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Population Growth, Factor Accumulation, and Productivity

New insights — from new data — on the relationship between population growth, factor accumulation, and productivity.

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Summary findings

In research on how population growth affects economic performance, some researchers stress that population growth reduces the natural resources and capital (physical and human) per worker while other researchers stress how greater population size and density affect productivity.

Despite these differing theoretical predictions, the empirical literature has focused mainly on the relationship between population growth and output per person (or crude proxies for factor accumulation). It has not decomposed the effect of population through factor accumulation and the effect through productivity.

Pritchett uses newly created cross-country, time-series data on physical capital stocks and the educational stock of the labor force to establish six findings:

- There is no correlation between the growth of capital per worker and population growth.
- The common practice of using investment rates as a proxy for capital stock growth rates is completely unjustified, as the two are uncorrelated across countries.
- There is either no correlation, or a weak positive correlation, between the growth of years of schooling per worker and the population growth rate.
- Enrollment rates are even worse as a crude proxy for the expansion of the educational capital stock, as the two are negatively correlated.
- There is no correlation, or a weak negative correlation, between measures of total factor productivity growth and population growth.
- Nearly all of the weak correlation between the growth of output per person and population growth is the result of shifts in participation in the labor force, not of changes in output per worker.

This paper — a product of the Poverty and Human Resources Division, Policy Research Department — is part of a larger effort in the department to . Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Sheila Fallon, room N8-030, telephone 202-473-8009, fax 202-522-1153, Internet address sfallon@worldbank.org. January 1996. (33 pages)

Population growth, factor accumulation, and productivity

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Population growth, factor accumulation, and productivity[1]

Introduction

Is population growth good or bad for economic performance? This question has stubbornly resisted a satisfying theoretical or empirical resolution[2]. Some theories suggest that more rapid population growth should be bad for economic performance because with a larger population each worker will have less productive factors, both non-accumulated and accumulated, to work with. Other theories suggest that greater population growth will lead to greater productivity either by inducing innovation, producing innovation, or through creating greater economies of scale, specialization or agglomeration (Boserup, 1981, Simon, 1992, Kremer, 1993). Robert Cassen's (1994) recent summary of the state of the art in research on population and development, states nicely the conventional wisdom of contrasting negative factor accumulation effects versus possibly positive productivity effects:

> What about the effect of population on ***per capita*** income? Here simple economics suggests that the effect is probably negative. Unless population exerts a strong positive influence on capital formation-and the suggestion that it does is a minority opinion-the more people there are, and the less capital there is per person; as a result even though total output may be larger with a bigger population, output per person is smaller. There are however, three arguments against this: larger population may generate economies of scale; they may induce favorable technological change; and when population is growing, the average age of the labor force will be younger, which may have beneficial productivity effects.

The fact that the different theories predict a different causal mechanism whereby

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[1] Many thanks to Deon Filmer for insightful comments.

[2] For discussion of the nature of the "general agreement" that "persistent widespread poverty" is influenced by population growth rates adopted by the in the Programme of Action of the recent International Conference on Population and Development in Cairo see Demeny, 1994.

population affects economic performance suggests a possible resolution of the old and persistent empirical puzzle of the generally small and statistically insignificant impacts of population growth on the growth of GDP per capita (Kuznets 1960; Kelley and Schmidt 1994, Kling and Pritchett 1995). Table 1 presents the basic regressions of the per annum growth rate over the entire period of output per worker and population growth[3]. The table shows the weak, ambiguous, and imprecisely estimated correlation of output growth with population growth, especially in the developing countries, that is typical of the literature.

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[3] A number of more recent papers (Brander and Dowrick 1994, Kelley and Schmidt 1994) have gone beyond the growth rates over the entire period of data availability and have either disaggregated the data into shorter subsets and run separate regressions (e.g. by decades in Kelley and Schmidt) or have made the data into a panel using growth rates over shorter periods (e.g. five year averages in Brander and Dowrick). However, I only use the growth rates over the entire period because populations, and more especially the data on populations, change only very slowly compared to the large, rapid changes seen in output. Although population data is available at five year intervals for nearly every country in the world through U.N. and World Bank sources this is only because the data are created to be reported. For instance, in table 5 of the UN Demographic Yearbook, 1990 (published in 1992) annual estimates of mid-year population 1981-1990 are reported for Tanzania, El Salvador, and Nigeria even though the latest population census for those countries was, respectively, 1978, 1971 and 1963! This is not to say that the population figures are necessarily unreliable about the level of a country's population. But it is questionable whether the change in a country's population growth rate between say, 1980-85 and 1985-90 in countries whose latest census is 1985 or before (which is the case for 45 of 60 African and 28 of 36 American countries) has any real information content at all. Second, even if the data were perfect, actual population growth represents primarily individual country growth trends and very little variation across time periods, in sharp contrast the huge changes and very low persistence of economic growth rates over time (Easterly, et. al., 1993). At five year average observations over the 30 year period 1960 to 1990, 84 percent of the total sample variance in population growth rates is accounted for by country fixed effects. In contrast in the same sample, country fixed effects account for only 23 percent of the variation in GDP growth rates (this small fraction is even more dramatic for annual data while the share of output variation due to country effects is quite small even over as long a periods as a decade). Therefore, the move to shorter periods of data is unlikely to provide any meaningful information about long-run growth effects.

Table 1: Population growth and the growth of GDP per worker Dependent variable: Growth rate of GDP per worker, 1960-87.						
	Summers-Heston (PWT5) data			World Bank data		
	All	LDC	DC	All	LDC	DC
Population growth	-.024. (.132)	.267 (.880)	-.649 (1.10)	-.322 (1.74)	-.123 (.336)	-.516 (.866)
N	112	89	23	80	58	22
R-Squared	.000	.009	.055	.038	.002	.036
Note: Absolute value of t-statistics in parenthesis.						

Perhaps the factor dilution effects of population growth leaving each worker with less to work with are on average just offset by the productivity enhancing effects that make each worker more productive that the net impact of population growth on output per worker is small enough to be statistically indistinguishable from zero. This paper explores this possibility empirically using recently created cross national, time series, data sets on GDP, physical capital stocks and the educational attainment of the labor force. This data and the use of a standard model of economic growth allows the decomposition of the growth of output per worker into a component due to the accumulation of factors of production (physical and human capital) and a residual (which can be called "total factor productivity" or TFP).

I take the approach that the aggregate GDP (value added) function can be adequately approximated as a constant returns to scale Cobb Douglas production function with factor neutral technical progress using physical capital (K), human capital (H) and labor (L) (equation 1).

1)

$$Y(t) = A(t) K_t^{\alpha_k} H_t^{\alpha_H} L_t^{\alpha_L}$$

With these particular (and restrictive) assumptions the growth rate of output per worker can be expressed (by dividing through by the labor force, taking natural logs, and differentiating with respect to time) as linear function of the growth of the physical capital stock growth ($\dot{k}$), human capital per worker growth ($\dot{h}$) and a change in the production function multiplier ($\dot{a}(t)$) (equation 2).

2)

$$\dot{y} = \alpha_K \dot{k} + \alpha_H \dot{h} + \dot{a(t)}$$

In equation 3, I define TFP growth as the residual part of growth captured in this model by the time rate of production change of the production function scale factor[4].

3)

$$\dot{TFP} \equiv \dot{y} - \alpha_K \dot{k} - \alpha_H \dot{h}$$

Since I am working with a production function I use the growth of output per worker as the dependent variable. The growth of output per person is a different conceptual question as it involves the determination of participation rates (see below). I use the labor force series implicit in the Summers Heston (1991) data set which are derived from the ILO series on "economically active population" rather than use just labor force aged population[5].

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[4] I deliberately use the initials TFP to emphasize that this is not productivity in the broad sense, but a particular model dependent concept. Any other growth model would give a different definition of TFP.

[5] Much of the literature (e.g. Mankiw, Romer, Weil, 1992) does not use actual estimates of the labor force in assessing output per worker but instead output per person aged 15-64 usually calling this the "potential" labor force. This is typically defended on the grounds that data on labor force are notoriously unreliable and because the concept of "economically active population" which is used to estimate the labor force is extremely difficult to pin down. However, no matter how bad the ILO data on the "economically active population" are, they are better than assuming

I) Population growth and physical capital per worker

Q: Did countries with more rapid population growth have a lower rate of growth of capital per worker?

A: No.

To answer this question I use two newly created estimates of the stocks of physical capital [6]. Nehru and Dhareshewar (N-D) (1993) use World Bank data on gross investments since 1960 and an estimate of the initial capital stock to create perpetual inventory estimates of the stock of physical capital for 93 developed and developing countries from 1960 to 1987.[7] Independently, King and Levine (K-L) (1994) created estimates of capital stocks using the perpetual inventory method and an initial capital stock estimate, but using the GDP and investment rate data from Summers and Heston (1991) Penn World Table, Mark 5 (PWT5) for 136 developed and developing countries for 1960-1988. In spite of the differences in methods and data, the correlation between the country capital stock growth rates calculated from the these two series is a quite high .88.

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what is known to be false, a 100 percent participation rate for all men and women of a certain age group. Moreover, the assumption implicit in using "labor force aged population" is false in a way which creates biases because of the relationship between population growth and labor force participation.

[6] I want to emphasize that all of the empirical estimates are of a simple, linear, bivariate relationship. I am only asking the factual question about the linear correlation between the various variables and population growth. I am not estimating and particular structural model or identifying any parameters. All statements about the "relationship" or "effect" or "impact" of population growth should be interpreted in this very limited sense of linear association.

[7] The two principal drawbacks of the Nehru capital stock series is that they do not incorporate any information on the relative price of investment goods or on the composition of investment. DeLong and Summers, 1991, have shown both of these to be important in relating investment to economic performance. Investment prices vary a great deal across countries and comparisons of capital stocks across countries will overstate the productive stock of capital in countries with high capital goods prices. They also show that equipment investment (e.g. machinery) tends to be much more important in explaining growth that other types (e.g. structures and transport).

Table 2 presents the results of regressing the growth of capital per worker on population growth for both series for three country groups: all countries, just developing countries (LDCs) and just developed countries (DCs). For the entire sample the N-D data shows a very small and insignificant *negative* effect while the K-L data show a small and insignificant *positive* effect. Intriguingly, when the sample is split into developed and developing countries the estimate is positive (while insignificant) for both capital stock series in the LDC sample, but negative (although still insignificant) for both developed country samples.

Table 2: Population growth and the growth of physical capital per worker.

Dependent variable: Growth rate of physical capital per worker, 1960-87.

	Nehru-Dhareshewar data			King-Levine data		
	All	LDC	DC	All	LDC	DC
Population growth	-.083 (.313)	.077 (.163)	-.699 (.738)	.200 (.736)	.407 (.901)	-.652 (.732)
N	89	66	23	112	89	23
R-Squared	.001	.000	.025	.005	.009	.025

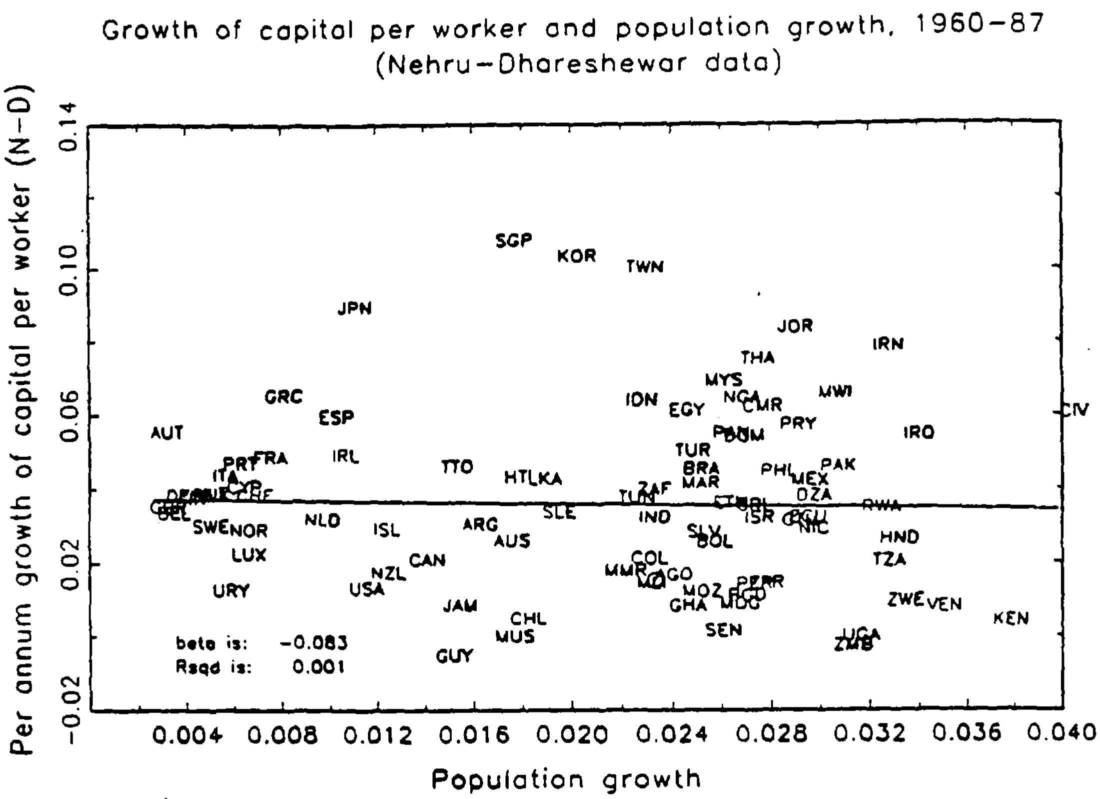
Note: Absolute value of t-statistics in parenthesis.

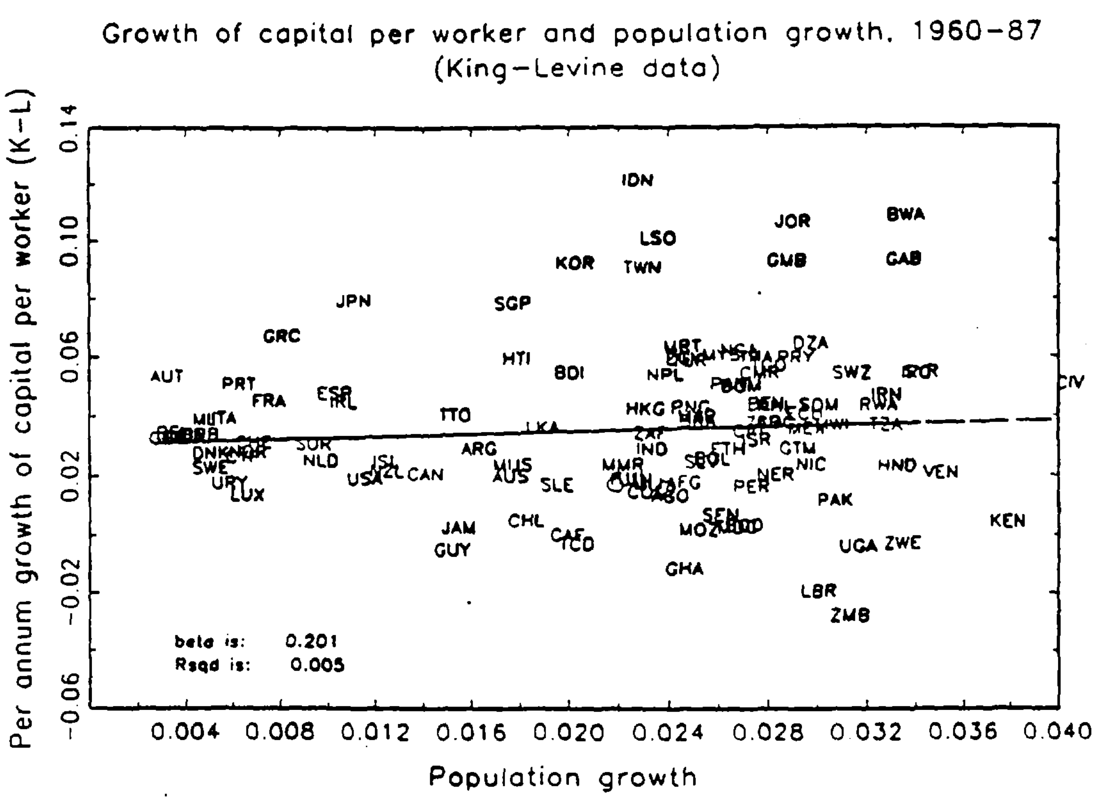
In either case the role of population growth as a determinant of the accumulation of physical capital per worker is very small, as indicated by the extremely low R^2 values. For the LDCs never more than 1 percent of the capital per worker growth variance is associated with population growth. As illustrated in figure 1 there is tremendous variation in the rate of capital stock growth per worker, from a maximum of over 10 per annum in the East Asian Dragons to a average of minus one percent per annum in Zambia, while the population growth rates are rather more narrowly concentrated, especially among the developing countries, between about 1.5 and 4 percent[8].

Given the long history of debate about the impact of population growth, isn't this striking (lack of a) relationship inconsistent with an enormous previous literature? Actually, no, as all of the previous cross-national empirical literature that I am aware of examines the relationship across countries between population growth and either investment or savings rates expressed as shares of GDP. While examining the relationship between population growth and either savings rates or investment rates may be of interest for understanding the impacts of demographic shifts on these aggregates, it is, it turns out, completely irrelevant for the present purpose of examining the impact on capital accumulation. It is irrelevant for the very simple reason that, over the period this data covers, average investment rates are uncorrelated with the growth rate of the capital stock. The correlation between the ratio of investment to GDP and the growth rate of the capital stock growth is only .058 in the World Bank-N-D data and only

[8] This feature of the tremendous variation in economic outomces versus labor force growth is pointed out sharply in the most recent World Development Report, 1995 (figure 2.5).

Figure 1: Population growth and growth rate of physical capital per worker





022 in the PWT5-K-L data set. Figure 2 shows the relationship between the country specific average investment rates and the per annum growth rates of physical capital in the two series[9].

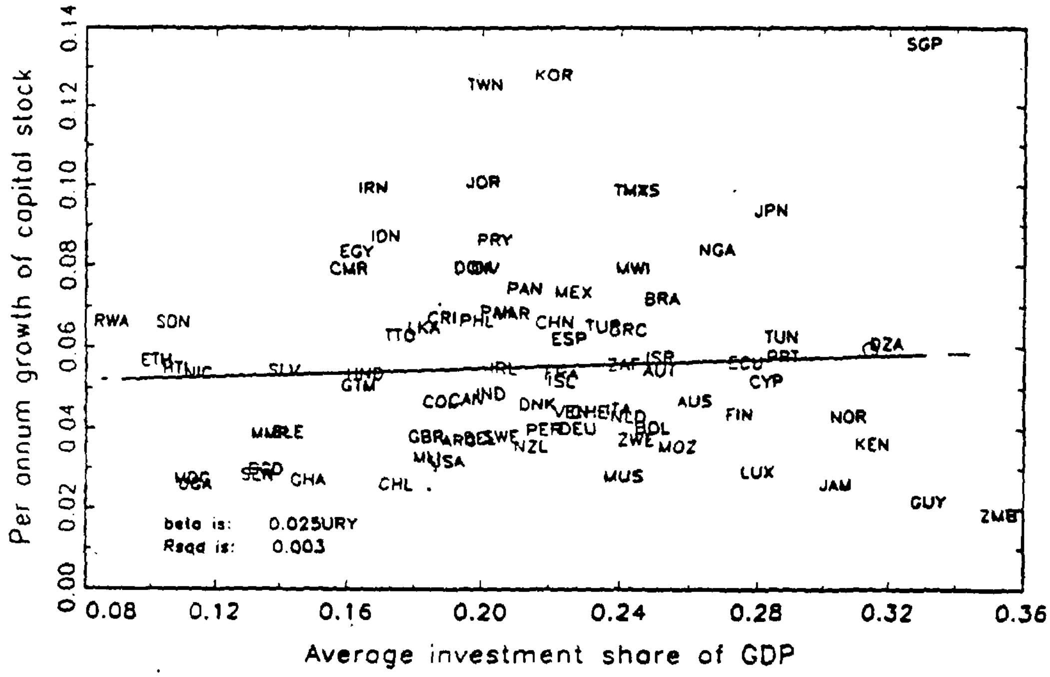
Even if one were concerned about the population growth impact on investment or savings rates, the most recent empirical results are ambiguous. Brander and Dowrick (1994) find a negative, but statistically insignificant, relationship between investment and birth rates using fixed effects estimates for the poorest countries. For the more developed countries they find a non-linear effect such that higher birth rates *raise* investment rates up to a birth rate of about 3 percent. As for savings rates, Kelley and Schmidt (1994) temper the usual finding of very little cross-national correlation between savings rates and population growth only in finding a strong and significant negative correlation of population growth on savings when the period of estimation is limited to the 1980s.

[9] This lack of correlation merits a brief explanation. Starting from the simple perpetual inventory equation for capital: $K_t = K_{t-1} + I_t - \delta * K_{t-1}$, we can derive an expression for the percentage growth in the capital stock as

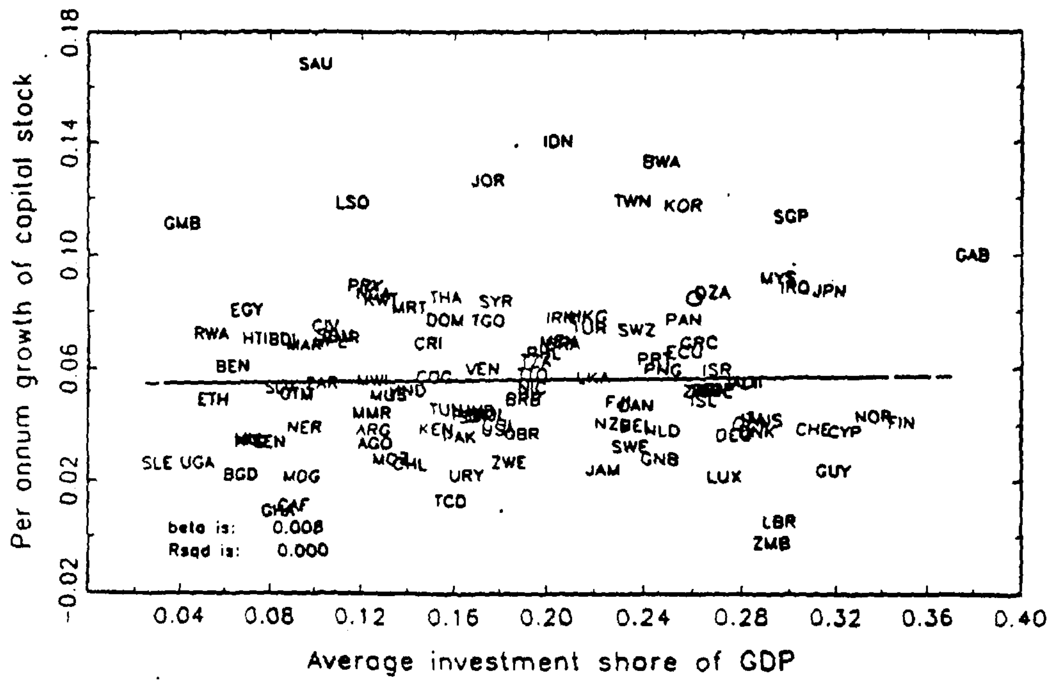
$\hat{K}_t = (\frac{Y_{t-1}}{K_{t-1}}) * (\frac{I_t}{Y_{t-1}}) - \delta$, which is the inverse of the capital output ratio times the investment ratio less the depreciation rate. If every country had the same capital-output ratio then the investment share of GDP would be a good proxy for the growth rate of capital. While it was once thought that capital-output ratios remained roughly constant during development (Kaldor 1961), the existing data on capital stocks strongly suggest this is not so (King and Levine 1994, Young 1994). When the capital-output ratio is not constant this creates an enormous problem with using investment rates as a proxy for the growth of the capital stock. If a country with a low K/Y ratio (say 1) suddenly increases its investment ratio to 20 percent the growth rate of capital would be 20 percent per annum (assuming a 5 percent depreciation). On the other hand, a 20 percent investment ratio in a country with a capital-output ratio of 3 would produce capital growth of only 1.6 percent. This concern about the implications of varying K/Y ratios is far from merely theoretical. In the N-D data Korea's investment ratio is 21.5 while the growth of the capital stock was 12.5 percent as Korea's K/Y ratio was rising rapidly while Germany's average investment ratio was slightly higher, at 22.3 percent but Germany's growth rate of the capital stock was only one-third as large, 3.9 percent.

Figure 2: Growth of physical capital and the average investment to GDP ratio

Average investment share and growth of capital stock, 1960–1990
(World Bank investment and Nehru–Dhareshewar capital data)



Average investment share and growth of capital stock, 1960–1988
(PWT5 investment and King–Levine capital data)



II) Growth in the years of schooling

Q: Did countries with more rapid population growth have less growth in schooling per worker?

A: No.

In order to examine the impact of population growth on education I use two recently created estimates of the mean years of schooling of the labor force aged population. Nehru, Swanson and Dubey (N-S-D) (1994) create an estimate of the average years of schooling of the population aged 15-64 using a perpetual inventory method based on enrollment rates. Barro and Lee (B-L) (1993) have created an estimate of the years of schooling of the population aged 25 and above using estimates of the highest level of school completed from census or survey data.

Table 3 presents the estimates of regressing the percentage per annum of the years of schooling of the labor force on population growth for each of the two series. In the whole sample, higher population growth is associated with *faster* percentage growth of years of schooling. In LDCs faster population growth, using either data series, is associated with an *increased* rate of growth of schooling per person, by about .9 percentage points (.88 and .87), a point estimate which borders on statistical significance.

Table 3: Population growth and the growth of years of schooling of the labor force aged population.

Dependent variable: Per annum percentage growth rate of years of schooling per worker

	Nehru-Swanson-Dubey data			Barro-Lee data		
Sample:	All	LDC	DC	All	LDC	DC
Population growth	1.4 (6.14)	.88 (1.89)	.373 (.947)	.935 (3.88)	.871 (2.04)	-.213 (.503)
N	81	59	22	93	71	22
R-Squared	.323	.059	.043	.142	.057	.012

Note: Absolute values of t-statistics in parenthesis.

Of course the percentage growth rate of the years of schooling may be somewhat misleading. A percentage change rate will be very large when beginning from a small base (e.g. an increase of one year of schooling from 1 to 2 is a hundred percent increase while an equal absolute increase of one year from 10 to 11 is a ten percent increase). Since the countries that tend to have rapid population growth also have an initially low stock of schooling this leads to a positive correlation of population growth on percentage change stocks. Table 4 shows the same set of regressions, done in the growth rate of the level (not the natural log) of schooling (hence the rate is the absolute increase in school years per worker per year, not the percentage change). Population growth is not significantly related to the rate of growth of schooling years using this measure either, as illustrated in figure 3. Even in the LDCs, where one expects the negative result to be the strongest, the Nehru-Swanson-Dubey data gives a negative (and insignificant) estimate (-.53) while the Barro-Lee data is slightly positive (.10), also insignificant.

Figure 3: Population growth and the growth rate of years of schooling of the labor force

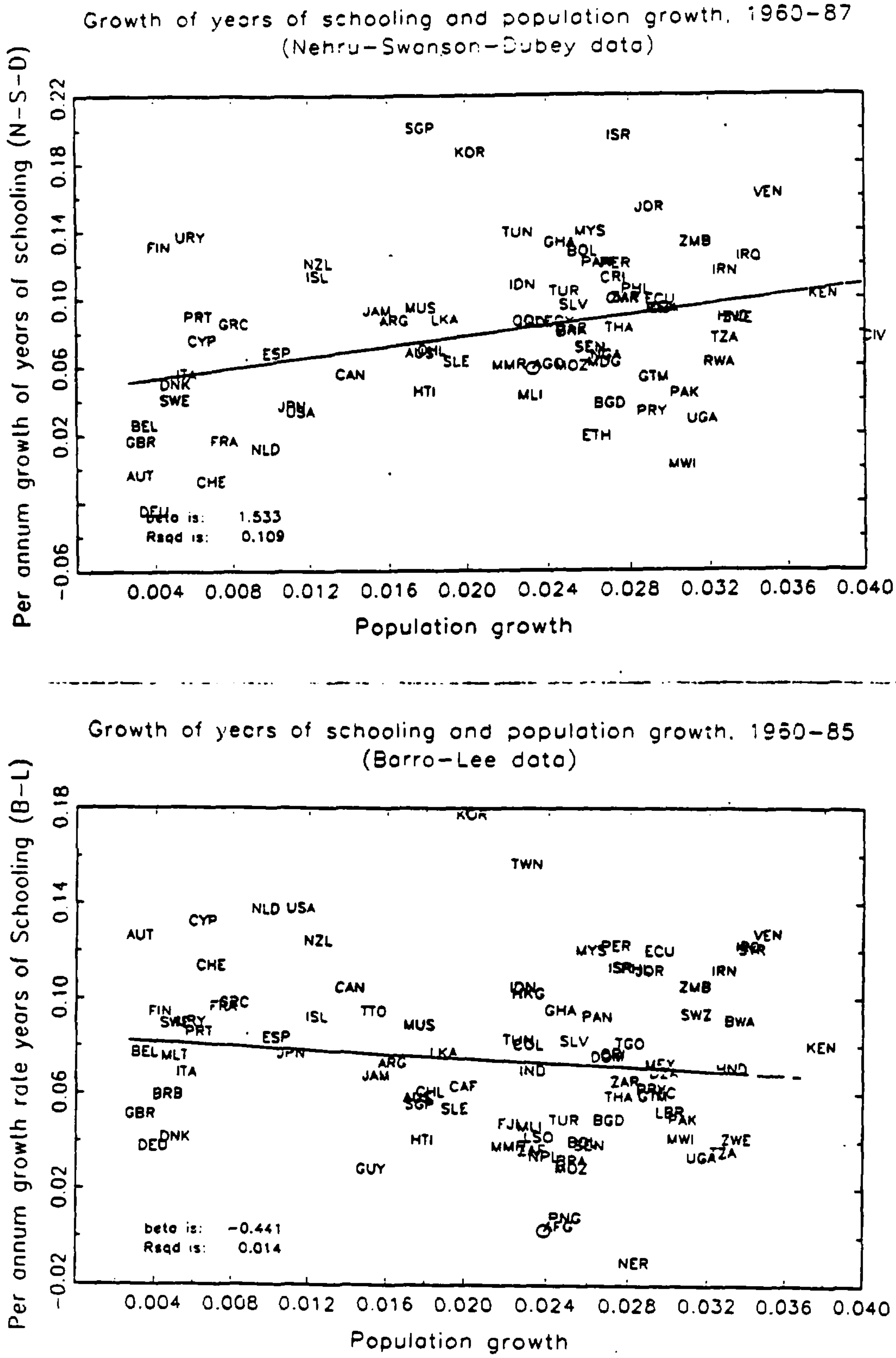


Table 4: Population growth and the growth of years of schooling of the labor force aged population

Dependent variable: Per annum growth of years of schooling (absolute) per worker

	Nehru-Swanson-Dubey data			Barro-Lee data		
Sample:	All	LDC	DC	All	LDC	DC
Population growth	1.53 (3.07)	-.533 (.635)	3.89 (1.69)	-.440 (1.14)	.101 (.167)	1.80 (1.11)
N	81	59	20	91	71	20
R-Squared	.109	.007	.137	.014	.000	.064

Note: Absolute values of t-statistics in parenthesis.

Is this result consistent with the literature and, more importantly, with common sense? If the budget devoted to education is fixed (either at the household or public expenditure level) then a greater growth of the school aged population (which tends to be highly correlated with population growth overall) would appear to lead to less schooling per child. However, this intuition is not completely borne out by the data. Schultz (1987) using multi-variate estimates in cross country data found no particular impact of the fraction of the population aged 6-17 on the enrollment rate[10]. Kelley (1995) reviews the literature on the impact of population growth on education and finds that neither the aggregate cross-country nor the household level empirical studies confirm the feared reduction in schooling from rapid population growth and/or large family size.

However, Schultz's (1987) paper does show that while a larger young cohort did increase (or at least not decrease) enrollment rates it also tended to reduce teachers salaries,

[10] For his preferred estimates for total school system enrollments (table 10) the impact of larger share of population in the 6 to 17 age bracket was to *raise* the overall enrollment ratio.

decrease teacher-student ratios and reduce expenditures per child. Hence the discussion often focuses on whether or not rapid population growth deteriorates not the quantity but the quality of education. This is a critically important point, as the correct measure of schooling is not whether or not a child sat in a schoolroom, but what they learned.

But, how does one measure the amount of learning quality of education? The first, and widely unresisted, temptation is to use expenditures per pupil as a proxy for quality, but this is wrong, for at least three reasons. First, since in every developing country education is predominantly publicly produced, assuming that educational output is produced in a cost minimizing way such that increases in expenditures automatically translate into improvements in performance is almost certainly false. The relationship between quality and costs is tenuous, at best. Hanushek (1986) shows that in the U.S. studies do not show any clear relationship between resource inputs (whether measured as expenditures per pupil, teachers per student, etc) and outputs as measured as test score improvements. Harbison and Hanushek (1992) and Hanushek (1995) show that much of this ambiguity about the relationship between resource inputs and educational outputs holds true in developing country studies as well. Jimenez, Lockheed and Paqeuo (1991) present five country case studies in which private school students outperformed public school students (even after correcting for selection effects) while unit costs were lower in private than public schools, usually by a substantial margin which implies public systems are not efficient. Moreover, there are enormous differences across countries in the cost of producing a year of primary or secondary schooling, even after accounting for general differences in wage levels. Table 5 gives representative figures of the cost per secondary school year as a fraction of GDP per capita for selected countries. This unit cost ranges from a low of 12 in the Philippines to 343 in Tanzania. It is difficult to know what part of this represents quality differences and what part cost differences due to differences in supply and what part pure inefficiency and what part pure measurement error, but it is difficult to believe that secondary education in Korea is only one fifth as good as that in Cote d'Ivoire. If one examines test scores and expenditures across countries or over time within a country, one comes to the same conclusion. Fourteen year old German students score about the same on reading as Greek students, even though the German system spends six times as much per pupil (Elley, 1994). In the United States between 1960 and 1990 expenditures per pupil have tripled, with no evidence of significant improvement in test scores (Hanushek and others 1994). Given this array of facts, it is difficult to maintain that the relationship between costs and educational outputs is sufficiently tight that per pupil costs can reliably be used as indicators of quality.

Table 5: Estimates of the cost of secondary schooling in various countries, mid 1980s[b].

Country	Cost[a] as a percent of GDP per capita
Asia	
Bangladesh	30
Korea	23
Philippines	12
Papua New Guinea	65
Median	21.3
Sub-Saharan Africa	
Niger	217
Chad	28
Tanzania	343
Kenya	22
Ghana	13
Cote d'Ivoire	109
Median[c]	62

Source: Tan and Mingat, 1992 (table B-4.1), World Bank, 1988 (table A-18).
Notes: a) In Africa the estimate is public recurrent expenditure per pupil, while in Asia the estimate is total unit cost, b) estimates are 1983 for Africa, various years in the 1980s for Asia, c) the median is for all countries reported in the original source, 31 for Sub-Saharan Africa, 11 for Asia.

Second, an oft used indicator of school quality, teachers per student, is an extremely dubious indicator of school quality. Classroom level studies show very little difference in student performance in primary schooling across large ranges of classroom size and very few country's school systems push these upper limits[11]. For instance, in Korea the student-teacher ratio in primary education in 1980 was 47.5 compared to only 30.4 in the Philippines, yet on

[11] This probably accounts for the ambivalent signs in statistical studies. Harbison and Hanushek (1992) review the results of 30 studies of the relationship of teacher/pupil ratios in developing countries and report that 8 find a positive and significant effect, 8 find a negative and significant effect and 14 find a statistically insignificant effect.

internationally comparable tests of science achievement of ten year old in the mid 1980s Korea students received scores 60 percent higher than those in the Philippines (Tan and Mingat, 1992).

Third, another way to measure the impact of population growth on schooling quality would be to measure outputs, such as cognitive skills acquired or better yet from an economic vantage point, actual improvements in productivity. However, measuring the quality of education by outputs is extremely difficult. For instance, say we measure just the productivity enhancing aspect of education by the wage increment to schooling derived from wage equations. If more rapid population growth were associated with poorer quality schooling the wage regressions could show that schooling had less impact on wages where population growth was higher. Using data from Psacharopoulus (1993) recent update of returns to schooling I regress the coefficient on years of schooling in a regression on (log) wages on the rate of population growth in the period preceding the observation and the country's stock of education at the time[12]. In this data there is no (partial) correlation at all between the wage increment from education and prior population growth. Using data on wage increments from a year of schooling as a proxy for school quality provides no support for the population growth-education quality deterioration thesis.

The point of going on at length on this seemingly unrelated point is that many have estimated the impact of population growth on expenditures per pupil as a proxy for quality and concluded that population growth is harmful for educational quality. However, the concerns

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[12] The data are taken from Psacharopoulus (1993) which gives the most recent available estimates for sixty-two countries. Since the estimates are from different years, the data for population growth and human capital stock (from the N-S-D series) are matched.

about expenditures per pupil (or some other input) as a proxy for quality are not a minor quibble but represent real, first order, problems. While higher population growth is not associated with lower growth of the *quantity* of schooling per person, whether the *quality* of schooling per person has been affected is, and will remain, given the available data on school quality, an open question.

III) Population and productivity

Q: Did countries with more rapid population growth have more rapid productivity growth?

A: No.

Most of the theories that suggest that a larger population might be good for economic growth suggest a mechanism whereby an increased population increases the productivity with which factors are used. A quick review of the (at least) four reasons why a larger population might be good for growth might be helpful. These are: a) innovation by population pressures, b) innovation produced by greater numbers, c) scale economies, d) agglomeration economies. Each of these possible economic growth impacts of population have different implications, as some are related to the absolute numbers of individuals some are related to the change in the number of individuals and levels of output and some the distribution of population.

The pressure of greater population itself may induce changes that lead to greater productivity. Boserup (1981) for instance argues that in historically agrarian societies greater population pressure led to innovations both in productive technique and in social organization. Even if the rate of innovation per person does not increase with greater population or density as Boserup suggests, but is constant with population growth then a greater population will lead to a greater rate of technological progress[13].

Second, many of the "new" growth theories focus on the fact that knowledge is non-rival, so that once an innovation is made any number of people can use the same idea[14]. Empirically, larger countries do not seem to have higher rates of technical progress but the country might not be the relevant unit for measuring innovation[15]. Kremer (1993) shows that, at least until recently, higher rates of world population growth were associated with more rapid technical progress.

Third, even with a given technology and inputs, greater population could lead to greater output through either economies of scale or of agglomeration. While many industrial activities are clearly characterized by some economies of scale there is very little evidence of scale economies at the national level (Backus, Backus, and Kehoe, 1993) as, in general, the larger countries (measured either as population size or total output) do not grow faster. The very rapid growth of small economies such as Singapore, Hong Kong, and, more recently Mauritius, suggests that international trade can easily substitute for the size of the domestic economy in particular industries[16].

Finally, even in the absence of economies of scale, greater population, can lead to

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[13]Of course the rate of innovation per person could be declining with population growth if more rapid population growth reduced the accumulation of innovation capital. However, what innovation capital is and whether population growth affects it are completely open empirical questions.

[14] The "new" in new growth theories of course must be qualified. The implications of the non-rivalry of knowledge for growth have been known for some time as Kuznets (1961) for instance discusses them quite nicely.

[15] Although this raises the question of the diffusion of innovations; do they remain within localities or countries. If diffusion is rapid across country boundaries then the whole world is better off with larger population even if large countries are not. For evidence on international spillovers see Bernstein and Mohnen, 1994 and Coe and Helpman, 1993.

[16] See Srinivasan (1985) for a discussion of the costs and benefits of being small.

agglomeration economies, that is, the density of economic activity accounts for greater productivity. Agglomeration economies can come from either reduced transaction costs, increased specialization, facilitation of within-industry spill-overs of innovations, or financing the fixed costs of social overhead capital[17]. Agglomeration economies at some level are an obvious fact as the existence of cities, for instance, is the product of agglomeration economies so concentration must increase resource productivity at least up to some point. The cross national evidence is somewhat weaker, although the growth regressions in Kelley and Schmidt (1994) show consistently strong positive effects of population density across a variety of samples and time periods[18].

However, in this present work I will not try to disentangle the various channels of effect, I will simply correlate growth of TFP to population growth. To implement the decomposition of output growth into a factor accumulation component and TFP described in equation (3) I have to choose a α_K and α_H. I use two methods to fix these coefficients. First, I use a cross-country growth regression to estimate the two coefficients. Second, since the regression approach raises some anomalies I use non-regression based estimates that are suggested by theory and the national accounts data. The regression estimates are described in appendix 1 while the data behind the estimates for the non-regression estimates are described in appendix 2.

Regression estimates of TFP. Using the PWT5 (GDP), K-L (Capital), B-L (Schooling)

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[17] This is a second important element of Boserup's (1981) story of the importance of population density in promoting urbanization in ancient times.

[18] Kelley and Schmidt (1994) also include a term for the absolute size of population and find generally positive, but smaller and less robustly significant, scale effects.

data the results suggest an exactly zero population growth correlation while the World Bank (GDP), N-D (Capital), N-S-D (Schooling) data suggest a modest negative impact (table 6). For the developing countries taken alone, the coefficient is statistically insignificant in both data sets. Figure 4 shows the relation between population and TFP growth for the two data sets.

Table 6: Population growth and TFP (using regression estimates of TFP) 1960-1987.

Dependent variable: TFP growth, regression method

Source of data	PWT5, K-L and B-L			World Bank, N-D, N-S-D		
Countries:	All	LDC	DC	All	LDC	DC
Growth of Population	-.084 (.756)	.008 (.044)	-.091 (.366)	-.333 (2.47)	-.238 (1.03)	-.231 (.897)
N	92	71	21	80	59	21
R-Squared	.006	.000	.007	.073	.018	.041

Notes: Absolute values of t-statistics in parenthesis.

TFP with factor shares. As discussed in appendix 1, the regression estimates used to create the TFP estimates, especially the share on human capital, are unsatisfactory. The growth framework I am using suggests an alternative calculation: use the shares of income attributable to physical and human capital derived from national accounts for the coefficients to calculate TFP. This is easier said than done, how much easier can been seen in appendix 2 where I describe the combination of data on national income shares, education of the labor force, returns to education, and guesswork I use to come up with the assumption that the share of capital is .4 and the share of human capital is .3. Crudely put, if I take .4 as the share of income to physical capital based on national accounts data, then .6 is the share of national income to labor and if half of labor share of output is the return to education then the human capital share is .3[19]. I use these shares to calculate TFP and then regress this derived TFP based on assumed shares on population growth.

Do countries with more rapid population growth have more rapid TFP growth by this second measure? No. As shown in table 7 the results are again, if anything, that more rapid population growth leads to slower TFP growth. For the developing countries alone, the population growth association is very weak in both data sets. In the developed countries the correlation of population growth with TFP is large and *negative*, even statistically significantly so using World Bank GDP data overall, but not in the LDC sample.

Table 7: The impact of population growth on TFP using estimates of TFP based on assumed factor shares 1960-1987.

Dependent variable: TFP growth, factor shares method

Sources of data:	PWT5, B-L, K-L			World Bank, N-S-D, N-D		
Countries:	All	LDC	DC	All	LDC	DC
Growth of Population	.009 (.065)	-.003 (.014)	-.819 (1.28)	-.811 (4.42)	-.142 (.416)	-1.41 (2.18)
N	92	71	21	80	59	21
R-Squared	.000	.000	.080	.200	.003	.201

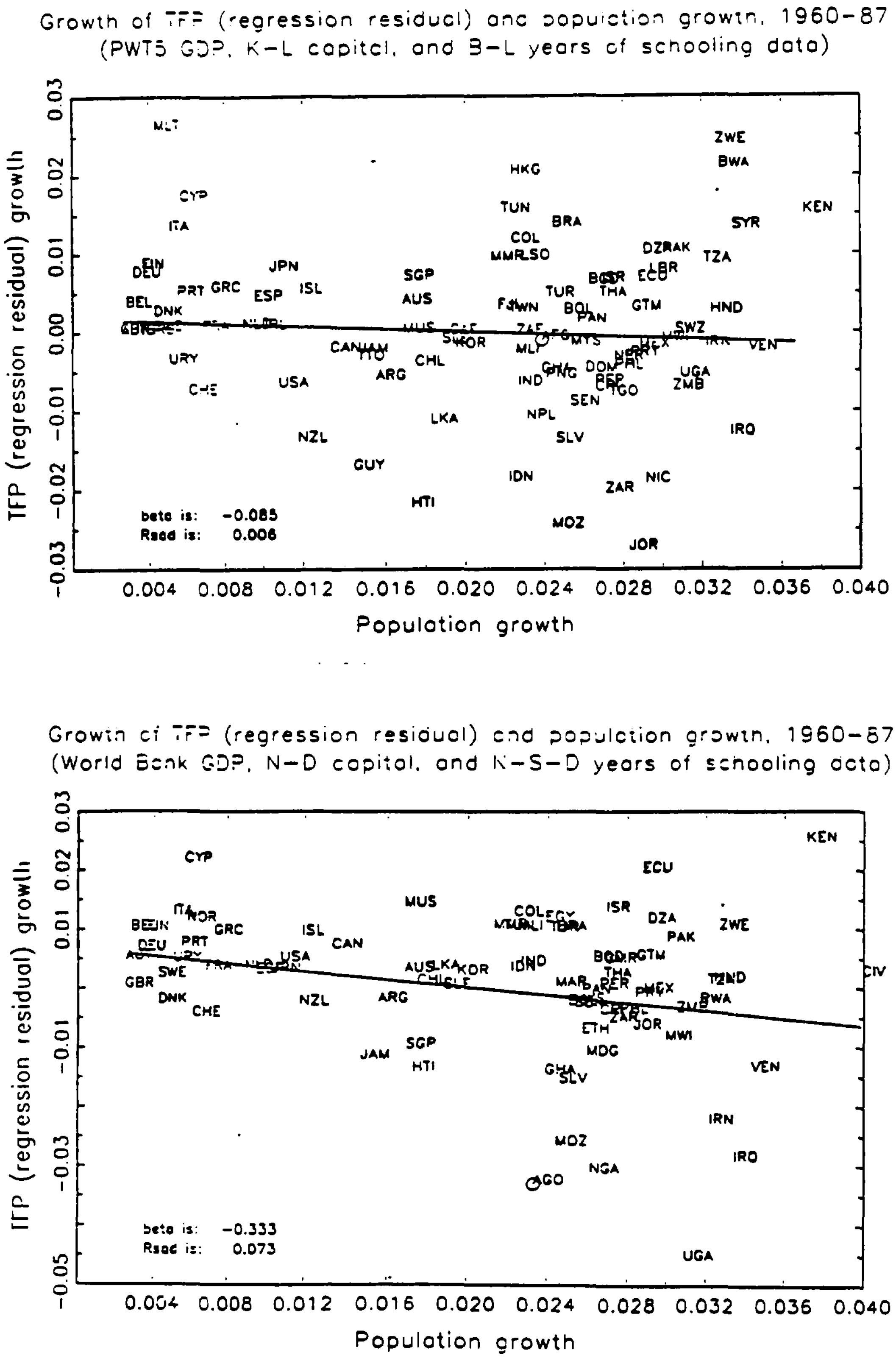
Notes: Absolute values of t-statistics in parenthesis.

IV) Output per worker and per person

Before concluding, I would like to point out how the present work compares with the previous empirical literature that examines correlation of population and economic growth. I

[19] Mankiw, Romer, Weil, 1991, use 1/3, 1/3, 1/3. We find both in the regressions as well as in the national accounts that capital share is higher, at least .4, but agree that half of all labor income is returns to education.

Figure 4: Population growth and the growth of TFP (regression estimates)



would like to make two points, one empirical and one on interpretation. Empirically, it appears that output per person growth is lower with more rapid population growth not because output per person falls, but principally because of differences in labor force participation. This empirical finding raises the question of the welfare consequences of demographically induced shifts in labor force participation.

Empirical. More rapid population growth is associated with slower growth rate of labor force participation in our data. Figure 5 displays the relationship between labor force participation and population growth. This relationship explains why the negative effects of population growth that are found in the literature are likely predominantly shifts in labor force composition. For instance, Brander and Dowrick (1994) find a relatively large and significant effect of population growth on output per person growth. But when they decompose that effect into an output per worker effect and a workers per person effect, the output effect is nearly all mediated through changes in labor force participation. Similarly, much of the work on the "dynamics" of the effect of population growth simply traces out the obvious implications of the fact that labor force participation rate vary by age[20].

The same would be true in our data. Table 8 shows the comparison between the association of population growth and growth of output per <u>person</u> and output per <u>worker</u>. As expected the effect of population growth is consistently more negative on output per person than on output per worker, by about .4, in both samples for both data sets. While the data sets disagree even on the sign of the population growth correlation with GDP per worker in LDCs

[20] For instance, Barlow (1994) estimates current output per capita as a function of current population growth and lagged fertility. He finds (not surprisingly) that controlling for lagged fertility (lagged 17 years, which has a positive effect on output per person) current population growth has a negative effect on output per <u>person</u>. To some extent this is rediscovering the obvious: that labor force participation rates are higher for adults than children.

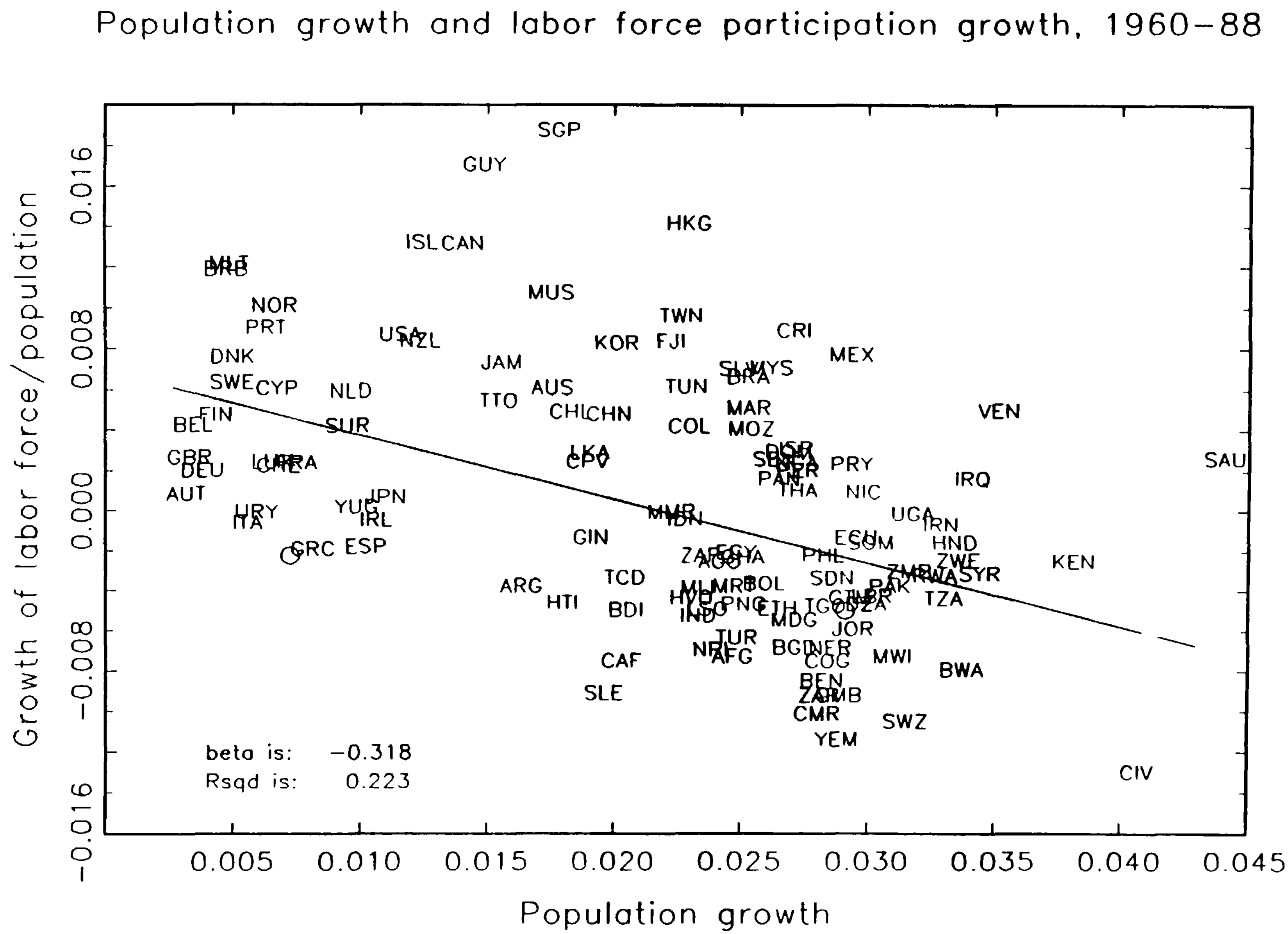


Figure 5: Population growth and the changes in labor force participation

(.226 vs. -.43) both estimates are insignificant. This evidence is also consistent with the hypothesis that all of the typically estimated negative impact (even when it is found to be statistically significant) between population growth and per capita output is a labor force participation effect.

Table 8: Comparison of the correlation of population growth with output per person and output per worker, 1960-1990.

Data:	PWT5 data				World Bank data			
Country Sample:	All		LDC		All		LDC	
Dependent variable	GDP/ Worker	GDP/ Person	GDP/ Worker	GDP/ Person	GDP/ worker	GDP/ Person	GDP/ Worker	GDP/ Person
Population growth	-.024 (.132)	-.363 (1.91)	.266 (.880)	-.172 (.547)	-.322 (1.74)	-.596 (3.09)	-.123 (.336)	-.441 (1.12)
N	112	112	89	89	80	80	58	58
R-Squared	.000	.032	.009	.003	.038	.109	.002	.022

Notes: Absolute values of t-statistics in parenthesis.

Welfare interpretation I did not relate the growth of output per person growth and population growth because these empirical results can be (and often are) wildly misguided in their interpretation. The question of the welfare consequences of changes output per person that are mediated entirely by changes in the ratio of labor force to population, either because of changes in the age structure of population or changes in labor force participation of adults (particularly women) are much too complicated, theoretically and empirically, to be of much interest.

Each time my wife and I have had a child (we have had three) our household per capita income has fallen by a substantial amount but my household welfare level rose (also by a substantial amount)[21]. If the effect on other households of my children is roughly zero then economy wide welfare increased at the same time economy-wide per capita income fell. While there are many situations in which per capita income is a reasonable proxy for welfare, using per capita income as a proxy for the welfare impact of births is certainly not one of them.

GDP per capita as a welfare indicator is also wrong when a person shifts between market and non-market activities. Say a household is just indifferent between having one of its members performing household activities and working full-time in the market at a going wage (for a clean hypothetical assume the choice is either-or). If the market wage then increases even by a very small amount, the household member may switch into full-time market labor force participation. GDP per capita will rise by the full amount of the additional marketed output whereas household welfare has increased by only a small amount. This anomaly occurs because GDP statistics exclude many non-marketed services which have traditionally been "women's work" in many societies. Output changes from changes in female labor force participation exaggerate the shift in household welfare[22].

Of course, the welfare interpretation of household composition shifts and female (also force changes depends on the fact that births are a choice, not merely something that exogenously happens to a couple. As I have argued elsewhere, although there certainly are unwanted births and not every birth is the result of a *woman's* conscious choice, the welfare

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[21] Some economists, although only economists, might question why my welfare rose by a substantial amount since the conditions for intertemporal optimality in consumption specify that marginal utility per dollar should be equalized between goods. However, given the integer constraint on children, the long lags in the production function, and the resolution of the uncertainty created by the non-trivial health risks, even an economist can be joyful at a birth.

[22] The same, of course, is true of shifts in hours worked. Hypothetically, if workers in country X worker 60 hours a week and workers in country Y who worked 40 hours a week, the fact output per worker in country X was higher would not indicate that welfare was higher. The value of leisure foregone from the additional hours worker needs to be taken into account.

consequences of births are best understood within a choice based framework (Pritchett, 1994, 1995).

Conclusion

The belief that population growth, especially in developing countries, is bad is the predominant view of the educated public. This proposition's widespread acceptance derives at least partially from its base in an incredibly simple and powerful intuition: if there is a fixed amount of stuff (land, capital, savings, water, budget for education, or whatever) then if there are more people to share the stuff the average stuff per person must go down. In the face of this compelling line of reasoning the more ambiguous and tenuous theory based on endogenous behavioral responses to population pressures, and complicated econometric work never has a chance at persuasion. However, the evidence presented here suggests the basic premise is wrong: there is not a fixed amount of stuff.

There is certainly not a fixed amount of capital stuff. Some countries have accumulated capital very rapidly while others have barely maintained or depreciated their existing stock. More specifically there is no correlation between the rate of capital accumulation per worker and the rate of population growth. Both measures of capital suggest that, in developing countries, capital per worker grew more rapidly when population growth was rapid (although these estimates are small and statistically insignificant). The absolute physical capital growth was much more rapid in countries with rapid population growth, slightly more than enough to offset the impact of more workers.

We also show that the amount of children given the education stuff is also not fixed. Many developing countries have dramatically expanded the years of schooling of their populations, in many cases more than doubling the educational levels of 1960. Again, there is no evidence that countries with more rapid population growth have seen a slower expansion of the education of their labor force, either in absolute or percentage terms. While the quality of schooling may have suffered, that is far from clear.

Those two results however do leave a deeper puzzle. The residual of output per worker that is not accounted for by factor accumulation (call it TFP) is weakly negatively associated with more rapid population growth. In fact, whatever negative relationship there is between growth of output per worker and population is mediated exclusively through a deterioration in TFP and not at all through the factor dilution channels that are the major focus of most population theories.

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Appendix 1: Estimating TFP using regressions

Table A.1 reports the estimates output per worker growth as a function of factor accumulation per worker using two different data sets. One is the World Bank data on output[23] combined with the N-S-D years of schooling and the N-D physical capital (derived from World Bank investment rates) and the estimates of the labor force from Penn World Tables, Mark 5 (PWT5) from Summers and Heston (1991). The second data set PWT5 data on output with the Barro-Lee data on years of schooling and the King-Levine series on physical capital stocks (derived from PWT5 investment rates).

Table A.1 gives the estimates of output per worker growth on the growth of physical capital per worker and the growth rate in the years of schooling (expressed in absolute, not percentage growth, as using percentage growth gives a *negative* coefficient). The results have two problems when interpreted within a Solow type growth production function. The capital share is too high. Under the Solow model assumptions the capital coefficient should be the capital share in national income. This is more typically estimated from national accounts to be around .3 to .4 than the results of .5 (or above) that the regressions suggest. Second, the coefficient on years of schooling is much lower than one would expect for a human capital share (and not always even significant)[24].

Table A.1: Estimates of the growth in output per worker as a function of factor accumulation.

Dependent variable: Growth of output per worker

Data:	PWT5, B-L, K-L			World Bank, N-S-D, N-D		
Countries:	All	LDC	DC	All	LDC	DC
Growth Capital per worker	.495 (12.0)	.472 (9.89)	.636 (9.71)	.550 (9.31)	.521 (7.16)	.571 (9.07)
Growth of Years of schooling	.070 (2.16)	.092 (2.30)	-.037 (1.03)	.009 (.321)	.050 (1.10)	.036 (1.39)
N	92	71	21	80	59	21
R-Squared	.667	.663	.846	.539	.525	.821

Notes: Absolute values of t-statistics in parenthesis.

[23] World Bank data on GDP at market prices expressed in constant prices in dollars using 1987 Atlas exchange rates.

[24] The fact that human capital accumulation does not contribute as significantly to growth as one would expect from factor shares is not unique. Spiegel (1994) for instance, in estimating a neoclassical growth regression (table 9) finds that human capital ranges from .061 to .123 without initial income as a covariate and from -.059 to .041 when including initial income. Similarly, Judson (1993) finds (table 6) coefficients on human capital (using Nehru data on education) between .088 (fixed effects) and .127 (between). Pritchett (1995) discusses these issues in depth.

Appendix 2: Shares of factor income to physical and human capital

The estimates of a "production function" relationship in appendix 1 are unsatisfactory for two reasons. First, cross country from individual level studies on the returns to education suggest that education is in fact highly productive at the individual level. Since the Solow (or extended Solow) models are constant returns to scale the model itself tells us what the coefficients ought to be: the factor income shares. Zero cannot be the correct answer for the fraction of GDP attributable to human capital. The issue of the impact of human capital on growth is discussed much more in depth in Pritchett (1995a).

This appendix describes the basis of our guesses for the share of factor income accruing to physical capital and human capital.

Physical capital The aggregate numbers from the national accounts of OECD countries give figures between .295 (for Sweden) and .531 (for Greece). The average is .403.

Table A1.1: Shares of capital in factor income in various OECD countries, 1990

Country	Share of capital income in GDP
United States	0.344
Canada	0.364
Japan	0.412
Australia	0.423
Austria	0.397
Greece	0.531
Italy	0.507
Germany	0.392
United Kingdom	0.349
France	0.403
Sweden	0.295
Belgium	0.417
Average	0.403

Note: Source, OECD, 1993. Reported is the share of capital (consumption of fixed capital plus operating surplus) as a share of factor income (GDP less indirect taxes plus subsidies).

For the U.S. Jorgenson, Gollop and Fraumeni (1987) use highly sectorally disaggregated estimates of capital, labor, and value added to estimate that the share of capital in income varied only between .364 in 1949 to .384 in 1969.

Reported capital shares for developing countries are harder to come by. Reported capital shares in the national accounts are typically not able to disentangle capital income from proprietor's income (which includes all of peasant agriculture), so the reported "capital" share is substantially overstated.

The capital output ratios estimated in the Nehru and Dhareshewar and King and Levine also provide a check on the share of capital income. King and Levine show that the average capital-output ratio for OECD countries is 2.51 and is 1.6 for non-oil, non-OECD countries. The Nehru-Dhareshewar capital output ratio is 2.47 for the whole sample. If the K/Y ratio is 2.5 then if the rate of return to capital, r, is 16 percent then the share of capital rK/y is .4. At a K/Y ratio of 1.6 the rate of return has to be 25 percent for the capital share to be .4.

All in all .4 seems a fair estimate, perhaps a little generous to capital, but less so than the regressions, where the coefficient was more like .5.

Human capital Calculating the share of labor income that is due to human capital is trickier, as there is no national accounts counterpart. One calculation is to assume a wage increment to each year of schooling and then calculate on the basis of the labor force in various educational categories what the share of human capital would be. That is, if educational group j (say, primary school completers) has completed k_j years of schooling and the wage increment to each year of schooling is r and the wage of workers with no schooling is w0 then the share of the total wage bill that can be attributed to human capital is:

$$\textit{Human capital share} = \frac{\sum_j (w_j - w_0) * \frac{L_j}{L}}{\sum_j w_j * \frac{Lj}{L}} ,$$

where the wage in category j is,

$$w_j = w_0 * (1+r)^{k_j} .$$

The results in table A1.2 suggest that the share of human capital in the total wage bill developing countries is probably between .35 and .5, while the share is likely considerably higher for developed countries. The rate of return of 10 percent is about the average estimate from Psacharopoulus (1993) while 14 percent was chosen to produce a human capital share of .5, since that is what this paper uses.

Table A1.2: Shares of human capital in the wage bill		
Region	Assumed wage increment from a year of schooling:	
	10%	14%
Developing countries	.364	.504
Sub-Saharan Africa	.263	.369
Latin America	.434	.576
South Asia	.302	.437
OECD	.621	.751
Note: Calculation is done using data from Barro and Lee (1993) on the distribution of the labor force across educational attainment categories, assuming a standard number of years of schooling for each educational attainment category and an equal percentage wage increment for each year of schooling.		

An even simpler calculation is that if someone knew the wage of someone with no human capital ($w_{HK=0}$) and the average wage (w_{avg}) then the share of human capital is:

$$\textit{Human capital share} = 1 - \frac{w_{HK=0}}{w_{avg}} \ .$$

Mankiw, Romer, Weil (1992) use this to propose a human capital share of wage bill of ½ because the U.S. minimum wage has historically been about half the average wage (although actually the minimum as a fraction of the average has fallen from around .5 in 1970 to .37 in 1992, Statistical Abstract of the United States, 1993, table 675). This data is much harder to come by in developing countries, as the minimum wage is less enforced and less likely to be applicable, and is harder to obtain solid data on in any case.

Although it is somewhat generous to human capital, I assume a human capital share of .5 of the wage bill, hence .3 overall (.5*.6).

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