that public policies aimed at supplying education to a burgeoning young population may be costly initially, but pay off in the long run since a better-educated labor force has a more positive impact on growth. Admittedly, our evidence is only indirectly suggestive of this hypothesis.

Hypothesis 5. Since education and health can also affect fertility rates and promote economic growth, a regression model that excludes education and health variables may lead to larger effects of population growth on economic growth. We found mixed results for this hypothesis. Controlling for health increased coefficients for total population growth and decreased coefficients for adult population growth. Controlling for education decreased coefficients for adult population growth, but had no effect on total population growth coefficients. We conclude only that these control variables often influence the results and perhaps interact with measures of population growth. Our findings therefore do not inform economic or demographic theory, but they do suggest that specification of these variables can be influential.

Hypothesis 6. The partial association between population growth and economic growth will be more positive (less negative) when the regression controls for the quality of policies and institutions (the interaction effects hypothesis). We found limited support for this hypothesis in that controlling for governance quality (e.g., indexes of governance quality, trade openness, and the rule of law) and public education expenditure increased the significance of the effects of adult population growth on economic growth. This seems consistent with the idea that policies that discriminate against labor or that improperly enforce property rights tend to negatively influence the relationship between labor demand and economic growth.

Hypothesis 7. The effect of population growth on economic growth has been more adverse since 1980. More than any other hypothesis, this one received very strong support from our MRA. All of our meta-regressions suggested that wider sampling of post-1980 data significantly strengthened the adverse effects of population growth measures. This strong but still puzzling finding suggests that the burden of higher population growth has been increasing over time, even as population growth rates have been reduced in much of the developing world.

Hypothesis 8. The effect of population growth on economic growth is more adverse in developing countries. We found no strong support for this hypothesis, and in several instances found contradictory evidence. Specifically, the sampling of developing countries was associated with higher *t*-statistics for the effects of adult population growth on economic growth. In other findings it appeared that specific conditions of development—governance quality, education policies, levels of education and health—had significant influence on the relationship between population change and economic growth, but these various "level of development" variables did not exert a single consistent influence on the relationship between population growth and economic growth.

Hypothesis 9. Differences in econometric methods account for some of the diversity in results, but it is difficult to say in which direction. We did not find much consistency in the effects of alternative econometric techniques on the findings of this literature. The use of weighted least squares, ten-year panels, and different time coverage sometimes affected results, but no consistent patterns emerged, except that the use of panels (rather than cross-sections) sometimes reduced *t*-statistics and coefficients. These results support the notion that different estimation techniques regularly create robustness issues in cross-country econometrics.

While economists' explorations of demographic issues have become increasingly complex in the new growth empirics literature, a meta-regression analysis of this literature explains many of the specific sources of variation in key findings. These explanations have implications for policymakers and researchers. With regard to research, some issues in this literature merit closer study, especially if policy relevance is the yardstick by which one evaluates this research. First, in some instances geography appears to be another conditioning factor linking population growth to economic growth, but links between geography and demography have received little attention outside a small circle of researchers. Second, time matters. The demographic transition is difficult to model empirically, especially insofar as it predicts quite opposite effects over time, with having additional children first being a constraint on economic growth before eventually becoming a potential catalyst to such growth. Researchers should explore the complex means by which population growth influences development outcomes over longer periods of time. Finally, the considerable extent to which methodological choices explain variations in this literature must have an important bearing on future macroeconomic research into linkages between population growth and economic growth. Researchers should give careful thought to the structure and scope of their data, the choice of estimation technique, and, especially, the selection of control variables. The implication of this "methods matter" result is that researchers need to pay closer attention to the extent to which their results are sensitive to alternative assumptions and techniques.

With regard to policymaking, we provide robust evidence that population growth has had significantly more adverse effects on economic growth in the post-1980 period.[15] We find evidence that growth in the young population is the main drag on economic growth, while the effects of adult population growth are more varied and dependent upon such other factors as institutions and policies, especially with regard to labor, health, and education. Our results also identify some mechanisms through which population growth influences economic growth. Specifically, we found evidence that resource-dilution effects are consequential, since controlling for investment or savings tends to reduce the effect of population growth on economic growth. At the very least, these findings should prompt policymakers in developing countries to reconsider the importance of population growth, an issue that has been ignored since the late 1980s.

Appendix A. Construction of the dataset

The dataset was constructed in three steps. First, relevant studies were identified via ECONLIT, in which we used keyword searches such as "population growth," "demographic," "fertility," "age dependency," and "birth rate." These searches were carried out in conjunction with the term "economic growth" as well as separately. Each relevant paper found via ECONLIT was then explored for references to other studies that might have been missed by the search or not included in ECONLIT. These additional papers were then obtained from the journals in question or via standard web search engines. Finally, general economic growth studies (i.e., not necessarily focusing on population growth, but perhaps including population variables) were explored via the references of a major review of the empirical growth literature by Durlauf, Johnson, and Temple (2005), as well as the economic growth research website administered Jonathan Temple «http://www.bris.ac.uk/Depts/Economics/Growth/».

While these three steps completed our preliminary search, not all the regressions from the first-round papers could be included in our final MRA dataset. Our second-round selection criteria were as follows. First, we included only studies in English that were available as of December 2007. Second, we excluded any studies where some measure of economic growth was not the dependent variable. This excluded many papers in which population growth measures were themselves the dependent variable. Third, we included only studies that supplied sufficient information on the direction and magnitude of the effect of population growth on economic growth as well as the corresponding standard error and *t*-statistic. Fourth, we excluded studies where information on model specifications and/or estimation techniques was unavailable or not clearly explained. Fifth, we excluded specifications that included a nonlinear relationship between population growth and economic growth. For example, some specifications in the literature included interaction terms of population growth with initial income, and others specified the log of fertility. Because we are interested in coefficient magnitudes and not just *t*-statistics, we omitted these specifications to ensure consistency. Even so, by excluding these nonlinear specifications we eliminated less than 5 percent of the total number of regressions for which we collected data.

In sum, our dataset comprised 22 journal articles, six working papers, one book chapter, and one conference series publication. The final dataset contained data on 471 regressions from 29 prominent studies in the literature. While the number of studies is perhaps too small to be considered an exhaustive search of the vast literature on economic growth, most if not all of the widely cited studies are included. Hence, we believe this dataset is a sufficiently representative description of the relevant literature.

TABLE A1 Studies used in the meta-analysis

Author(s)	Type of population growth estimate	Number of estimates	Average coefficient of population growth
Barro 1991	fertility rate	2	–0.178
Barro and Lee 1994	total population	2	0.240
Beaudry et al. 2002	working-age pop.	36	–0.424
Beaudry et al. 2005	working-age pop.	19	–0.529
Bloom et al. 2000	total population	6	–1.689
	working-age pop.	6	1.996
Bloom and Malaney 1998	total population	2	–1.070
	working-age pop.	4	0.745
Bloom and Sachs 1998	total population	2	–1.034
	working-age pop.	2	–0.056
Bloom and Williamson 1998	total population	12	–1.298
	working-age pop.	10	1.852
Brander and Dowrick 1994	total population	45	–0.529
	birth rate	36	–0.792
Cho 1996	total population	2	–0.257
Commander et al. 1997	total population	10	–0.254
Easterly et al. 1997	total population	2	–0.815
Galor and Zang 1997	total population	10	–0.224
	fertility rate	18	–0.552
	age-dependency ratio	13	–2.429
	labor force	18	0.396
Grier and Tullock 1989	total population	9	0.635
Hamoudi and Sachs 1999	total population	5	–1.268
	fertility rate	2	–0.008
	working-age pop.	5	1.851
Kelley and Schmidt 2001	total population	3	–0.803
	labor force	1	–0.950
Klasen 2002	total population	5	–0.736
	working-age pop.	5	0.824
Kling and Pritchett 1994	labor force	120	–0.020
Kormendi and Meguire 1985	total population	6	0.615
Landau 1986	total population	1	–0.199
Lee and Lin 1994	total population	8	0.695
	age-dependency ratio	8	0.003
Levine and Renelt 1992	total population	5	–0.200
Mankiw et al. 1992	working-age pop.	3	–0.167
Mauro 1995	total population	7	–0.539
Otani and Villanueva 1990	total population	8	–0.981
Ram 1986	total population	8	0.874
Sachs and Warner 1997	total population	2	–0.210
Skinner 1987	total population	1	–0.658
Yasin 2003	total population	2	–0.002

NOTES: See "Articles used in the meta-analysis" for a bibliography. The dataset contains a total of 471 estimates. All population growth measures are growth rates, except the age-dependency ratio.

Articles used in the meta-analysis

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Appendix B. Statistical results

TABLE B1 Correlation matrix between population growth measures

	1 Age-dep. ratio	2 Birth rate	3 Fertility rate	4 Total pop.	5 Labor force	6 Working age
1. Age-dependency ratio	1.00					
2. Birth rate	0.77	1.00				
3. Fertility rate	0.79	0.97	1.00			
4. Total population growth	0.59	0.63	0.65	1.00		
5. Labor force growth	0.53	0.76	0.78	0.88	1.00	
6. Working-age population growth	0.54	0.35	0.36	0.87	0.56	1.00

NOTES: Correlations are based on panel data constructed as 10-year averages or initial values covering 1960 to 2001.

TABLE B2 MRA results for *t*-statistic regressions (*t*-stat) and coefficient regressions (coeff.) for total population growth only

MRA explanatory variable	γ(*t*-stat)	λ(coeff.)	MRA explanatory variable (control set includes)	γ(*t*-stat)	λ(coeff.)
Constant (base specification effect)	0.73	0.11	East Asia dummy	0.29	0.32
Dependent variable is GNP per capita	2.86	0.26	Latin America dummy		
Dependent variable is GDP per worker	–2.39**	–0.30	South Asia dummy	–0.75	–0.39
Estimator is dynamic panel	–4.60	–0.61	SSA dummy	1.32	0.31
Estimator is fixed-effects panel	0.46	–0.36	Age-dependency ratio	–0.51	–0.51#
Estimator is IV	–0.19	–0.55	Civil rights	–0.53	–0.17
Estimator is WLS	–1.88**	–0.63*	Coastal population density	–11.81**	–4.66**
Time span <12 years	–0.08	0.30	Education	–3.85***	–0.88***
Time span is 12–25 years	1.46	0.82#	Geography	–6.58#	–4.10*
Data is 10-year panel structure	–2.39**	–0.77**	Governance quality	1.04	0.27
Data is 5-year panel structure	–2.57	0.24	Health	1.63*	0.77*
Sample is all Africa	–2.26	–0.88	Inequality	4.62*	–0.93
Sample is Asia	–3.01#	–1.08#	Investment	1.59*	0.40**
Sample is developed countries	2.69#	0.34	Monetary policy	0.25	–0.002
Sample excludes poorest 40 percent	0.40	0.12	Total population	–3.79	–1.79
Sample is land-poor			Population density	6.57#	2.82#
Sample is land-rich			Public education expenditure	–2.82	–0.49
Sample is Latin America	–0.86	–0.58	Public expenditure	1.14	0.49**
Sample is less developed countries	–0.35	–0.34	Savings	–1.10	–0.95**
Sample is low-income LDCs					
Sample is middle-income LDCs					
Sample excludes sub-Saharan Africa (SSA)			R-squared	0.62	0.48
Sample is sub-Saharan Africa	–1.34	–0.80*	Adjusted R-squared	0.51	0.33
Time span mostly covers post-1980 period	–1.85***	–0.87*	Number of observations	163	163

NOTES: In the case of "γ(*t*-stat)" the dependent variable is the *t*-statistic associated with a population growth coefficient from a cross-country growth regression. In the case of "λ (coeff.)" the dependent variable is the slope coefficient associated with a population growth coefficient from a cross-country growth regression (see Headey and Hodge 2008 for a fuller discussion of these different models). Although the results are estimated by OLS, standard errors are derived from a bootstrap estimation with 1000 replications. (*), (**), and (***) indicate significance at the 10%, 5%, and 1% levels, respectively, and (#) indicates marginal insignificance at the 10 percent level.

TABLE B3 MRA results for *t*-statistic regressions (*t*-stat) and coefficient regressions (coeff.) for working-age and labor force growth measures

MRA explanatory variable	γ (*t*-stat)	λ (coeff.)	MRA explanatory variable (control set includes)	γ (*t*-stat)	λ (coeff.)
Constant (base specification effect)	–4.63	–1.05**	East Asia dummy	–2.09***	–1.75**
Dependent variable is GNP per capita			Latin America dummy	–4.11	–1.00
Dependent variable is GDP per worker	2.11	0.68	South Asia dummy	9.74***	2.71**
Population growth is labor growth	1.57	0.28	SSA dummy	–0.16	–0.16
Estimator is dynamic panel			Age-dependency ratio	–0.35	–0.03
Estimator is fixed-effects panel			Civil rights	1.17	1.48#
Estimator is IV	–0.40#	0.19	Coastal population density	–3.62	–2.42*
Estimator is WLS	–0.22	0.12	Education	–0.25	–0.14
Time span <12 years	0.03	0.004	Geography		
Time span is 12–25 years	1.17***	0.08	Governance quality	5.33*	1.50
Data is 10-year panel structure	1.47	0.05	Health	–1.62***	–1.23***
Data is 5-year panel structure	0.47	–0.97*	Inequality	1.35#	0.34
Sample is all Africa	1.23***	0.15*	Investment	0.34	0.19
Sample is Asia	2.58***	0.49***	Monetary policy	0.28#	0.05
Sample is developed countries	0.21	–0.06	Total population		
Sample excludes poorest 40 percent			Population density	4.74*	3.36**
Sample is land-poor	0.88**	0.10#	Public education expenditure	2.06**	0.59**
Sample is land-rich	0.21	–0.01	Public expenditure		
Sample is Latin America	1.93***	0.32***	Savings	4.12*	1.99*
Sample is less developed countries	1.40***	0.18***			
Sample is low-income LDCs	1.24***	0.16**			
Sample is middle-income LDCs	0.41	0.00			
Sample excludes sub-Saharan Africa (SSA)	0.29	–0.18	R-squared	0.83	0.87
Sample is sub-Saharan Africa	5.84**	2.66**	Adjusted R-squared	0.80	0.84
Time span mostly covers post-1980 period	–1.60***	–0.33***	Number of observations	229	229

NOTES: In the case of "γ (*t*-stat)" the dependent variable is the *t*-statistic associated with a population growth coefficient from a cross-country growth regression. In the case of "λ (coeff.)" the dependent variable is the slope coefficient associated with a population growth coefficient from a cross-country growth regression (see Headey and Hodge 2008 for a fuller discussion of these different models). Although the results are estimated by OLS, standard errors are derived from a bootstrap estimation with 1000 replications. (*), (**), and (***) indicate significance at the 10%, 5%, and 1% levels, respectively, and (#) indicates marginal insignificance at the 10 percent level.

TABLE B4 MRA results for *t*-statistic regressions (*t*-stat) and coefficient regressions (coeff.) for fertility, age-dependency ratio, and birth rate

MRA explanatory variable	γ(*t*-stat)	λ (coeff.)	MRA explanatory variable (control set includes)	γ(*t*-stat)	λ (coeff.)
Constant (base specification effect)	–0.04	–4.48**	East Asia dummy		
Dependent variable is GNP per capita			Latin America dummy		
Dependent variable is GDP per worker	–1.05**	–1.35#	South Asia dummy		
Population growth is birth rate	–3.05#	3.43#	SSA dummy	0.18	0.27
Population growth is fertility	0.01	2.01#	Age-dependency ratio		
Estimator is dynamic panel			Civil rights	–0.02	
Estimator is fixed-effects panel			Coastal population density		
Estimator is IV			Education	–1.53	4.33*
Estimator is WLS	–0.40	0.29	Geography		
Time span <12 years	1.33	0.61	Governance quality		
Time span is 12–25 years	–3.94*	1.39#	Health		
Data is 10-year panel structure			Inequality	0.50	–0.55
Data is 5-year panel structure			Investment	0.45	0.87
Sample is all Africa			Monetary policy		
Sample is Asia			Total population		
Sample is developed countries			Population density	2.56	2.19
Sample excludes poorest 40 percent	0.70	0.18	Public education expenditure	–1.09**	–1.44*
Sample is land-poor			Public expenditure	–1.60	–3.05
Sample is land-rich			Savings		
Sample is Latin America					
Sample is less developed countries (LDCs)	0.88	0.12			
Sample is low-income LDCs					
Sample is middle-income LDCs					
Sample excludes sub-Saharan Africa (SSA)			R-squared	0.39	0.43
Sample is sub-Saharan Africa			Adjusted R-squared	0.22	0.28
Time span mostly covers post-1980 period	–3.11**	–1.40**	Number of observations	79	79

NOTES: In the case of "γ (*t*-stat)" the dependent variable is the *t*-statistic associated with a population growth coefficient from a cross-country growth regression. In the case of "λ (coeff.)" the dependent variable is the slope coefficient associated with a population growth coefficient from a cross-country growth regression (see Headey and Hodge 2008 for a fuller discussion of these different models). Although the results are estimated by OLS, standard errors are derived from a bootstrap estimation with 1000 replications. (*), (**), and (***) indicate significance at the 10%, 5%, and 1% levels, respectively, and (#) indicates marginal insignificance at the 10 percent level.

Notes

1 Kling and Pritchett (1994), Kelley and Schmidt (1994, 1995), Brander and Dowrick (1995), and others have commendably undertaken informal sensitivity analyses as well as replications and extensions of previous results in the literature.

2 In an earlier version of our article we included results of tests for research bias. Results are available on request from d.headey@cgiar.org.

3 As Dasgupta (1995: 1881) puts it: "the study of a single household is not a propitious one in which to explore the possibilities of collective failure."

4 Birdsall and Sinding (2005: 5) conclude that "debate among economists about the effects of population growth has often clouded rather than clarified policy."

5 Of the merits of MRA, Standley and Jarrell (2005: 303) write: "Armed with the results of a MRA, the reviewer is in a better position to identify trends and to make inferences about the literature. As long as the meta-model is not misspecified, it represents the best scientific estimate of the underlying effect found in the literature. The reviewer can systematically estimate the critical parameter in question using the entire empirical literature rather than a chosen few that the usual space restrictions permit."

6 See Kelley (1988, 2001) for overviews.

7 In labor economics, Card and Kruger (1995) undertook a meta-analysis of the effect of a minimum wage on employment. Gorg and Strobl (2001) conducted a meta-analysis of the literature on multinational companies and productivity spillovers. Mookerjee (2006) performed a meta-analysis on the relationship between exports and economic growth. In environmental economics, a number of meta-analyses have been conducted, including tourism multipliers, air pollution valuation, risk and value of life, pesticide price policy, travel time savings, and transport externality and policy issues (see van den Bergh et al. 1997 for a review). In the demography literature Waldorf and Byun (2005) used meta-analysis to investigate the sources of variation in the numerous estimated effects of age structure on fertility.

8 In this case we focus solely on linear models. Some specifications in the literature include interaction terms with initial income, and others specify the log of fertility. Because we are interested in coefficient sizes and not just *t*-statistics, we omit these regressions.

9 The constant in an MRA regression is sometimes erroneously referred to as the "true" effect, but this presumes that the baseline methods are the "true" methods, which may not be the case.

10 The age-dependency ratio is the ratio of the working-age population to the non-working-age population.

11 A few studies use other measures, such as change in the age-dependency ratio. Most of these measures were taken from the same source (the United Nations), and most are self-explanatory. The fertility rate and the birth rate are perhaps exceptional in that these are sometimes measured in gross terms, and sometimes net of infant deaths. However, in our preliminary analysis we found that these measurement issues did not significantly influence results, so we grouped gross and net measures together.

12 We do this by running a regression with all 471 *t*-statistics as the dependent variable (because these are scale-independent) against dummy variables for five of the six population measures (total population growth is the omitted "base" category) plus all other dummy variables for alternative types of methods (we do not report the full regression, but it is available on request from d.headey@cgiar.org). As noted above, in such a regression the intercept term reflects the average *t*-statistic for total population growth after controlling for all other methodological effects, and the intercept term plus the coefficient of the dummy variable for each of the five population measures represents the expected *t*-statistic for that particular measure.

13 Other details of this regression are as follows. Large countries are those with more than one million people in 1980, which is standard in the literature. The *r*-squared of our regression was 0.25 and the coefficient on initial GDP per capita was negative but insignificant, while the period dummies for

the 1980s and 1990s were significant and negative. A Wald test to determine whether young-age and working-age population growth coefficients were of equal absolute magnitude was rejected at the 1 percent level. We also ran a small set of sensitivity tests, such as restricting the sample to developing countries and adding simple control variables. Generally the results were robust, but adding more control variables tended to reduce the difference between the two coefficients, rendering the overall effect of population growth more neutral.

14 More direct tests would involve modeling interaction effects between population growth and population density. Also, the fact that adult population growth effects increased in developing countries is arguably inconsistent with Malthusian theory.

15 To some extent, population growth issues have been surmounted or subsumed by related issues, such as migration, aging, HIV/AIDS, malnutrition, and the broader set of issues covered by family planning and reproductive health. But it is also true that many social scientists have increasingly regarded high population growth either as a symptom of low economic growth or as a variable that is difficult to influence with direct policy measures.

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