

# Demographics and Productivity\*

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## Abstract

This paper examines the relationship between workforce demographics and aggregate productivity. Changes in the age structure of the workforce is found to be significantly correlated with changes in aggregate productivity. Different demographic structures may be related to almost one quarter of the persistent productivity gap between the OECD and low income nations as well as part of the productivity divergence between 1960 and 1990.

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## Introduction

This paper will explore the connection between workforce demographics and aggregate productivity. Given the outpouring of empirical growth papers over the last decade, the effect of demographics has been relatively neglected. When demographics are considered, the focus tends to be on the dependency ratio (the ratio of workers to non-workers), not on the internal demographic composition of the workforce.

Demographic measures have several characteristics which sidestep many of the difficulties that bedevil other variables used in the empirical growth literature. First, demographic

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measures are strongly predetermined. The current age structure of the workforce was determined roughly twenty years ago and should be predetermined with respect to current output movements. Second, demographics have significant time series variation. The post war baby boom in the United States and other nations significantly affected the age structure of the workforce. This time series variation allows for exploiting the panel nature of the data.<sup>1</sup>

Using a large panel of countries, this paper will show that changes in workforce demographics have a strong and significant correlation with the growth rate of productivity. Changes in the proportion of workers between the ages of 40 and 49 seem to be associated with productivity growth. A 5% increase in the size of this cohort over a ten year period is associated with a 1-2% higher productivity growth in each year of the decade. The results are robust to specification changes and appear to have predictive power. An out of sample prediction of output growth from 1990 to 1995 predicts almost 12% of the actual variation.

Demographics may help to explain cross country productivity differences. Low productivity levels in poor countries may be associated with workforces that are very young. This paper suggests that roughly one quarter of the persistent differences between the OECD and low income nations may be related to different demographic structures. Productivity movements between rich and poor nations also appear to be related to relative demographic shifts. Since about 1980 the rich nations have had aging workforces while the poor nations have seen relatively static demographics. During the same period rich and poor countries have seen productivity levels diverge.

The paper will proceed as follows. Section 1 reviews the existing literature on demographics and growth. Section 2 will discuss the empirical strategy. Section 3 will discuss results, including a variety of different specifications. Section 4 discusses the implication of these results for observed cross country productivity patterns.

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<sup>1</sup>The combination of time series variation and predeterminedness is rare in the empirical growth literature. For most variables which change over time like trade, investment, and schooling, the direction of causality is difficult to determine. Variables which are plausibly exogenous, such as geographic measures, tend to lack time series variation.

# 1 Literature Review

Recent work in the empirical growth literature has shown the limits of the neoclassical growth model's ability to explain cross country income differences. Factor accumulation variables like schooling, investment, and population growth rates are undoubtedly important in explaining cross country output differences. Unfortunately, the problem of endogeneity in factor accumulation variables is very difficult to overcome, leading researchers away from growth regressions and toward an accounting approach which utilizes the microeconomic evidence on returns to investment in physical and human capital.<sup>2</sup> Klenow and Rodriguez-Clare (1997), and Hall and Jones (1999) emphasize the importance of productivity differences and suggest that only half of cross country income differences can be explained by differences in physical and human capital accumulation.

Several useful studies have appeared recently exploring productivity differences. Hall and Jones (1999) and Acemoglu, Johnson and Robinson (2001) emphasize the importance of institutions. Frankel and Romer (1999) show that trade has a positive effect on growth. These papers all use instrumental variables to solve the problem of endogeneity. Due to the lack of time variation in their instruments, these papers are limited to an examination of long run productivity differences.

Demographic data combine a number of useful qualities of other variables used in growth studies. There is significant time series variation in demographics. There is micro evidence indicating that experience is important. The age structure of the workforce is strongly predetermined. Surprisingly, demographic change has been relatively neglected in the empirical growth studies of the previous decade. Of the sixty variables considered by the two million regressions of Sala-i-Martin (1997), the only demographic characteristics included are the population growth rate and the ratio of workforce size to population size. In a recent comprehensive survey of the empirical growth literature, Durlauf and Quah (1999) cite only Barro and Lee (1994) on the subject of the demographic structure of the population.

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<sup>2</sup>One notable exception to this is Caselli, Esquivel and Lefort (1996), where a GMM estimator is used to deal with endogenous factor accumulation. The results are roughly compatible with the growth accounting literature.

Changes in the demographic structure of the workforce will lead to changes in aggregate human capital in the form of experience. The notion that the societal return to human capital is larger than the private return has been much noted and studied. In particular, several studies have searched for externalities to human capital in the form of education, with varying success.<sup>3</sup> The case for externalities in education is often made without detailed theoretical models in mind.<sup>4</sup> The existing literature tends to treat the externalities to worker quality as externalities to schooling. The models seem to apply equally well to differences in worker experience. This has been under explored because changes in the experience profile of workers tends to be much more transitory than the secular increases we observe in education. While this limits the usefulness of experience externalities in thinking about very long run trends, demographic trends are sufficiently slow moving that effects can last for decades. It is also true that the demographic profile of poor nations and rich nations are dissimilar in ways which that have persisted for decades.

The focus of the work that has been done on demographics has largely focused on the dependency ratio. Bloom, Canning and Sevilla (2001) find that increases in the size of the working age population can produce a “demographic dividend” to economic growth. Kögel (2001) finds a relationship between total factor productivity and the dependency ratio. Several papers expand their scope beyond dependency ratios to examine the entire population distribution. In an empirical study of US states, Persson (2002) finds that the age structure of the entire population affects output. Sarel (1995) finds a significant effect of the age structure of the population on output in a cross section of countries.

This paper differs from these works in focusing on the age structure of the workforce, rather than the entire population. By using the entire population, these papers will tend

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<sup>3</sup>In a study of US states, Acemoglu and Angrist (2000) cannot reject the equality of private returns and the social return to schooling. However, Moretti (2003) finds that the proportion of college graduates in a metropolitan area generates positive externalities. Cross country studies looking for externalities to schooling have been similarly inconclusive, with the most recent and convincing work such as Caselli et al. (1996) rejecting large social returns to education.

<sup>4</sup>Nelson and Phelps (1966), Lucas (1988), and Romer (1990) describe aggregate growth models with externalities to schooling, but in each case the externality is essentially assumed. Lucas (1978) and Kremer (1993) suggest models of externalities that are more detailed in their description of mechanisms. In Lucas (1978), the quality of managers plays a large role in determining aggregate output. In Kremer (1993), the quality of the entire workforce can have large externalities.

to conflate dependency ratio effects from the direct effects caused by the characteristics of workers. Also, the regressions in these papers are performed in a convergence framework including a lagged output term as an explanatory variable. Since the age structure of the population will vary over time in a very structured way (the size of the group aged 30-35 today is roughly the same as the group aged 25-30 five years ago) it is not clear how to interpret the results of a regression including lagged dependent variables.

## 2 Methodology and Data

### 2.1 Estimation

The following discussion will be in terms of output per worker, but the econometric framework will be applied to capital stocks and productivity as well. Log output per capita in country  $i$  at time  $t$ ,  $y_{i,t}$ , is assumed to be a function of a time invariant country fixed effect,  $f_i$ , a time trend common to all countries,  $\mu_t$ , and a vector of explanatory variables  $x_{i,t}$ ,

$$y_{i,t} = f_i + \mu_t + \beta x_{i,t} + u_{i,t}. \quad (1)$$

Serial correlation in the error term is a potential problem only partially mitigated by the fact that output is measured at 5 year intervals. Serial correlation should not affect the consistency of the parameter estimates, but will result in misstated standard errors. In order to deal with this, I exploit the panel structure of the data and cluster standard errors by country. This allows for an arbitrary covariance structure within each country and should produce consistent estimates of the standard errors as long as output is not a unit root process.

To deal with the possibility of a unit root, estimation is done both in levels and first differences.<sup>5</sup> If output follows a random walk, the error term will have the following struc-

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<sup>5</sup>In order to conserve space, only the results in differences are presented. The results of the regressions in levels are not significantly different.

ture.

$$u_{i,t} = u_{i,t-1} + \epsilon_{i,t} \quad (2)$$

Productivity growth will be stationary with i.i.d. errors. Taking first differences of (1)

$$\Delta y_{i,t} = \mu_t + \beta \Delta x_{i,t} + \epsilon_{i,t} \quad (3)$$

yields a regression equation in output growth where  $\Delta$  is the first difference operator. Since serial correlation is also possible in the differenced regression, errors will be clustered by country.

The dependent variables are the log of output and the results of a decomposition of output into physical capital, human capital and productivity. The regressors are the proportion of the workforce by age group, with W10 indicating workers between 10 and 19, W20 workers between 20 and 29, etc. W60 indicates workers older than 60 years of age. Since these variables are proportions, the sum of all the age groups is one for each country year pair. For this reason, one group is excluded. I choose to exclude W40 because the forty year old age group generally has the highest coefficient when included. By excluding W40, significant coefficients on the other age groups indicate that they are significantly different from the implied zero coefficient on W40.<sup>6</sup>

Demographics are assumed to have a level effect, not a growth effect. Demographics will affect the distance a country sits from the world technological frontier, but will have no impact on the movement of the frontier. The current level of output (or productivity) is assumed to be a function of current workforce demographics. As long as the demographic profile of the workforce is unchanging, the growth rate is exogenously determined. However, this implies that the growth rate of output is a function of *changes* in workforce demographics.

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<sup>6</sup>Since the proportions sum to one, a decrease in one category always results in the increase of another. Estimating in levels makes it straightforward to examine the impact of changes in cohort sizes. It is also possible to use the log of the workforce proportions as regressors. Doing so has no qualitative impact on the results. It is also possible to add interaction terms to the regressions. Unfortunately, the limited number of available observations makes it difficult to separately identify interaction terms.

I am also interested in the channels through which demographics operate. Following Hall and Jones (1999), I decompose output into the contribution from physical capital, human capital, and productivity. Utilizing a framework suggested by Wong (2001) I can then examine the relative importance of each of these channels in explaining the impact of demographics on output.

Productivity is calculated as a Solow residual. I assume a Cobb-Douglas production function taking physical capital, human capital from schooling, and productivity as inputs.

$$y_{i,t} = k_{i,t}^\alpha (A_{i,t} h_{i,t})^{1-\alpha} \quad (4)$$

where  $y_{i,t}$  is output,  $k_{i,t}$  is capital per worker,  $h_{i,t}$  is human capital per worker, and  $A_{i,t}$  represents productivity. Capital's share of output,  $\alpha$  is assumed to be  $1/3$ .<sup>7</sup> The human capital production function is assumed to have a Mincer form

$$h_{i,t} = e^{\phi(s_{i,t})} \quad (5)$$

where  $s_{i,t}$  is the average years of schooling in country  $i$  at time  $t$  and  $\phi(s)$  is an increasing function that is assumed to be piecewise linear with decreasing returns to scale. The coefficients are taken from Psacharopoulos (1994), which surveys the literature on returns to schooling.<sup>8</sup> The production function can be solved for the productivity term.<sup>9</sup>

Output can be rewritten as

$$y_{i,t} = \left( \frac{K}{Y} \right)_{i,t}^{\frac{\alpha}{1-\alpha}} A_{i,t} h_{i,t}. \quad (6)$$

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<sup>7</sup>Gollin (2002) shows that capital's share is roughly equal across counties.

<sup>8</sup>The choice of coefficients follows Hall and Jones (1999). For the first four years of schooling the return to schooling in sub-Saharan Africa, 13.4 percent, is used. For schooling from four to eight years the world average return to schooling, 10.1 percent, is used. For schooling beyond 8 years the OECD return to schooling, 6.8 percent, is used. The precise method of calculating human capital from schooling turns out to be unimportant for the following results.

<sup>9</sup>The productivity measure being used here takes into account differences in human capital in the form of schooling, but not differences in human capital that are due to experience.

Taking logs of both sides

$$\log(y_{i,t}) = \frac{\alpha}{1-\alpha} \log\left(\frac{K}{Y}\right)_{i,t} + \log(A_{i,t}) + \log(h_{i,t}). \quad (7)$$

Equation 7 provides a guide to decomposing movements in output. By construction, all output differences across countries and time must come from differences in one of the three right hand side variables. The capital output ratio is used instead of capital per worker because the capital output ratio correctly captures differences in capital accumulation that are not attributable to productivity differences.<sup>10</sup> The  $\log(h)$  term captures human capital from schooling, leaving  $\log(A)$  as a Solow residual. As shown by Wong (2001), performing separate regressions on  $\frac{\alpha}{1-\alpha} \log\left(\frac{K}{Y}\right)$ ,  $\log(A)$ , and  $\log(h)$  using the same regressors will produce a set of coefficients which sum to the coefficients of the same regression performed on output per worker. The relative magnitudes of the coefficients will indicate the importance of each channel in determining the demographic impact on output.

## 2.2 Data

The data on workforce composition are from two sources. The International Labor Organization (ILO) has compiled cross country data on the number of workers by five year age groups spanning age ten to age sixty five. These are available at ten year intervals starting

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<sup>10</sup>To see the relationship between productivity and capital per worker, start with the Solow model with neutral technological progress:

$$y_{i,t} = A_{i,t} f(k_{i,t}) \quad (8)$$

$$\dot{k}_{i,t} = s_i A_{i,t} f(k_{i,t}) - (n_i + \delta) k_{i,t} \quad (9)$$

where  $f(k_{i,t})$  is a neoclassical production function with decreasing returns to capital per worker,  $A_{i,t}$  is an exogenous productivity parameter,  $k_{i,t}$  is capital per worker,  $n_i$  is population growth, and  $\delta$  is depreciation. We can state the requirements for a steady state where  $\dot{k}_{i,t} = 0$ .

$$(n_i + \delta) k_{i,t}^* = A_{i,t} f(k_{i,t}^*) s_i \quad (10)$$

It can be shown that the steady state level of capital per worker,  $k_{i,t}^*$  is an increasing function of the productivity level  $A_{i,t}$ . A shock to productivity will therefore produce an increase in the steady state level of capital per worker. On the other hand, the steady state level of the capital-output ratio,

$$\left(\frac{K}{Y}\right)_{i,t}^* = \frac{k_{i,t}^*}{A_{i,t} f(k_{i,t}^*)} = \frac{s_i}{n_i + \delta} \quad (11)$$

is not a function of the productivity level.

in 1960. Though the data is provided as worker counts, the ILO's unique contribution is a compilation of surveys on participation rates. Participation rates are combined with data on population by five year age groups from the UN in order to produce worker counts. The underlying population data are available at 5 year intervals over the same period of time.

The data are transformed in two ways. First, in order to reduce the number of coefficients being estimated, the age categories are collapsed to ten year groups. Second, the data are normalized by population and workforce size. The regressor W30 therefore indicates the proportion of the workforce between ages 30 and 39. The workforce numbers are only available at ten year intervals while output and human capital data are available at five year intervals. I therefore use the population data from the UN to impute the intermediate values for the workforce. The population demographic data used in the imputation is limited to the working age population in order to avoid contaminating the imputed data with information about dependency ratios.

There are two potential areas of concern for the workforce data. First, The ILO data is relatively new and legitimate concerns may be raised about data quality.<sup>11</sup> Second, workforce demographics represent a product of population demographics and age specific labor participation rates. Age specific participation rates are potentially endogenous as they may be affected by aggregate economic conditions.<sup>12</sup> The UN population data provides an instrument that can address both problems. First, the population measures are likely more reliable than the workforce data. Second, population measures are independent of participation rates. In order to avoid the issue of the excludability of dependency ratios, only the working age population proportions are used as an instrument. Also, the IV estimates are only performed on the data at ten year intervals using only unimputed workforce data.

Data for output are from the Penn World Tables version 6.0. Following Hall and Jones

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<sup>11</sup>As noted above, the ILO produces workforce demographics by combining UN population data with the results of participation rate surveys. These participation rates have measurement error for several reasons. First, they are based on country by country surveys that are of varying quality. Second, survey years are not harmonized between countries, so some values are necessarily interpolated or extrapolated. Third, for countries lacking sufficient survey data, the ILO estimates participation rates by using the participation rates in similar countries.

<sup>12</sup>Overall participation rates do not enter the analysis.

(1999), output data are adjusted to exclude income from mining and oil.<sup>13</sup> Data for capital per worker are from Easterly and Levine (2001).<sup>14</sup> The schooling data used to calculate human capital stocks are from Barro and Lee.

Two different samples are used, an 87 country sample that includes all countries for which complete data exists, excluding oil exporters. The second sample is limited to 19 countries in the OECD. The data for each sample make up a panel at five year intervals from 1960 to 1990. One additional years worth of data, 1995, is used to assess out of sample predictions for output. Some additional data for the OECD is also used in robustness checks. Hours worked data for 19 countries is available from Groningen Growth and Development Centre and The Conference Board (2004). More detailed multifactor productivity measures for the G-7 countries are available from Jorgenson (2003)<sup>15</sup>. These will be used to see if more detailed TFP measures significantly alter the results.

## 3 Results

### 3.1 Demographics and Output

Column (1) in Table 1 describes the results of estimating the model for output in differences with a full set of country dummies and with the dependency ratio as an additional control.<sup>16</sup> The sample is comprised of 87 non-oil countries. All point estimates in column one are negative, indicating that an increase in the size of the excluded group, aged forty to fifty years, is associated with higher output. The dependency ratio is insignificant and the inclusion of the dependency ratio does not significantly change the coefficients on the other regressors.

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<sup>13</sup>This correction is taken from UN national accounts data, as collected in Aiyar and Feyrer (2002). Because the regressions in this paper exclude oil exporting countries, the corrections are quite minor and have very little impact on the results

<sup>14</sup>Their calculations, in turn, are based on the Penn World Tables 5.6. Both are available from the World Bank website (<http://www.worldbank.org/research/growth>).

<sup>15</sup>Data available at <http://post.economics.harvard.edu/faculty/jorgenson/data/kuz-data.html>

<sup>16</sup>Adding a set of country dummies allows for different productivity trend growth in each country in the sample. The results are not significantly different if the country dummies are excluded.

The differences between the age groups are extremely large. According to the column one estimates, a five percentage point shift from the thirty year age group to the forty year age group is associated with over a 15% increase in per worker output.<sup>17</sup> Supposing this shift occurred over a 10 year period, this is associated with approximately 1.5 percentage points to output growth in each year.<sup>18</sup>

The remaining columns of Table 1 decompose the results for output into the effect of demographics on physical capital, human capital, and productivity following the methodology of Wong (2001). Table 1 shows the results of regressing output and each of the components of output on the demographic variables. By design, the coefficients on the three components of output sum to the coefficient on output. The relative magnitudes of the coefficients indicate the importance of demographics for each of the components of output. The most striking feature of this table is the overwhelming importance of the productivity channel. The productivity coefficients are uniformly an order of magnitude higher than the factor coefficients.

The regressions on capital output ratios and human capital show no significant pattern. For the capital-output ratio, none of the regressors has a t-statistic above one and the set of demographic regressors is jointly insignificant. For human capital, large cohorts in their twenties and fifties correlate with increasing human capital stocks, though the set of regressors is jointly insignificant.

Table 1 shows that there is a strong correlation between the demographic structure of the workforce and output. This relationship is being driven by the productivity residual, and is not primarily the result of factor accumulation. The remainder of this section will examine the relationship between demographics and productivity more directly. It will also show that simple reverse causality from productivity to demographics is not driving the results.

The regressions in Table 1 use imputed values for the age structure of the population.

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<sup>17</sup>Demographic shifts of this size, while not the norm, are present in the data. Between 1980 and 1990, the proportion of workers in the US aged between 40 and 49 rose by 4.6%.

<sup>18</sup>Though not reported here, regressions restricted to the OECD sample are not significantly different than regressions on the whole sample.

This presents several potential problems. First, the imputation may be invalid. Second, participation rates may be endogenous. Changes in productivity growth may induce changes in participation rates that may be driving the results. A third concern is that immigration may be moving the age structure in response to productivity shifts.<sup>19</sup>

In order to address these problems, several regressions were performed. First, the imputation procedure was tested by using only the ten year interval unimputed values. By moving to the unimputed data, the population data becomes available for use as an instrument for the workforce data. Contemporaneous population demographics will strongly covary with workforce demographics, yet be orthogonal to age specific participation rates. The use of lagged population demographics as an instrument can address the question of immigration and, more generally, the question of reverse causality. The reduced form for the IV regressions is useful because it allows the use of the larger sample of population data directly.

Table 2 presents the results of these regressions. Column (1) presents the base result, regressing the productivity residual against a set of demographic measures, utilizing imputed figures for decade midpoints.<sup>20</sup> Column (2) uses only unimputed values of the demographic measures as regressors. Columns (3) and (4) report the results of IV estimations where workforce measures are instrumented on contemporaneous and lagged population measures.<sup>21</sup> Columns (5) and (6) show the reduced form for columns (3) and (4). By using the population figures directly, data at five year intervals are available, increasing the sample size compared to the IV regressions. In the two reduced form columns, the regressors are labeled by the appropriate age at the end of the lag period.<sup>22</sup> The regressions are therefore

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<sup>19</sup>It is likely that immigration is working against the results. US INS data suggests that immigration is skewed toward younger cohorts. In 1996 44% of working age immigrants were under the age of 30, compared to 27% in the population. An increase in immigration due to a productivity increase would likely increase the young worker cohorts, associating them with higher productivity.

<sup>20</sup>This column is identical to column 2 of Table 1.

<sup>21</sup>The instrument set in the latter case is restricted to the population structure of people who will be in the workforce at the end of the lag period. The instruments for the 10 year lagged IV regressions are therefore constructed from the population aged 5 to 55 since they will comprise the working age population 10 years hence.

<sup>22</sup>For example, in the ten year lagged regression, the regressor labeled P50 is the proportion of people aged 40 to 49 years ten years earlier measured as out of the population aged 5 to 55 ten years earlier.

directly comparable to the IV regressions.

The results are extremely consistent across estimation methods, with all confidence intervals overlapping. The point estimates suggest that movements into the 40 year old group from all other age groups is associated with higher productivity. For the younger cohorts, the point estimates are significant in most cases and consistent in magnitude. For the cohorts aged 50 and above, the results are more equivocal. The 50-59 cohort has a negative point estimate in all cases, but is only significant in only one of the four cases where participation rates are accounted for. All the point estimates for this cohort are smaller in magnitude than for the younger cohorts. The 60 plus cohort has a negative point estimate in all but one case, but is significant only in the OLS case.

Table 2 shows that large cohorts aged 15-39 are associated with significantly lower productivity. The magnitude of coefficients for this group are consistently large and extremely stable across estimation methods. The magnitudes are roughly an order of magnitude larger than suggested by microeconomic evidence on the link between wages and experience. The IV regressions suggest that these results are not driven by participation rates. The regressions using lagged population values further show that immigration is not likely to be causing the results.

For the older cohorts the results are much less clear. The OLS results suggest that large cohorts aged 50 and older are associated with lower productivity compared to the comparison 40-49 group. The coefficients for the older cohorts appear to be smaller than for the younger cohorts and are less precisely estimated. The IV coefficients are not significant different than zero though the confidence intervals are large enough that one cannot reject the OLS results.

## **3.2 Hours Worked**

One factor which may be influencing the results discussed thus far is the relatively crude way in which productivity is constructed. For example, labor input is measured in terms of the number of workers and does not account for differences in the number of hours

worked. Also, more sophisticated productivity measures take into account quality and age differences in the physical and human capital stocks. Unfortunately, the data are not available to make corrections for the entire sample. This section will exploit the data that are available in order to assess whether these factors are driving the results.

Hours per worker data are available from the Groningen Growth and Development Centre and The Conference Board (2004) for 19 countries and can be used to construct GDP per hour from the GDP per worker data used in the earlier regressions. Table 3 shows the results of regressions using higher quality OECD data for 19 countries. The first three columns are organized in a similar fashion to the decomposition performed in Table 1. Column (1) replicates the results of column (1) of Table 2 with a sample restricted to countries for which hours data were available. Column (2) is a regression of average hours worked against the standard set of demographic variables. Column (3) is a regression of TFP corrected for hours worked. The coefficients for columns (2) and (3) sum to the value of column (1) by construction, with the magnitudes of the coefficients indicating the contribution of each element. The results suggest that differences in hours worked are contributing to the base results. All point estimates are negative indicating that a larger proportion of 40 year old workers is associated with increased hours. However, none of the coefficients are significant and the demographic measures are jointly insignificant. More importantly, the magnitude of the hours effect is an order of magnitude smaller than the effect we see on the productivity residual. The results therefore cannot be explained by hours worked.

The final column of Table 3 shows the results of regressing Total Factor Productivity for the G-7 as measured by Jorgenson (2003). The results are broadly consistent with the results presented in earlier sections, though the magnitude of the effects are less than half of those found in the base estimation. Even so, the magnitude of the effects are still quite large. Consistent with the IV and reduced form estimates of the previous section, the negative correlation of cohort size with productivity is more discernable in the young cohorts than the older cohorts.

### 3.3 Out of Sample Predictions, 1990-1995

One of the useful features of demographic change is its predictability. The model should, in theory, allow us to predict future movements in output. As a robustness check, I examine the ability of the model to make out of sample predictions. Out of sample projections of output growth for 1990-1995 were constructed using demographic data and the coefficients estimated using the 1960-1990 data.<sup>23</sup> Figure 1 graphs these growth projections against actual growth in real GDP per worker for 1990-1995.

An OLS regression on the demographic predictions versus actual output growth in the 1990-1995 period results in a point estimate that is not significantly different than one and is significantly different from zero at the 1% level. The  $R^2$  of this regression is 0.116.<sup>24</sup> Demographic changes appear to predict almost twelve percent of the growth in real GDP per worker in the 1990-1995 period. The projections are based on a regression in differences without a country dummy so that only changes in demographic measures are used in making the prediction.

## 4 Cross Country Productivity Differences

The link between demographics and productivity growth can also provide insight into cross country productivity patterns. The demographic characteristics of the workforce differ greatly across countries with different income levels. Figure 2 illustrates the proportion of the workforce between the ages of 40 and 49 by income level.

Two facts are immediately apparent. The poorer nations have a lower proportion of forty year old workers than the richer nations in every year. This is associated with lower

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<sup>23</sup>These regressions and projections are based on a larger group of countries than the estimates presented earlier in the paper. For consistency across specifications, the earlier estimates were limited to countries that had complete data for output, human capital, physical capital and demographics. For the out of sample predictions, only output and demographics were needed. All countries with the necessary data were used. Limiting the sample to the smaller group generates similar results.

<sup>24</sup>If the initial regression includes country fixed effects, the resulting prediction has an  $R^2$  of 0.161 with the actual growth rate. This prediction obviously includes information on the long run growth trend for each country. The  $R^2$  falls to 0.091 if only demographic information is used for prediction after the initial estimation with country fixed effects.

productivity in the poor nations throughout the sample. The second aspect of the graph is the trend. The wealthy nations saw a relatively static 40 year old cohort until about 1980. From 1980 until 2000 the proportion of 40 year olds increases dramatically. This is not true of the poor nations.

There are two implications. First, some proportion of the persistent productivity gap between rich and poor nations is associated with the persistent differences in the age structures. Second, the changes over time may be associated with the observed productivity divergence between the rich and poor nations. Figure 3 shows the average log productivity difference between the OECD and the low income group of countries over time. An additional line shows the component of the gap associated with demographics. In each year of the sample, one quarter to one third of the log productivity gap is associated with differences in workforce demographic structure. This graph also shows the divergence in productivity between the OECD and the low income nations. The increase appears to be unrelated to demographic changes between 1960 and 1980, but the acceleration in the increase after 1980 may be associated with divergence in the demographic structure.

## 5 Conclusion

The results presented in this paper show that workforce demographics are strongly correlated with productivity and output. The results suggest that a significant portion of the productivity gap between rich and poor countries is related to different demographic structures. The results also appear to capture some of the productivity divergence between the poor and rich countries since 1980. Given the importance of productivity in explaining cross country income differences, this is a useful result. Unlike most of the variables used in the growth literature to study productivity, demographics have substantial time series variation.

While emphasizing the importance of demographics, this paper is agnostic as to the mechanisms through which demographic change and productivity are related. However,

unlike many factors studied in the growth literature, contemporaneous reverse causality is not driving the results. The regressions using lagged demographics indicate that movements in productivity are not causing contemporaneous changes in demographics. This is not to say that the reverse is necessarily true. The evidence in this paper is not sufficient to establish a causal link between demographic change and productivity growth. An alternative possibility is that there is some omitted factor which had an impact on fertility in the past but which affects productivity with long lags.

Understanding this relationship is important because of the useful and predictable characteristics of demographics and because the significance of the relationship is strong. Almost every region in the world is experiencing significant demographic change. The rich nations are rapidly becoming older and most have birthrates below replacement level. Some poor countries are experiencing dramatically reduced birthrates in the wake of population explosions. Understanding how these changes will affect productivity over the coming decades is of crucial importance. While this paper shows that there is a relationship between productivity and demographics, more research is needed to understand the mechanisms behind this relationship.

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Figure 2: The Proportion of Workers Aged 40-49 By Income Group

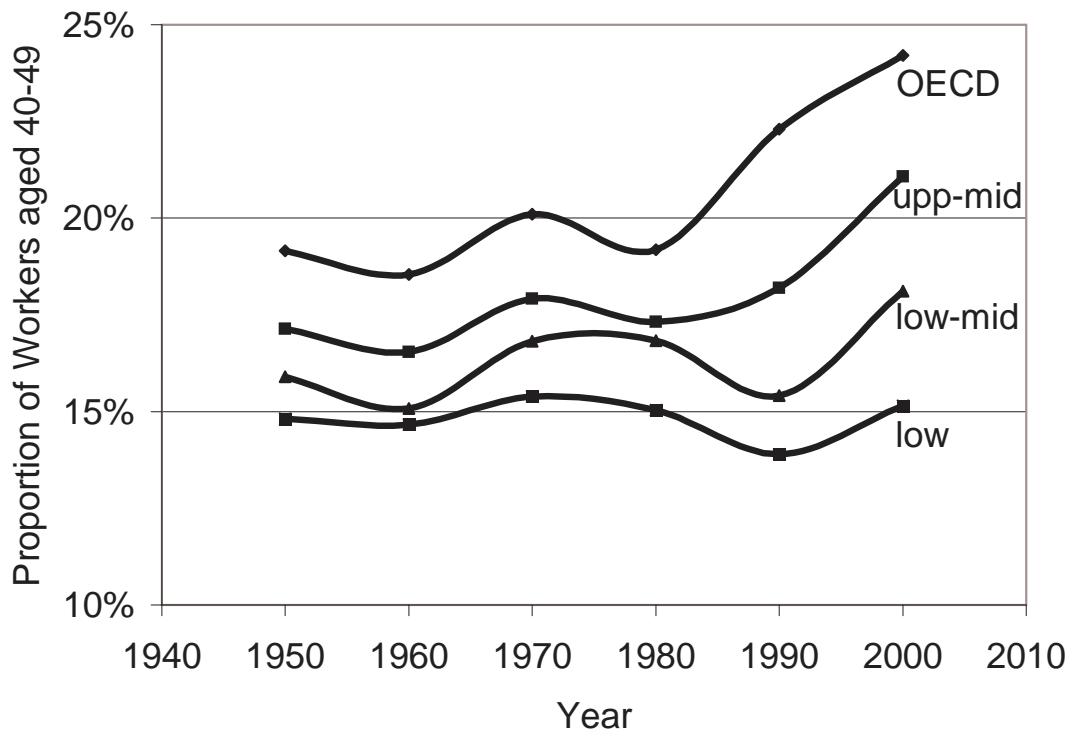


Figure 3: Log productivity gap between OECD and low income countries

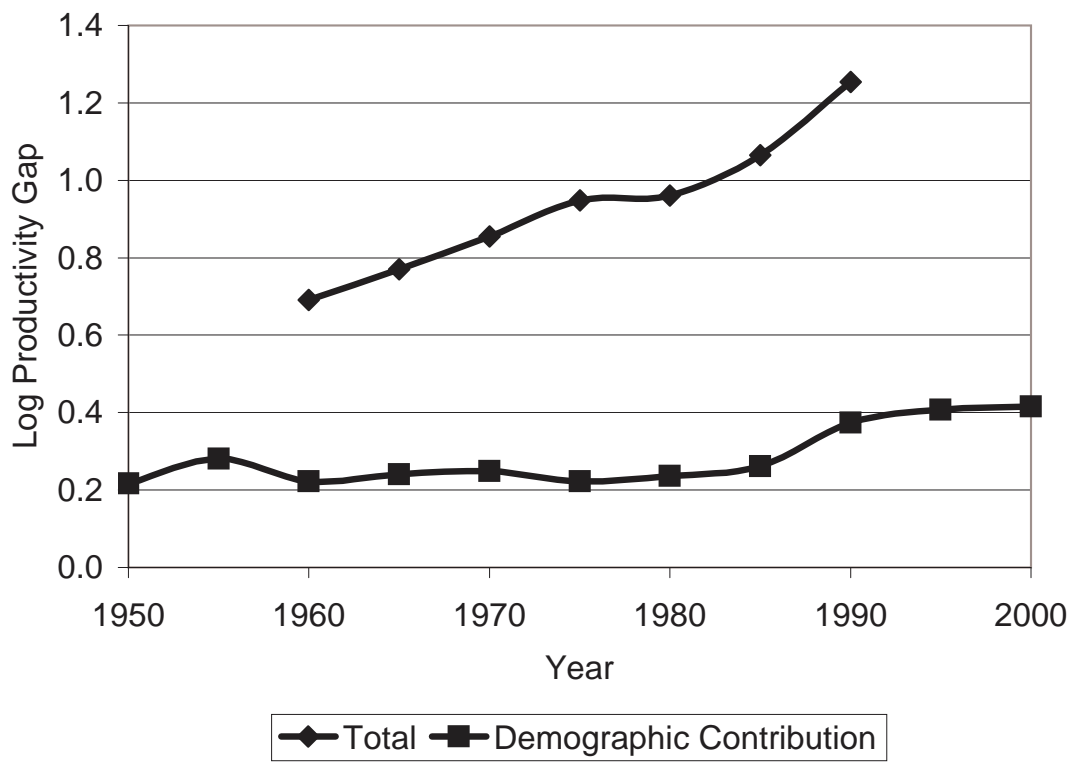


Table 1: Effect of Workforce Composition on Output – Channels

	(1)	(2)	(3)	(4)
	$\Delta\log(\text{gdpw})$	$\Delta\log(A)$	$\frac{\alpha}{1-\alpha}\Delta\log(K/Y)$	$\Delta\log(h)$
$\Delta W_{10}$ imputed	-2.800 [0.812]**	-3.271 [1.297]*	0.035 [0.503]	0.327 [0.230]
$\Delta W_{20}$ imputed	-2.411 [0.743]**	-3.169 [1.122]**	0.127 [0.411]	0.513 [0.226]*
$\Delta W_{30}$ imputed	-3.173 [0.808]**	-3.828 [1.206]**	0.326 [0.419]	0.194 [0.239]
$\Delta W_{50}$ imputed	-1.592 [0.802]+	-2.120 [1.051]*	0.129 [0.472]	0.487 [0.326]
$\Delta W_{60}$ imputed	-1.813 [0.846]*	-2.066 [1.211]+	-0.038 [0.430]	0.185 [0.317]
$\Delta\text{deprat}$	0.938 [0.706]	0.478 [1.001]	0.294 [0.422]	0.138 [0.164]
year=1965	0.082 [0.033]*	-0.125 [0.047]*	0.233 [0.018]**	-0.023 [0.008]**
year=1970	0.051 [0.026]+	-0.216 [0.036]**	0.254 [0.013]**	0.011 [0.008]
year=1975	0.065 [0.039]+	-0.223 [0.061]**	0.291 [0.024]**	0.001 [0.010]
year=1980	0.012 [0.030]	-0.27 [0.044]**	0.249 [0.014]**	0.024 [0.008]**
year=1985	-0.022 [0.042]	-0.308 [0.063]**	0.285 [0.021]**	0.008 [0.011]
year=1990	-0.079 [0.040]*	-0.312 [0.059]**	0.201 [0.021]**	0.033 [0.011]**
Observations	499	499	499	499
Countries	87	87	87	87
R-squared	0.54	0.3	0.42	0.59
$\Delta W$ joint p-value	0.01	0.05	0.90	0.19

Standard errors in parentheses

All columns are estimated with a full set of country dummies  
+ significant at 10%; \* significant at 5%; \*\* significant at 1%

Table 2: The Effect of Workforce Age Structure on Productivity

	Dependent variable $\Delta\log(A)$					
	(1)	(2)	(3)	(4)	(5)	(6)
Lags	OLS		IV		Reduced Form	
Regressors	imputed worker	unimputed worker	unimputed worker	unimputed worker	0 yrs pop	10 yrs pop
$\Delta W_{10}$	-3.271 [1.297]*	-3.138 [1.922]	-4.059 [2.274]+	-3.95 [2.604]	-2.75 [1.502]+	-2.417 [1.182]*
$\Delta W_{20}$	-3.169 [1.122]**	-2.975 [1.429]*	-2.952 [1.436]*	-1.987 [1.721]	-4.162 [1.226]**	-3.379 [1.039]**
$\Delta W_{30}$	-3.828 [1.206]**	-3.975 [1.401]**	-4.249 [1.408]**	-3.486 [1.661]*	-4.548 [1.287]**	-3.684 [1.069]**
$\Delta W_{50}$	-2.12 [1.051]*	-0.738 [1.767]	-0.431 [1.925]	-1.864 [2.222]	-2.002 [1.174]+	-1.804 [1.175]
$\Delta W_{60}$	-2.066 [1.211]+	-1.41 [2.494]	0.426 [3.278]	-2.239 [3.358]	-1.496 [1.574]	-1.293 [1.521]
$\Delta\text{deprat}$	0.478 [1.001]	0.269 [1.278]	0.345 [1.257]	1.062 [1.301]	0.292 [1.011]	0.76 [1.200]
year=1965	-0.125 [0.047]*				-0.159 [0.047]**	-0.153 [0.046]**
year=1970	-0.216 [0.036]**	0.228 [0.060]**	0.236 [0.064]**	0.18 [0.076]*	-0.223 [0.044]**	-0.211 [0.042]**
year=1975	-0.223 [0.061]**				-0.251 [0.042]**	-0.246 [0.043]**
year=1980	-0.27 [0.044]**	0.07 [0.095]	0.079 [0.109]	0.001 [0.121]	-0.255 [0.021]**	-0.253 [0.023]**
year=1985	-0.308 [0.063]**				-0.344 [0.025]**	-0.343 [0.026]**
year=1990	-0.312 [0.059]**	-0.047 [0.068]	-0.051 [0.084]	-0.107 [0.087]	-0.293 [0.028]**	-0.285 [0.029]**
Observations	499	246	246	246	499	499
Countries	87	87	87	87	87	87
R-squared	0.3	0.54			0.3	0.29

Standard errors in parentheses

-All columns are estimated with a full set of country dummies

-For IV columns, instruments are lagged population proportions.

-For lagged reduced form columns, the population proportions are predicted from lagged population values.

+ significant at 10%; \* significant at 5%; \*\* significant at 1%

Table 3: Regression using OECD data

	(1) $\Delta\log(A)$	(2) $\Delta\log(\text{hours})$	(3) $\Delta(\log(A)$ $-\log(\text{hours}))$	(4) $\Delta\log(A)$ Jorgenson
$\Delta W_{10}$ imputed	-4.282 [0.835]**	-0.277 [0.220]	-4.005 [0.748]**	-2.119 [0.744]*
$\Delta W_{20}$ imputed	-3.264 [0.733]**	-0.325 [0.258]	-2.939 [0.805]**	-1.192 [0.555]+
$\Delta W_{30}$ imputed	-2.498 [0.610]**	-0.346 [0.270]	-2.152 [0.683]**	-0.937 [0.564]
$\Delta W_{50}$ imputed	-2.16 [0.930]*	-0.122 [0.314]	-2.038 [0.967]*	-0.963 [1.208]
$\Delta W_{60}$ imputed	-2.499 [1.182]*	-0.456 [0.298]	-2.044 [1.050]+	0.411 [0.426]
year=1965	0.232 [0.022]**	-0.017 [0.010]	0.249 [0.024]**	0.177 [0.042]**
year=1970	0.046 [0.051]	-0.041 [0.009]**	0.087 [0.049]+	0.099 [0.046]+
year=1975	0.128 [0.036]**	-0.04 [0.006]**	0.168 [0.033]**	0.107 [0.017]**
year=1980	-0.127 [0.063]+	-0.045 [0.013]**	-0.082 [0.060]	0.013 [0.045]
year=1985	0.146 [0.048]**	-0.018 [0.007]*	0.164 [0.044]**	0.054 [0.040]
year=1990	-0.134 [0.062]*	-0.028 [0.013]*	-0.106 [0.054]+	-0.046 [0.041]
year=1995				-0.039 [0.008]**
Observations	113	113	113	49
Countries	19	19	19	7
R-squared	0.55	0.62	0.62	0.72

Standard errors in parentheses

+ significant at 10%; \* significant at 5%; \*\* significant at 1%