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Human Capital and Macroeconomic Growth: Austria and Germany 1960-1997. An Update

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HUMAN CAPITAL AND MACROECONOMIC GROWTH:
AUSTRIA AND GERMANY 1960-1997
AN UPDATE

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Abstract

In an influential paper Mankiw, Romer, and Weil (1992) argue that the evidence on the international disparity in levels of per capita income and rates of growth is consistent with a standard Solow model, once it has been augmented to include human capital as an accumulable factor. In a study on Austria and Germany we augment the Solow model to allow for the accumulation of human capital. Based on a perpetual inventory estimation procedure we construct an aggregate measure of the stock of human capital of Austria and Germany by weighting workers of different schooling levels with their respective wage income. We obtain an estimate of the wage income of workers with different schooling from a Mincer type wage equation which quantifies how wages change with years of schooling. We find that the time series evidence on Austria and Germany is not consistent with a human capital augmented Solow model. Factor accumulation (broadly defined to include human capital) appears to be less (and not more) able to account for the cross-country growth performance of Austria and Germany when human capital accumulation is included in the analysis. Our results indicate that differences in technology are a driving factor in understanding cross country growth between these two neighboring countries with similar political and institutional background.

1. Introduction

Current thinking in growth theory is divided in two approaches which offer a coherent explanation of sustained economic growth. One strand of theory continues to see capital accumulation (broadly defined to include human capital) as the driving force behind economic growth. A second approach gives technical change a leading role in the growth. In an influential empirical paper Mankiw, Romer, and Weil (1992) (hereinafter MRW) argue that the evidence on the international disparity in levels of per capita income and rates of growth is consistent with a standard Solow model, once it has been augmented to include human capital as an accumulable factor. MRW argue that because saving and population growth rates vary across countries, different countries reach different steady states. The Solow model correctly predicts the direction of how these variables influence the steady state level of income. It fails, however, to correctly predict the magnitude of the influence. The estimated size of capital's share of income is too large to conform to independent observations of capital's income share. MRW proceed by including human capital accumulation as an additional explanatory variable in their cross country regressions. They argue, that because human capital accumulation is correlated with saving and population growth, omitting human capital accumulation biases the estimated coefficients on saving and population growth. They find that the inclusion of human capital indeed changes the estimated effects of saving and population growth to roughly the values predicted by the augmented Solow model. Furthermore, they show that the augmented Solow model accounts for about eighty percent of the cross-country variation in income. Based on their findings MRW conclude that it is doubtful to dismiss the Solow growth model in favor of endogenous-growth models.[1]

This paper offers a case study on the growth experience of two individual economies, Austria and Germany in the post-war period. A case study on individual economies makes it possible to isolate the effect of capital deepening (broadly defined to include human capital) on the one hand and technical change on the other in the growth process. In their cross-country regressions MRW make the assumption that all countries experience the same rate of technological progress. We take MRW

[1] The revival of the Solow model has been supported also by estimates of the growth experience of East Asian countries see Young (1995). For a survey on this debate see Klenow and Rodriguez-Clare (1997).

seriously and augment the Solow model to allow for human capital as an accumulable factor. We show that the human capital augmented Solow model is not consistent with the time series evidence of Austria and Germany. Our results indicate that differences in technology are a significant factor in understanding cross-country economic growth of Austria and Germany. The striking differences in total factor productivity growth between two similar countries which are as geographically close as Germany and Austria casts doubts on the notion of a common rate of technical progress and thus of the validity of the results obtained by MRW. Cross country differences in growth rates of Austria and Germany appear to be driven by differences in the rate of technical change and not so much by differences in factor accumulation.[2]

In order to augment the Solow model to allow for the accumulation of human capital, we estimate the human capital stock of Austria and Germany based on a perpetual inventory procedure for five categories of educational attainment. We use data on completion of educational levels rather than enrollment rates (as has been done by previous studies). The estimates obtained by this procedure are then modified to benchmark the census observations of the five categories of educational attainment and to allow for education-specific survival rates. We then construct an aggregate measure of the stock of human capital of Austria and Germany by weighting workers of different schooling levels with their respective wage income. We obtain an estimate of the rate of return of different schooling levels from a Mincer type earnings-equation which quantifies how wages change with years of schooling.

The paper comes in six sections. Section 2 presents some stylized facts about growth and convergence in Austria and Germany. Section 3 summarizes the augmented Solow model and its implication for testing. Section 4 presents the methodology of estimating the human capital stock of Austria and Germany and relates our methodology to previous estimates in the literature. The section gives also a

[2] A paper by Islam (1995) using panel estimation which allows for correlated country specific technology effects shows that MRW's results are considerably altered when differences in aggregate production functions across countries are taken into account. The panel estimates for capital's share of income are much closer to the general accepted values even when human capital accumulation is not taken into account. This suggests that much of the upward bias of the estimated coefficient on capital seems to be generated by an omission bias due to the missing variable of technical change. Islam's findings suggest that the coefficient on the investment variable picks up not only the variation in per capita incomes due to differences in countries' tastes for savings, but also part of the variation due to their differences in technical change.

summary of the results. Section 5 incorporates these human capital stock estimates in a growth accounting calculation to obtain measures of total factor productivity growth. Section 6 concludes.

2. Some Stylized Facts

In order to place the growth experience of Austria and Germany in international perspective we turn to the popular Summers and Heston purchasing power parity data set. Table 1 presents income per capita for major OECD countries in relation to the US. Three facts are noteworthy. First, in the period between 1960 and 1980 Austria was among the European countries which closed its income gap to the US fastest. Second, Germany exhibited a faster convergence rate than Austria when the 1950s are taken into account. Third, in both countries the speed of convergence has slowed down since the mid 1980s.

As shown in Figure 1 until the early 1970s the investment to GDP ratio (at constant prices) has remained roughly constant in Germany , while rising rapidly in Austria. By the early 1970s Austria and Germany had investment rates of approximately the same size.

Human capital accumulation has been quite rapid in both countries. Table 2 shows that over the past two and a half decades the proportion of the working population with a university education more than doubled in both countries. The proportion of the labour force with a degree to enter university („Abitur"/ „Matura") almost tripled while those with primary education declined rapidly.[3]

[3] For Germany the figures of the population census are not comparable over time due to changes in the education system and due to changes in classification. We corrected the figures of the census to make them comparable over time by assuming constancy of the education system and of classification, see section 4.1 for a description.

3. The Human Capital Augmented Solow-Model

MRW start with a production function which includes human capital as a third input

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t)L(t))^{1-\alpha-\beta} \tag{2}$$

where Y is output, K is physical capital, L is labour, H is human capital, and A is the level of technology. L and A are assumed to grow exogenously at rates n and g. The physical capital stock and the human capital stock are augmented at the constant savings rates s_k and s_h, respectively, and both stocks depreciate at the same rate δ. Physical capital evolves according to $dK_t/dt = s_k Y_t - \delta K_t$ and human capital evolves according to $dH_t/dt = s_h Y_t - \delta H_t$. Assuming that countries are in their steady-state MRW derive the following expression for the steady state per capita income

$$\ln(\frac{Y(t)}{L(t)}) = \ln A(0) + gt - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta}\ln(s_h) \tag{3}$$

with α as the physical capital's share of income and β as the human capital's share of income. MRW use this equation to see how differing saving in physical and human capital and labour force growth rates can explain the differences in per capita incomes across countries. In their empirical implementation of equation (3), MRW rely on the crucial assumption that the rate of technological progress, g, is the same for all countries. This way, t becomes a fixed number, and gt enters just as a constant term in their cross-section regression. The $A(0)$ term in equation (3) which reflects not just technology but resource endowments, climate and institutions, is seen to differ across countries and MRW assume that $\ln A(0) = a + \varepsilon$ where a is a constant and ε is a country-specific term. Incorporating these assumptions in equation (3) yields them the specification

$$\ln(\frac{Y}{L}) = a + \frac{\alpha}{1-\alpha-\beta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta}\ln(s_h) - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \varepsilon \qquad (4)$$

MRW estimate equation (4) and examine the plausibility of the implied factor shares. If OLS gives them coefficients on saving and population growth whose magnitudes are substantially different from the values predicted by the Solow model (approximately 0.5 for an assumed capital's share in income of roughly $^1/_3$), MRW reject the joint hypothesis that the Solow model and their identifying assumption are correct. MRW show how leaving out human capital as a third input will affect the residual. Combining (4) with an equation for the steady state level of human capital results in an equation for income as a function of the rate of investment in physical capital, the rate of population growth, and the level of human capital[4]

$$\ln(\frac{Y(t)}{L(t)}) = \ln A(0) + gt + \frac{\alpha}{1-\alpha}\ln(s_k) - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + \frac{\beta}{1-\alpha}\ln(h^*) \qquad (5)$$

From equation (5) it can be seen that in a specification of the production function without human capital as a third input, the level of human capital h^* is a component of the error term. Therefore, when human capital is omitted in a growth accounting calculation the estimates of TFP will be biased upwards.[5]

In our study on Austria and Germany we evaluate the Solow model by proceeding in the following way. We start from equation (3) which does not make any assumptions on $[\ln A(0) + gt]$ and we apply this growth accounting equation to time series data of Germany and Austria, respectively. In a first step, we do not include human capital as a third input into the total factor productivity analysis. We impose on equation (3) a value of α derived from national accounts data on factor shares and we ask how much of the variation in income over time the model can account for. We use a closely related equation as (3) without making the steady state assumption. We replace the investment as a

[4] The steady state level of human capital is given by $h^* = (\frac{s_k^{\alpha} s_h^{1-\beta}}{n+g+\delta})^{\frac{1}{1-\alpha-\beta}}$

[5] MRW use this argument also to show why omitting human capital will bias the estimated coefficients on saving and population growth.

share of income by the capital stock.[6] This standard growth accounting procedure allows us to decompose growth over time in a single country into a part explained by growth in factor inputs and an unexplained part - the Solow residual - which is typically attributed to technical change. The Solow model's prediction is that differences in saving and population growth account for a large fraction of the cross-country variation in per capita income between Austria and Germany. Accordingly, the model predicts that Austria has been growing faster than Germany in the post war period and thus has been catching up to the German income level because it lagged behind Germany in its capital accumulation making its marginal productivity of capital larger and thus capital formation more worthwhile.[7] If growth accounting yields estimates of the Solow residual which are large and differ significantly between the two countries, then we can reject the hypothesis that the Solow model and MRW's assumption of a common rate of technological progress across countries are correct.[8] We consider the Solow residual to be "large" if it exceeds the "unexplained residual variance" obtained by MRW in their cross-country regressions. In a second step, we correct for the possible upward bias of the TFP by including human capital as a third input in the estimates of total factor productivity.

The estimates of total factor productivity with physical capital and raw labour for Austria and Germany are given in Table 3. For the entire period the imposed value for capital's share in income is 0.29 for Austria and 0.28 for Germany. As it appears from the Table differences in factor accumulation between the two countries can account for part of the difference in the growth rates of Germany and Austria only. The contribution of technical change as measured by total factor productivity appears to be large in both countries. The Solow residual accounts for 67,1% of economic growth in Austria and about 57,2% of economic growth in Germany. These residuals by far exceed the

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[6] MRW use investment shares as a proxy for the capital stock which is justified under the steady state assumption.

[7] The same prediction holds in a Cass-Koopmans type model that endogenizes the savings decision.

[8] One could object against this "testing procedure" that two countries are not enough to reject the hypothesis of no differences in total factor productivity (henceforth TFP) across countries. Against this objection we want to stress that we have selected two neighbouring countries with similar political and institutional background for which the assumption of a common rate of technical progress is most likely to be true. If we can show that even for such "similar" countries TFP differ substantially, we feel comfortable to reject the hypothesis of no difference in TFP. Austria and Germany can be classified to form a „convergence club“ in the sense defined by Durlauf and Johnson 1991 in their classification using the „regression tree“ method.

unexplained variation obtained by MRW of roughly 40%.[9] The difference in the growth rate between Austria and Germany appear to be driven by differences in the rate of technical change and not so much by differences in capital accumulation. Moreover, the striking difference in total factor productivity between these two economies makes it easy to reject - even without a formal test - MRW's assumption of a common rate of knowledge advancement across countries.[10]

The above results make it appropriate to conclude that the Solow model is not very successful in explaining a high fraction of the variation in income between Austria and Germany. One of the reasons why the data do not come out in support of the Solow model suggested by MRW lies in the fact that we have not included human capital as an accumulable factor. Therefore, we might attribute something to technical change which, in fact, must be accounted for by human capital. Accordingly, the TFP estimates of Austria falsely turn out to exceed those of Germany because human capital growth in Austria exceeded that of Germany and our procedure attributes this to technical change. In a second step, we proceed to estimate the total factor productivity with human capital included to see whether the inclusion of human capital in the analysis can reverse the results found in this section. Before we can do so, however, we have to find an aggregate measure for human capital. We turn to measuring human capital in the next section.

4. Measuring Aggregate Human Capital

Measuring human capital is notoriously difficult. The reason is that in most countries educational data are available only for one or two years per decade. In recent years several researchers have attempted to construct measures of the stock of human capital in order to facilitate empirical studies on the role of human capital for cross-country growth comparisons (see Barro and Lee 1993 , Mulligan and Sala-

[9] We refer to the regressions in Table I of the textbook Solow model. The unexplained residual variation in MRW is defined by their adjusted $1-R^2$.

[10] Endogenous growth theory leads us to expect a larger TFP in Germany than in Austria, since the theory gives larger economies a comparative advantage in undertaking R&D. This prediction can be derived also in an endogenous growth model with externalities of the type of Romer 1986. For a discussion see Marin (1995). For an attempt to reconcile the empirical fact that larger countries do not necessarily innovate more see Jones (1995) and Young (1995).

i-Martin 1995a, 1995b). We describe now our methodology of creating time series data on the human capital stock of Austria and Germany.

4.1 Estimating Missing Observations

We construct time series data on educational attainment for Austria and Germany for the period 1960 to 1997. We use years of completed schooling of the working population of 15 years and over as our concept of human capital. The underlying information comes from population censuses. In addition we use information on school completion. Based on the available national census data we construct figures for five levels of educational attainment: „Pflichtschule" (compulsory education, includes primary school plus 5 years of secondary school), „Lehre" (apprenticeship, only available for Austria), „mittlere Schule" (Austria)/ „mittlere Reife" (Germany), „ Matura" (Austria)/ „Abitur" (Germany) (degree to enter university), „Fachhochschule" (college, exists in Germany only) and university.[11] The constructed data consist of 5 time series for each country.

For Austria we have one observation per decade for the 5 education levels from the population census (1961, 1971, 1981, 1991, for 1961 for university and „Matura" only). Before the population census 1971 completion of the so called university-like schools where added to the education level of „Matura". Therefore, we added people with university-like degrees to the education level „Matura" throughout the entire period. We used the first university degree whenever available for people who completed university. We have data on the „Matura", the graduation to enter university, for almost the entire period. For those years for which they were not available (1980-1986) we estimated the number of persons who acquired the „Matura" from data of successful completion of the respective school type. Data for graduates of the „mittlere Schule" were not always available. Whenever they were not available we estimated them from data on pupils of the last school year. In some cases we had the number of pupils who completed the last school year successfully. We have data on the number of persons who completed the „Lehre" (apprenticeship) for the entire period. The data of the

[11] „Pflichtschule" corresponds to Primary Education, „Mittlere Reife" (Germany) and „Mittlere Schule" (Austria) correspond to Secondary Education Stage I, „Abitur" (Germany) and „Matura" (Austria) correspond to Secondary Education Stage II, „Fachhochschule" and „Universität" correspond to Higher Education.

„Pflichtschule" (compulsory education) resulted as a residual of those people who have not completed the other education levels.

For Germany we have census information for 1961 (for university only), 1970, and 1987. The census figures are not comparable over time due to changes in the education system and due to changes in the census classification. The German education statistics make a distinction between „general education" (allgemeine Ausbildung) and „professional education" (berufliche Ausbildung). General education includes primary education (Pflichtschule), secondary education stage I (mittlere Reife) and secondary education stage II (Abitur). Professional education consists of the so-called „Berufsfachschulen" and „Fachschulen", and „Fachhochschulen" (colleges) and university. The census 1987 reports general education and professional education separately, while the census 1970 reported the highest educational attainment of a person only (which could be either a general or a professional attainment). Moreover, the German „Fachhochschulen" did not exist in 1970. They had two predecessor institutions, the so-called „Ingenieurschulen" and „höhere Fachschulen". The census 1970 contains information on the graduates of „Ingenieurschulen" , but not on those of „höhere Fachschulen" (the latter were treated simply as „Fachschulen"). These changes make the raw data not comparable over time. In order to achieve consistency over time we decided to introduce a new classification which combines both systems of classifications. From the general education classification we use the education levels „Pflichtschule", „mittlere Reife", and „Abitur", from the professional classification we use the education levels „Fachhochschule" (college) and university. For 1970, this required that we allocate the graduates of the „Berufsfachschulen" and „Fachschulen" to the other education levels (Pflichtschule, mittlere Reife, Abitur, and Fachhochschule). We were guided by the flow data on general and professional attainment of the graduates of „Berufsfachschulen" and „Fachschulen" in 1970 to allocate the stocks.[12] For 1987, our new classification required that we deduct the graduates of colleges and universities from the number of persons with „Abitur" or „mittlere Reife" (depending on whether the former or the latter are a required educational background for universities or colleges or their predecessor institutions). In order to know where to deduct what we proceeded in the following way. The required general educational background for the university and „Fachhochschule" is the

[12] The details of the allocation procedure are not reported and are available upon request.

„Abitur“ and „Fachabitur“, respectively. We treated the „Fachabitur“ just like the „Abitur“. The required general educational background for the predecessor institutions of the „Fachhochschulen“ - the „Ingenieurschulen“ and „höhere Fachschulen“ - was the „mittlere Reife“. The transformation of „Ingenieurschulen“ and „höhere Fachschulen“ into „Fachhochschulen“ started in 1969 and took several years of transition. We chose 1972 as the first year in which graduates of „Fachhochschulen“ had to have an „Abitur“ as required educational background. Therefore, before 1972 graduates of „Fachhochschulen“ were deducted from the „mittlere Reife“ and from 1972 on graduates of „Fachhochschulen“ were deducted from the „Abitur“. With this procedure we were able also to make the census data of 1987 comparable with the census data of 1970.

For Germany we have information on university graduates from 1960 to 1997. We have data on college graduates and on graduates of their predecessor institutions for 1960, and 1965 to 1997. We obtained the missing years 1961 to 1964 by interpolation. Data for graduates of „mittlere Reife“ and „Abitur“ were available for 1970 to 1997. For 1960 to 1969 we used available data for the most important subgroups (particularly the „Realschulen“ and the „Gymnasien“) of the respective school type to estimate the total flow.

We fill in most of the missing observations for the five-level classification from a perpetual-inventory method that exploits the available data on school completion and population by age. We use the available census data as benchmarks and then estimate the missing observations for the two countries from 1961 to 1997.[13] We carry out the estimation in three steps: first, we estimate the missing observations of each category of educational attainment by a perpetual inventory method. The flow of graduates are cumulated by imposing that the explained percentage of the census observations is the same across different age-cohorts. We allocate the flow of graduates among the age-cohorts in such a way as to achieve this constancy of the explained percentages across age-cohorts. We use accuracy tests to evaluate our method of estimation by looking how well our estimated values explain the actual values of the census years available. The step 1 estimate does not exploit the available statistics on

[13] Our estimation procedure is analogous to that of Barro and Lee (1993) with the exception that we use data on school completion while Barro and Lee use data on school enrolment to fill in missing observations.

benchmark stocks of educational attainment. In a second step, we modify our estimates in order to reproduce the benchmark observations of the five categories of educational attainment given by the population census. Now the distribution of graduates among the age-cohorts is chosen in such a way as to reproduce the benchmark observations of the census years. However, the step 2 estimate does not take into account that the shares of the different age-cohorts should sum to 100 percent. In a last step, we allow for education-specific survival rates. We adjust the survival probabilities of each educational attainment for each age-cohort by forcing the sum of the shares of each age-cohort to equal 100 percent. Furthermore, the survival rates are adjusted in such a way as to make them consistent with the requirement that the share of each age-cohort in all graduates of an education level should not become negative.[14]

Our procedure is a perpetual inventory method that starts with the census figures as benchmark stocks and then uses school completion data to estimate changes from the benchmarks. Let $L_{i,t}$ be the population with age *i* at time *t* and $H_{i,j,t}$ be the number of people within this population for whom *j* is the highest level of educational attainment. Let $H^{+}_{i,j,t}$ be the number of persons aged *i* who completed the education level *j* in year *t* and $H^{-}_{i,j,t}$ be the number of persons aged *i* whose education level was *j* in the year before and who completed a higher educational level in year *t*. Then the estimated number of persons aged *i* with educational attainment *j* at time *t* is given by

$$H_{i,j,t} = H_{i-1,j,t-1}(1-\delta_{i,t}) + H^{+}_{i,j,t} - H^{-}_{i,j,t} \tag{6}$$

where $\delta_{i,t}$ is the proportion of people with age *i*-1 in year *t*-1 who did not survive to year *t*. Each year we cumulate the net flow of graduates aged *i* of education level *j* in year *t*. This net flow is obtained by adding the number of graduates aged *i* of education level *j* in year *t*, $H^{+}_{i,j,t}$ and subtracting those who acquired a higher education level in year *t* (and whose education level was *j* in the year before *t*), $H^{-}_{i,j,t}$. For simplicity we assume here a typical educational carrier pattern. For Austria, people who acquired a university degree at time *t*+1 are assumed to have been exclusively former graduates of

[14] In some cases it was necessary to change the allocation of graduates among the age-cohorts every year to avoid negative stocks or negative survival rates.

„Matura“ at time *t*. People who completed all other education levels are assumed to be former graduates of „Pflichtschulen“. For Germany, graduates of universities and colleges are assumed to be former graduates of „Abitur“, graduates of „Abitur“ former graduates of „mittlere Reife“, and the latter are assumed to be former graduates of „Pflichtschulen“.

We estimate the survival rate that appears in equation (6) from

$$(1-\delta_{i,t}) = z_{i,j}\,\frac{L_{i,t}}{L_{i-1,t-1}} \tag{7}$$

$z_{i,j}$ is a factor which corrects the demographic survival rate of age *i* to allow for education-specific survival probabilities. $z_{i,j}$ is equal 1 in the step 1 and step 2 estimation procedure in which we assume that the survival rate is independent of educational attainment. In the step 3 estimation we adjust the survival rates for each educational level. In the third step, $z_{i,j} \neq 1$ and is endogenously determined by forcing the shares of the different age-cohorts in the flow of graduates not to take a negative value and to sum to 100 percent.

We use forward-flow estimates whenever possible. A forward-flow estimate for 1981, for example, uses the benchmark from 1971 to estimate attainment in 1981. For Austria, we perform forward-flow estimates for 1981 and 1991. We use backward-flow estimates based on 1971 to obtain 1961. For Germany, we use a forward-flow estimate for 1987 based on 1970, and a backward-flow estimate for 1960 based on 1970.

Tables 4a and 4b evaluate all three procedures for Austria and Germany. Block A of Table 4a and 4b provide measures of accuracy of the step 1 perpetual inventory estimation procedure by looking how well our estimated values explain the actual values of the census years. Although the estimated values explain a large fraction of the actual values - in no case deviated the estimated values by more than 35% - the table makes clear that the remaining measurement error is substantial. In general, the procedure performed much better for Austria than for Germany. This is not surprising given the changes in the education system and in classification in Germany which were absent in Austria. Furthermore, for Austria the estimation is based on 4 observations for four decades, while for Germany we have 3 observations only for the same period. Block B of Tables 4a and 4b evaluate the step 2 estimates with benchmarking by looking at the percentage with which the yearly number of graduates obtained by the perpetual inventory procedure had to be changed in order to reproduce the benchmark observation of the population census. As the positive percentages of Table 4b show the perpetual inventory procedure underestimated the census observation for all education levels in Germany. This was particularly pronounced for the „Fachhochschulen" and „mittlere Reife" for the forward-flow estimate of 1970-87. The annual number of graduates of „Fachhochschulen" had to be increased by 72.1% and those of „mittlere Reife" by 68.6% in order to reach the actual observation of the graduates of „Fachhochschulen" of the census of 1987. In Austria, the perpetual inventory estimates lead to either too high or too low levels of educational attainment compared to the census. For example, the annual flow of graduates of „mittlere Schule" between 1981 and 1991 had to be reduced by 41.2 in order to reach the census observation of 1991. Finally, we proceed to evaluate the step 3 estimates which allows for education-specific survival probabilities. Block C of Tables 4a and 4b gives the factor $z_{i,j}$ with which the demographic survival rates are corrected to obtain the education-specific survival rates. The correction factor tends to be larger for higher education levels confirming the intuition that people with more schooling tend to live longer.[15] In Figure 2 we display graphically all three estimates of the five education levels. We proceed by using the step 3 estimates of educational attainment in the remaining analysis. Table 5 and Table 6 give our estimates of the five education levels for Austria and Germany.

We translate these 5 education levels into years of schooling by assuming that a university degree requires 18 years of education, completion of the „Fachhochschule" takes 15 years of schooling, completion of „Matura"/„Abitur" 13 years, graduation of „mittlere Schule/ „mittlere Reife" 10 years, while completion of „Lehre" and „Pflichtschule" requires 9 years of education.[16] The 5 education

[15] The factor $z_{i,j}$ adjusts also for migration.
[16] In order to make the human capital stock data comparable between Austria and Germany, we treat the "Lehre" in the same way as the „Pflichtschule", because we have no data on „Lehre" for Germany.

levels for Austria and Germany are displayed in Table 5 and Table 6. We turn now how we aggregate these 5 levels of educational attainment into one measure of human capital.

4.2 Aggregation

One simple and common way to aggregate schooling levels into a measure of human capital is average years of schooling. Average years of schooling is computed by adding the product of the number of years of schooling times the number of people in each schooling category across schooling categories.

$$H = \sum_s s\rho(s) L \tag{8}$$

where $\rho(s) = L(s)/L$ is the share of the working age population with s years of schooling and L denotes the working population in the economy. The measure assumes that the productivity differential among workers with different levels of education is proportional to their years of schooling. For example, the measure presumes that a person with a university degree (18 years of schooling) is 18 times more productive than a person with one year of school. Furthermore, the linear aggregator in specification (8) supposes that workers of different schooling levels are perfectly substitutable. For example, college graduates can be substituted for university graduates without changing aggregate production. We find both assumptions unsatisfactory.

We construct an alternative measure of the stock of human capital which measures the productivity of a worker by the wage income she can obtain on the market. Our measure of human capital avoids the assumption of proportionality between years of schooling and productivity of a worker and gives people who are more productive a larger weight.[17] We allow also for a non linear relationship between the different schooling levels and human capital, reflecting the fact, that workers of different skills may not be perfect substitutes. We use an aggregator of the Cobb-Douglas type to relate workers with

[17] However, our measure of human capital does not take into account that people with the same amount of schooling who have studied different things might contribute to production differently. For example, our measure of human capital treats somebody with a degree in economics (which takes say 18 years) as equally productive as someone with a degree in Egyptology , if the latter takes also 18 years to complete.

different schooling levels to human capital. Taking logs, we specify the relationship between human capital and the sub labour inputs as

$$\ln H = \sum_s \omega_s \ln[\rho(s)L] \qquad \text{with } \omega_s = \frac{e^{\gamma s} L(s)}{\sum_s e^{\gamma s} L(s)} \tag{9}$$

where $\rho(s)$ is defined as before as the share of the working age population with *s* years of schooling and ω_s is the efficiency parameter of a worker with s years of schooling. We propose to measure the worker's efficiency by the wage income she can obtain on the market. $e^{\gamma s} L(s) / \sum_s e^{\gamma s} L(s)$ denotes the mapping from a workers years of schooling *s* to her human capital and is the share of the wage income of workers with *s* years of schooling in the total wage bill of the economy. The efficiency parameter ω_s is used as weight to add people up and is obtained from a Mincer type wage equation[18]

$$w(s) = e^a e^{\gamma s}$$

which relates male monthly earnings (net of taxes) to years of schooling s, a constant *a* and other variables (not shown in the equation) like years of experience, and industry dummies. The estimated parameter γ measures how wages rise with years of schooling and the Mincer regression constant *a* gives the wage of the zero skill worker. We obtain an estimate of γ=.07 and of *a*=8.5 with Austrian cross-sectional data of the years 1983 and 1987 from Hofer (1992). For Germany Mertens (1995) gets an estimate of γ= .06 and of *a*= 5.8.[19] She obtains these estimates with male monthly gross earnings from the Socio Economic Panel. Based on these wage equations we calculate the income shares of schooling level s in the total wage bill of the economy. We use a fixed-weight measure based on the income shares of 1990. Thus, we assume that one year of schooling generates the same amount of skill over time. [20] [21]

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[18] What we do here to find an aggregator for heterogeneous labour is analogous to the procedure of adding heterogeneous physical capital.

[19] Similar estimates are obtained by Moeller and Bellmann (1995)

[20] We were guided to use fixed-weights by the fact that rates of returns to schooling seem to be remarkable stable over time as Mertens (1995) and Hofer (1992) document. One year of schooling may not generate the

Table 7 gives the labour income shares of different schooling levels in the total wage bill of the economy. An inspection of Table 7 and Tables 5 reveals, as expected, that the wage income shares of schooling give the higher education levels a larger weight in the total wage bill compared to their percentage share in the population. From Table 7 we can calculate share of human capital in the wage bill. Adding up the education levels university, college, Abitur/Matura, and Mittlere Reife/Mittlere Schule (exluding "Lehre" and "Pflichtschule") human capital accounts for 34 percent of the wage bill in Austria and 45 percent of the wage bill in Germany.[22]

We divide the aggregate stock of human capital by the number of workers to get the human capital stock per person.

$$\ln(\frac{H}{L}) = h = \sum_{s} \omega_s \ln[\rho(s)] \qquad (10)$$

We can now compare our measure of the average stock of human capital with average years of schooling. This is done in Table 8 and displayed graphically in Figure 3. Two things appear from the graphs and the table. First, as expected, average years of schooling is substantially below the wage income weighted measure of human capital, because the latter gives higher education levels which are more scarce a larger weight.[23] Second, according to both measures human capital accumulation is

same amount of skill over time because some of the knowledge learned in schools may become obsolete due to technological change.

[21] For a discussion of the different concepts of human capital see Mulligan and Sala-i-Martin 1995b. Mulligan and Sala-i-Martin 1995a also use labour income to weight different schooling levels. Their methodology is somewhat different than ours, though. They use the Mincer wage equation to estimate the wage of the zero skill worker, while we use the equation to estimate the share of the wage income of different schooling levels in the total wage bill of the economy. The wage equation used here estimates the average increase in wage income across the 5 education levels and thus does not take into account that primary education might have a larger impact on wage income than secondary education etc.

[22] MRW use the ratio of average to minimum wages in the US (which is around 2.) to estimate a somewhat larger share of around 50 percent of wages which are due to human capital. Assuming a total wage share of 0.6 they derive a human capital share in national income of about 0.33.

[23] What seems to matter here is the assumption that workers of different schooling levels are not perfectly substitutable for each other. We make this assumption by using a Cobb-Douglas technology to aggregate different schooling levels. Apparently, the result is not generated by using wage income to weight workers efficiency. We obtain very similar results for human capital as average years of schooling when we use a linear aggregator for the different schooling levels and workers are still weighted with their wage income. The linear aggregator with wage income is not reported and available upon request. Mulligan and Sala-i-Martin 1995b report also much larger estimates for their labour-income based measure of human capital across US-States compared to average years of schooling.

much faster in Germany compared to Austria. In Germany in the period between 1960 and 1997 human capital per person rose by 29.1%, while in Austria by 14.8% only. Thus, Germany had a larger human capital stock than Austria to begin with and its human capital stock grew double as fast than that of Austria.[24] We decompose the human capital stock into its two components, the labour force and the human capital stock per person in Table 9 and Figure 4. In the early seventies, human capital was rising fast in Austria because both the labour force as well as human capital per person was expanding. In the same period, the growth of human capital in Germany was entirely due to the fact that each person was better endowed with human capital. The human capital stock in both countries expanded again rapidly in the late 1980s and less so in the 1990s.

5. Total Factor Productivity with Human Capital

We are now ready to calculate the total factor productivity incorporating human capital. We want to see whether the inclusion of human capital will lower and equalize the Solow residuals of the two countries. If this is the case we will conclude that MRW are right and that factor accumulation broadly defined to include human capital can indeed explain the cross-country growth performance of Austria and Germany.

To calculate total factor productivity we start from a Cobb-Douglas production function with physical capital and raw labour

$$Y = AK^{\alpha} L^{1-\alpha} \tag{11}$$

[24] The measure of human capital is sensitive to the number of education levels. We have five education levels for Germany (because of the „Fachhochschulen" which do not exist in Austria) , but only four for Austria (we treat the „Lehre" as the „Pflichtschule" in Austria, because we have no data on the former for Germany). This could be one of the reasons why Germany's human capital stock grew so much faster than Austria's. In order to see how much this matters for Germany, we reduced the number of education levels in Germany to four, by treating the „Fachhochschule" equal to the university". It turns out, that in this case the average human capital stock would have grown by 30.7% between 1960-97 rather than by 29.1%. If the „Fachhochschulen" are treated as equal to the „Abitur", then the human capital stock per person would have grown by 28.2% in the same period. We calculated the aggregate human capital stock for Austria with "Lehre" as an additional education level rather than treating the latter the same as the education level "Pflichtschule". In this case we get an increase in human capital between 1960 and 1997 of 30.2% and of human capital per capita of 24.2%. The latter is somewhat larger than 14.8% but still below the increase of Germany's human capital stock (without "Lehre") of 29.1%.

We then replace the labour force L by our quality adjusted labour input H given in (9)

$$Y = AK^{\alpha} H^{1-\alpha} \tag{11a}$$

We impose on equation (11a) the same value of (1-α) derived from national accounts data on factor shares as we did when calculating the total factor productivity with raw labour. To compute the quality-adjusted labour input H we impose the income shares of the five education levels of the year 1990 (given in Table 8).

We can decompose the human capital stock H into its two components

$$H = \frac{H}{L} L$$

where L is the labour force and H/L is the human capital stock per worker. Substituting $H/L*L$ for H in the production function we get

$$Y = AK^{\alpha} (\frac{H}{L})^{1-\alpha} L^{1-\alpha} \tag{11b}$$

To account also for different age-specific productivities of the physical capital stock, we use the net capital stock data provided by the Statistische Bundesamt and Hahn and Schmoranz (1984) for Germany and Austria, respectively. Both measures are produced by a similar procedure and use data for sub capital inputs of more than 20 sectors and two types of capital goods (equipment and construction). In contrast to the gross capital stock, the net capital stock accounts for the different vintages of capital goods by giving more recent investments a larger weight.[25]

We are now ready to recalculate the total factor productivities with the quality adjusted factor inputs which take account of education-specific and age-specific differences in productivity of the sub labour

[25] For the methodology see Statistisches Bundesamt (1992).

and capital inputs. The estimates of total factor productivity with human capital and the net capital stock are shown in Table 10 and displayed graphically in Figure 5. Several things appear from the Table. First, in Austria in the period 1960-97 the contribution of human capital to output growth is 8.3%. In the same period human capital contributes to annual growth with 17.5% in Germany. The results imply that in the period 1960-97 without human capital accumulation Austria and Germany would have grown less by 0.26 and 0.50 percentage points per year, respectively.[26] Second, technical progress remains the main vehicle of growth in Austria even when human capital accumulation is taken into account. The percentage contribution of the Solow residual is now 59.8% (compared to 67.1% with raw labour). In Germany the inclusion of human capital reduces the contribution of TFP to growth from 57.2% to 41.0%. Third, the Solow residuals of the two countries become more unequal when human capital is included in the analysis, reinforcing the results obtained from the estimates with raw labour. In sum, factor accumulation appears less (and not more) able to account for the cross-country growth performance of Austria and Germany when human capital is included in the analysis. The cross-country growth experience of Austria and Germany appears to be driven by differences in technology[27] [28]

6. Conclusions

This paper looks at the growth experience of Austria and Germany, two neighboring economies with similar political, cultural, and institutional background. We take MRW seriously in this paper and augment the Solow model to allow for the accumulation of human capital. We select Austria and Germany as the two countries of our case study because we believe that for these two economies MRW's assumption of a common rate of technical change is most likely to be true. We show that the

[26] We treat human capital as exogenous and do not attempt to explain this difference in the development of human capital between the two countries.

[27] We have run also growth accounting regressions with human capital for both countries. Human capital growth never enters significantly and usually with the wrong sign in both countries. The results are not reported and available upon request. Benhabib and Spiegel (1994) and Islam (1995) find also a negative point estimate on human capital with cross country data and with pooled data, respectively. For more detailed estimates of the relationship between human capital and TFP in Austria and Germany, see Koman and Marin (1997).

[28] Islam (1995) gets similar results in a panel data approach. He finds that persistent differences in the steady state levels of income between countries are due to differences in efficiency (which is close to the conventional concept of total factor productivity). The latter outweighs the impact of relative changes across countries in other variables, like the savings rate.

human capital augmented Solow model is not consistent with the time series evidence of Austria and Germany.

We construct a measure of the human capital stock of Austria and Germany which differs in two important ways from the most commonly used measure of human capital – average years of schooling. First, we measure a worker's productivity by the wage income she can obtain on the market which we estimate from a Mincer-type earnings equation. Second, we use a non-linear aggregator for the different education levels which avoids assuming that different schooling levels are perfect substitutes. It turns out that our wage-income weighted measure of human capital rises more than twice as fast as average years of schooling in both countries.

We then incorporate our measure of human capital into estimates of total factor productivity to see whether the inclusion of human capital lowers and equalizes the Solow residuals in the two countries. We find that in the period 1960 and 1997, without human capital accumulation, Austria and Germany would have grown by less than 0.26 and 0.50 percentage points a year, respectively. In other words, the percentage contribution of human capital to annual growth is 8.9 percent in Austria and 17.5 percent in Germany. Thus, human capital is more than twice as important for growth in Germany than it is in Austria. The latter development explains why the Solow residuals of the two countries become more unequal when human capital is included in the analysis. Thus, factor accumulation appears to be less (and not more) able to account for the cross-country growth performance of Austria and Germany when human capital is included in the analysis.

The paper documents a striking difference in the importance of technical change in the growth process between Austria and Germany. In Figure 5 we show that the two countries differ also in the pattern of their TFP over time. The figure gives over time cumulated percentage contributions to growth of total factor productivity. It reveals that over time technical change has lost importance for growth in Austria while it somewhat gained in importance in Germany. This pattern emerges also from the last column of Table 10 which gives growth accounting calculations for five-year subperiods. Between 1960 and 1997 59.8 percent of Austria's growth and 41 percent of Germany's growth is attributable to TFP. The same growth accounting calculation for 1990 to 1997 attributes only 40.6 percent of Austria's growth and 63.2 percent of Germany's growth to technical change. Thus in order to explain the difference in the growth experience of Austria and Germany in the post-war period one has to understand why the pattern of TFP is so strikingly different in these two otherwise similar economies.

Table 1

Per Capita Income Growth 1950-1992
USA = 100*

	1950	1960	1970	1980	1990	1992
Japan	16.2	30.3	57.5	65.7	80.8	85.8
Austria	32.5	51.5	57.3	68.1	71.3	73.2
Germany (West)	37.8	65.8	72.8	78.6	85.2	87.0
U.K.	58.9	67.0	64.5	67.2	72.1	70.2
France	45.7	58.8	71.3	76.5	77.7	78.5
Italy	31.5	46.0	58.3	66.2	70.1	72.0
Belgium	50.7	56.0	65.1	72.7	75.7	77.9
Finland	38.8	52.9	61.9	69.9	78.3	67.3
Switzerland	76.3	91.5	95.7	89.8	95.0	93.2
Sweden	66.0	78.0	84.9	81.3	82.6	79.2
U.S.A.	100.0	100.0	100.0	100.0	100.0	100.0

Source: Summers and Heston (1994).
* Ratio of per capita income in the country relative to that of the United States.

Table 2

Educational Attainment of the Working Population in percent

	Germany			Austria			
	1961	1970	1987	1961	1971	1981	1991
"Universität"	2.1	2.8	5.4	1.9	2.2	3.0	4.4
"Fachhochschule"	1.2	1.7	3.6				
"Abitur"/ "Matura"	2.7	2.9	7.9	5.3	6.8	8.8	12.5
"Mittlere Reife"/ "Mittlere Schule"	10.9	12.1	19.8	7.1	7.6	11.0	12.1
"Lehre"	n.a.	n.a.	n.a.	22.8	25.8	30.1	35.4
"Pflichtschule"	83.0	80.5	63.2	63.0	57.6	47.1	35.7

Sources: Volkszählung Statistisches Bundesamt, Wiesbaden and Österreichisches Statistisches Zentralamt. For Germany the figures are not identical with those of the population census. The population census figures are not comparable over time due to changes in the education system and due to changes in classification. We corrected the figures of the census to make them comparable over time by assuming constancy of the education system and of classification.

"Pflichtschule" corresponds to primary education, "mittlere Reife" (Germany) and "mittlere Schule" (Austria) correspond to secondary education stage I, "Abitur" and "Matura" (Austria) correspond to secondary education stage II and "Fachhochschule" (college) and "Universität" (university) correspond to higher education.

Table 3 Estimates of Total Factor Productivity Growth, Austria

Time Period	Growth of				Average	Percentage Contribution of		
	Output	Labour	Capital	TFP	Capital Share	Labour	Capital	TFP
1960-1965	4.16	-0.29	3.05	3.51	0.28	-5.06	20.77	84.29
1965-1970	4.79	-0.75	3.67	4.28	0.29	-11.16	21.85	89.31
1970-1975	3.93	0.75	4.42	2.11	0.29	13.57	32.79	53.64
1975-1980	3.31	0.62	3.69	1.87	0.27	13.81	29.71	56.48
1980-1985	1.43	-0.49	2.75	1.00	0.28	-24.31	54.31	70.00
1985-1990	3.19	0.77	2.70	1.84	0.30	16.84	25.35	57.81
1990-1997	1.97	0.24	2.91	0.89	0.32	8.32	46.77	44.90
1960-1997	3.18	0.13	3.29	2.13	0.29	2.84	30.11	67.05

Estimates of Total Factor Productivity Growth. Germany

Time Period	Growth of				Average	Percentage Contribution of		
	Output	Labour	Capital	TFP	Capital Share	Labour	Capital	TFP
1960-1965	4.82	0.53	6.24	2.68	0.28	7.83	36.59	55.58
1965-1970	4.05	-0.15	5.26	2.65	0.29	-2.57	37.20	65.37
1970-1975	2.18	-0.41	4.68	1.24	0.26	-13.86	56.80	57.06
1975-1980	3.26	0.73	3.42	1.83	0.26	16.43	27.55	56.02
1980-1985	1.14	-0.37	2.74	0.67	0.27	-23.41	64.70	58.71
1985-1990	3.37	1.46	2.48	1.59	0.31	30.12	22.50	47.38
1990-1997	1.56	-0.31	2.46	0.99	0.32	-13.32	50.08	63.24
1960-1997	2.83	0.18	3.81	1.62	0.28	4.60	38.21	57.19

Table 4a

Evaluation of the Estimation Procedures, Austria

	"Universität"	"Matura"	"Mittlere Schule"	"Lehre"	"Pflichtschule"
		A. Step 1: perpetual inventory procedure[1]			
1961 based on 1971	107,2%	81,9%	100,0%	100,0%	101,9%
1981 based on 1971	93,6%	98,2%	92,4%	97,7%	104,0%
1991 based on 1981	95,2%	97,2%	111,2%	102,7%	95,1%
		B. Step 2: perpetual inventory procedure with benchmarking[2]			
1961 based on 1971	-17,3%	40,1%	-21,8%	13,3%	
1981 based on 1971	15,7%	7,7%	19,6%	7,5%	
1991 based on 1981	11,6%	9,2%	-41,2%	-11,1%	
		C. Step 3: perpetual inventory procedure with benchmarking and education-specific survival rates[3]			
1961 based on 1971	(0,58;1,06;1,07)	(0,51;1,13;1,22)	(0,85;001;001)	(000;001;1,33)	
1981 based on 1971	(0,82;1,06;1,06)	(0,73;1,03;1,06)	(0,82;1,03;1,05)	(0,91;1,01;1,07)	
1991 based on 1981	(0,94;1,03;1,03)	(0,91;1,01;1,03)	(0,89;1,01;1,01)	(0,91;1,01;1,03)	

[1] Estimates obtained by the perpetual inventory procedure as a percentage of the actual observation of the population census.
[2] Percentage by which the yearly number of graduates of each age cohort at each education level had to be increased in the given period to reach the population census observation.
[3] The figures give the distribution of the estimated z_{ij}. z_{ij} is the factor with which the age-specific demographic survival rate is corrected to obtain the education-specific survival rates. We report the minimum, median and maximum values.

Table 4b

Evaluation of the Estimation Procedures, Germany

	"Universität"	"Fachhochschule"	"Abitur"	"Mittlere Reife"	"Pflichtschule"
		A. Step 1: perpetual inventory procedure[1]			
1961 based on 1970	97,6%	100,0%	100,0%	100,0%	100,1%
1987 based on 1970	89,7%	71,4%	81,2%	67,2%	115,1%
		B. Step 2: perpetual inventory procedure with benchmarking[2]			
1961 based on 1970	6,7%	72,1%	35,8%	30,8%	
1987 based on 1970	18,4%	72,1%	31,6%	68,6%	
		C. Step 3: perpetual inventory procedure with benchmarking and education-specific survival rates[3]			
1961 based on 1970	(000;1,09;1,12)	(0,98;001;1,19)	(0,69;001;1,24)	(0,93;001;001)	
1987 based on 1970	(0,86;1,05;1,06)	(0,64;1,09;1,12)	(0,29;1,08;1,12)	(0,75;1,03;1,21)	

[1] Estimates obtained by the perpetual inventory procedure as a percentage of the actual observation of the population census.
[2] Percentage by which the yearly number of graduates of each age cohort at each education level had to be increased in the given period to reach the population census observation.
[3] The figures give the distribution of the estimated z_{ij}. z_{ij} is the factor with which the age-specific demographic survival rate is corrected to obtain the education-specific survival rates. We report the minimum, median and maximum values.

Table 5

Population with Highest Level of Educational Attainment
(in percent)

A u s t r i a

	"Universität"	"Matura"	"Mittlere Schule"	"Lehre"	"Pflichtschule"	Total
1960	1.9	5.2	7.0	22.3	63.6	100
1965	2.0	6.4	7.0	24.2	60.3	100
1970	2.2	6.8	7.4	25.7	57.9	100
1975	2.5	7.4	8.9	27.2	54.0	100
1980	2.9	8.6	10.6	29.4	48.5	100
1985	3.4	10.1	11.5	32.5	42.4	100
1990	4.2	12.1	12.0	34.9	36.8	100
1997	5.4	14.2	13.0	37.0	30.4	100

G e r m a n y

	"Universität"	"Fachhochschule"	"Abitur"	"Mittlere Reife"	"Pflichtschule"	Total
1960	2.1	1.2	2.7	10.8	83.2	100
1965	2.4	1.4	2.7	11.1	82.4	100
1970	2.8	1.7	2.9	12.1	80.5	100
1975	3.5	2.2	3.6	13.8	76.9	100
1980	4.2	2.7	4.6	15.8	72.7	100
1985	5.1	3.3	7.0	18.8	65.9	100
1990	5.9	3.8	9.0	19.8	61.4	100
1997	7.2	4.5	10.4	19.6	58.3	100

Table 6

Population with Highest Level of Educational Attainment
(in persons)

A u s t r i a

	"Universität"	"Matura"	"Mittlere Schule"	"Lehre"	"Pflichtschule"	Total
1960	78.717	217.348	294.780	937.820	2.668.750	4.197.415
1965	81.638	266.973	292.993	1.007.115	2.509.451	4.158.171
1970	89.902	282.911	309.130	1.066.367	2.401.686	4.149.996
1975	107.907	319.317	380.294	1.167.064	2.315.055	4.289.636
1980	133.609	391.846	485.785	1.348.600	2.220.122	4.579.963
1985	161.630	474.982	540.582	1.528.128	1.993.589	4.698.912
1990	202.787	587.256	582.285	1.696.118	1.787.420	4.855.866
1997	273.507	724.058	662.020	1.884.731	1.549.606	5.093.921

G e r m a n y

	"Universität"	"Fachhochschule"	"Abitur"	"Mittlere Reife"	"Pflichtschule"	Total
1960	721.873	417.052	919.747	3.752.809	28.845.932	34.657.413
1965	847.452	498.947	940.503	3.897.414	28.972.077	35.156.393
1970	988.939	601.039	1.006.940	4.241.564	28.255.836	35.094.317
1975	1.251.559	783.975	1.317.696	4.997.520	27.839.670	36.190.420
1980	1.639.047	1.025.670	1.787.906	6.100.820	28.135.499	38.688.941
1985	1.994.101	1.287.602	2.765.092	7.403.633	25.961.197	39.411.625
1990	2.409.698	1.564.096	3.652.769	8.071.388	24.992.831	40.690.782
1997	2.986.681	1.855.986	4.297.123	8.120.077	24.129.026	41.388.892

Table 7

Income Shares of Schooling Levels in 1990

	Austria	Germany
"Universität"	0.07	0.10
"Fachhochschule"	n.a.	0.05
"Höhere Schule"	0.15	0.11
"Mittlere Reife"/ "Mittlere Schule"	0.12	0.19
"Lehre"	0.32	n.a.
"Pflichtschule"	0.34	0.55

Table 8

Average Years of Schooling and Average Human Capital
Austria and Germany

	Years of Schooling		Human Capital	
	Austria	Germany	Austria	Germany
	(1960=100)			
1960	100.0	100.0	100.0	100.0
1965	100.6	100.5	102.5	102.3
1970	101.0	101.2	104.0	106.1
1975	101.8	102.6	106.7	112.5
1980	102.8	104.3	109.4	118.4
1985	104.1	106.8	111.7	124.7
1990	105.6	108.9	113.6	127.5
1997	107.8	111.1	114.8	129.1

Table 9

Human Capital and Labour Force
(1960 = 100)

	Labour Force		Human Capital		Human Capital per Capita	
	Austria	Germany	Austria	Germany	Austria	Germany
1960	100.0	100.0	100.0	100.0	100.0	100.0
1965	98.5	102.7	101.0	105.1	102.5	102.3
1970	94.9	101.9	98.7	108.2	104.0	106.1
1975	98.5	99.8	105.1	112.3	106.7	112.5
1980	101.7	103.5	111.3	122.5	109.4	118.4
1985	99.2	101.6	110.8	126.7	111.7	124.7
1990	103.1	109.3	117.0	139.3	113.6	127.5
1997	104.8	107.0	120.3	138.1	114.8	129.1

Table 10 **Estimates of Total Factor Productivity Growth, Austria**

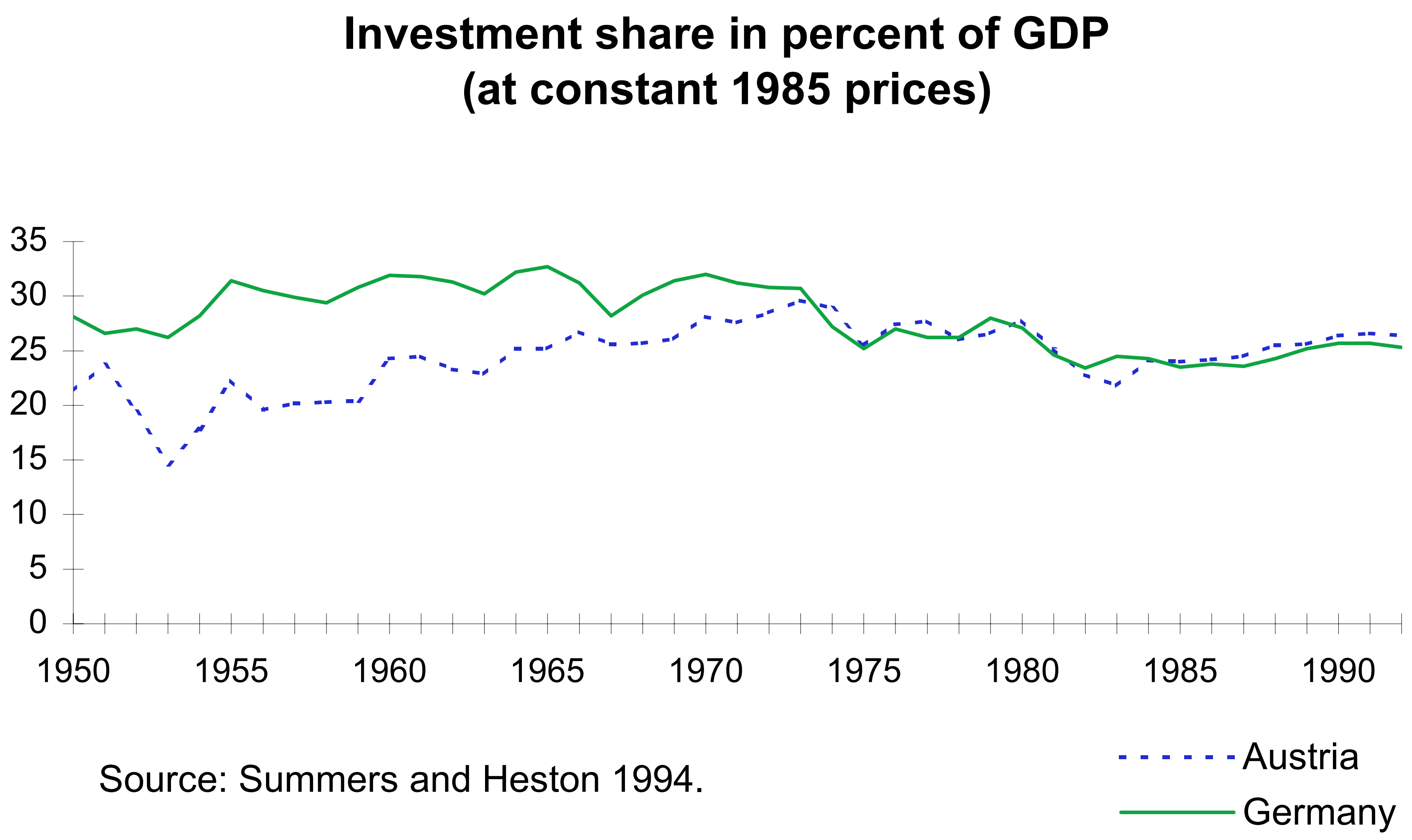
Time Period	Growth of Output	Growth of Labour	Growth of Human Capital	Growth of Weighted Capital *	Growth of TFP	Average Capital Share	Percentage Contribution of Labour	Percentage Contribution of Human Capital	Percentage Contribution of Weighted Capital *	Percentage Contribution of TFP
1960-1965	4.16	-0.29	0.50	2.43	3.32	0.28	-5.06	8.62	16.56	79.88
1965-1970	4.79	-0.75	0.29	3.65	4.07	0.29	-11.16	4.38	21.73	85.05
1970-1975	3.93	0.75	0.51	4.82	1.63	0.29	13.57	9.11	35.79	41.54
1975-1980	3.31	0.62	0.51	3.65	1.51	0.27	13.81	11.31	29.35	45.52
1980-1985	1.43	-0.49	0.41	2.40	0.81	0.28	-24.31	20.51	47.36	56.44
1985-1990	3.19	0.77	0.33	2.55	1.66	0.30	16.84	7.25	23.92	51.99
1990-1997	1.97	0.24	0.15	2.86	0.80	0.32	8.32	5.18	45.94	40.55
1960-1997	3.18	0.13	0.37	3.17	1.90	0.29	2.84	8.31	29.04	59.81

Estimates of Total Factor Productivity Growth, Germany

Time Period	Growth of Output	Growth of Labour	Growth of Human Capital	Growth of Weighted Capital *	Growth of TFP	Average Capital Share	Percentage Contribution of Labour	Percentage Contribution of Human Capital	Percentage Contribution of Weighted Capital *	Percentage Contribution of TFP
1960-1965	4.82	0.53	0.46	7.00	2.13	0.28	7.83	6.90	40.99	44.28
1965-1970	4.05	-0.15	0.73	5.38	2.09	0.29	-2.57	12.91	38.06	51.60
1970-1975	2.18	-0.41	1.18	4.59	0.40	0.26	-13.86	39.72	55.76	18.38
1975-1980	3.26	0.73	1.02	3.08	1.17	0.26	16.43	22.97	24.81	35.79
1980-1985	1.14	-0.37	1.05	2.30	0.03	0.27	-23.41	66.77	54.34	2.30
1985-1990	3.37	1.46	0.45	2.09	1.40	0.31	30.12	9.23	18.96	41.69
1990-1997	1.56	-0.31	0.18	2.08	0.99	0.32	-13.32	7.75	42.34	63.23
1960-1997	2.83	0.18	0.69	3.68	1.16	0.28	4.60	17.52	36.92	40.97

* For the methodology see text and Statistisches Bundesamt, Wiesbaden and Hahn and Schmoranz (1984).

Figure 1



Source: Summers and Heston 1994.

Figure 2a

Comparison of the three Estimates of Educational Attainment, Austr

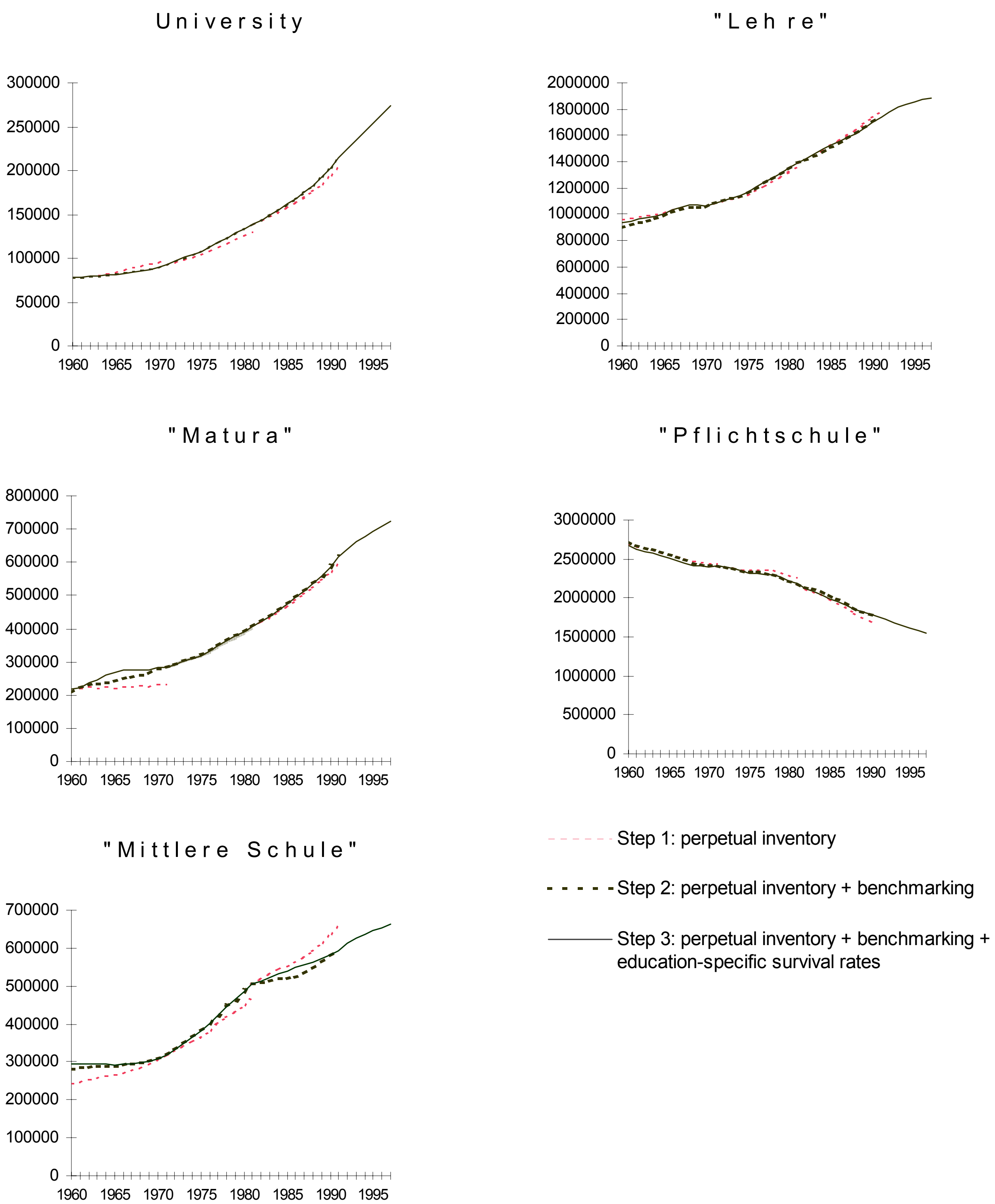


Figure 2b

Comparison of the three Estimates of Educational Attainment, Germany

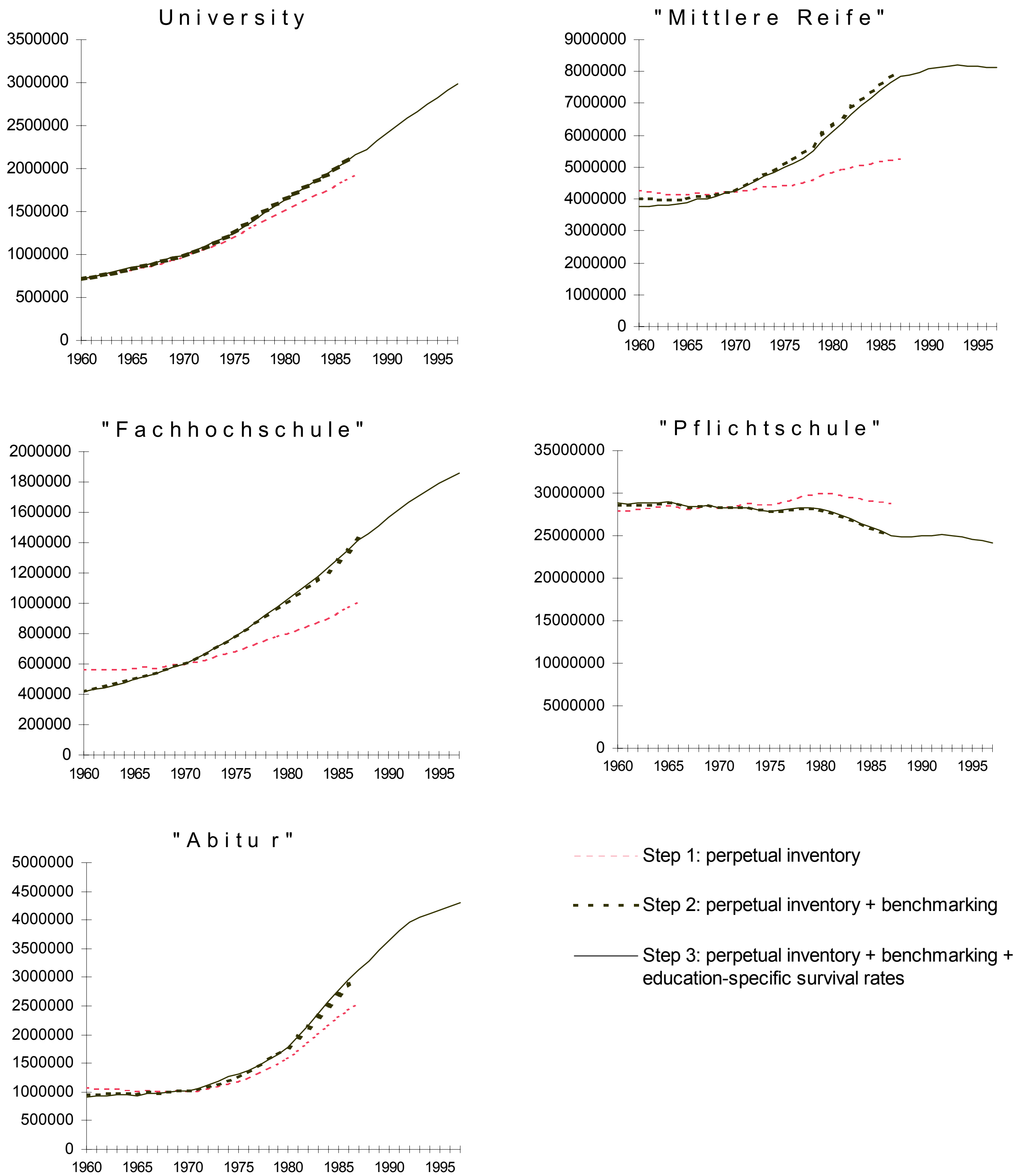


Figure 3

Human Capital and Years of Schooling, Austria and Germany

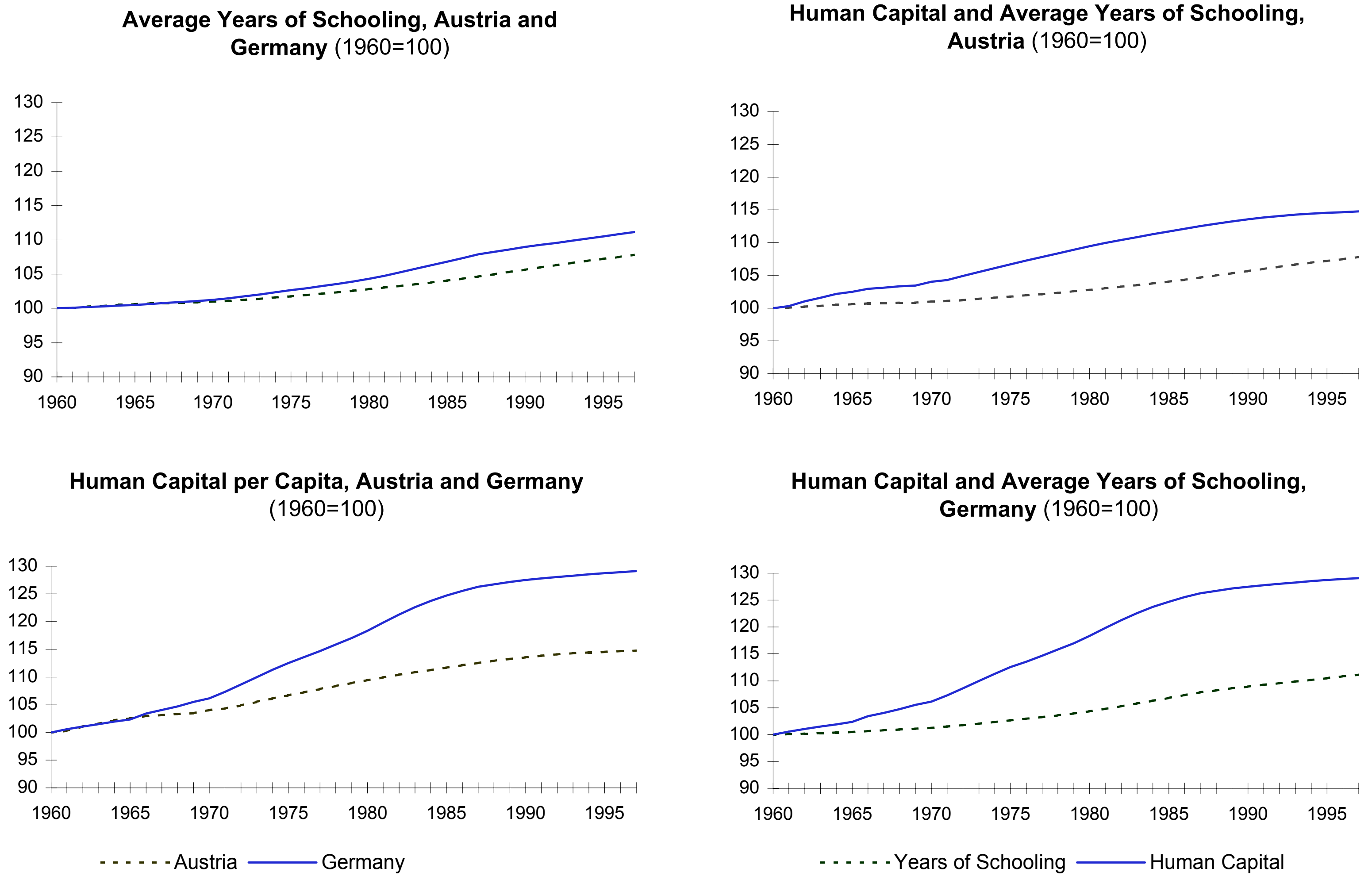


Figure 4

Human Capital and Labour Force, Austria and Germany

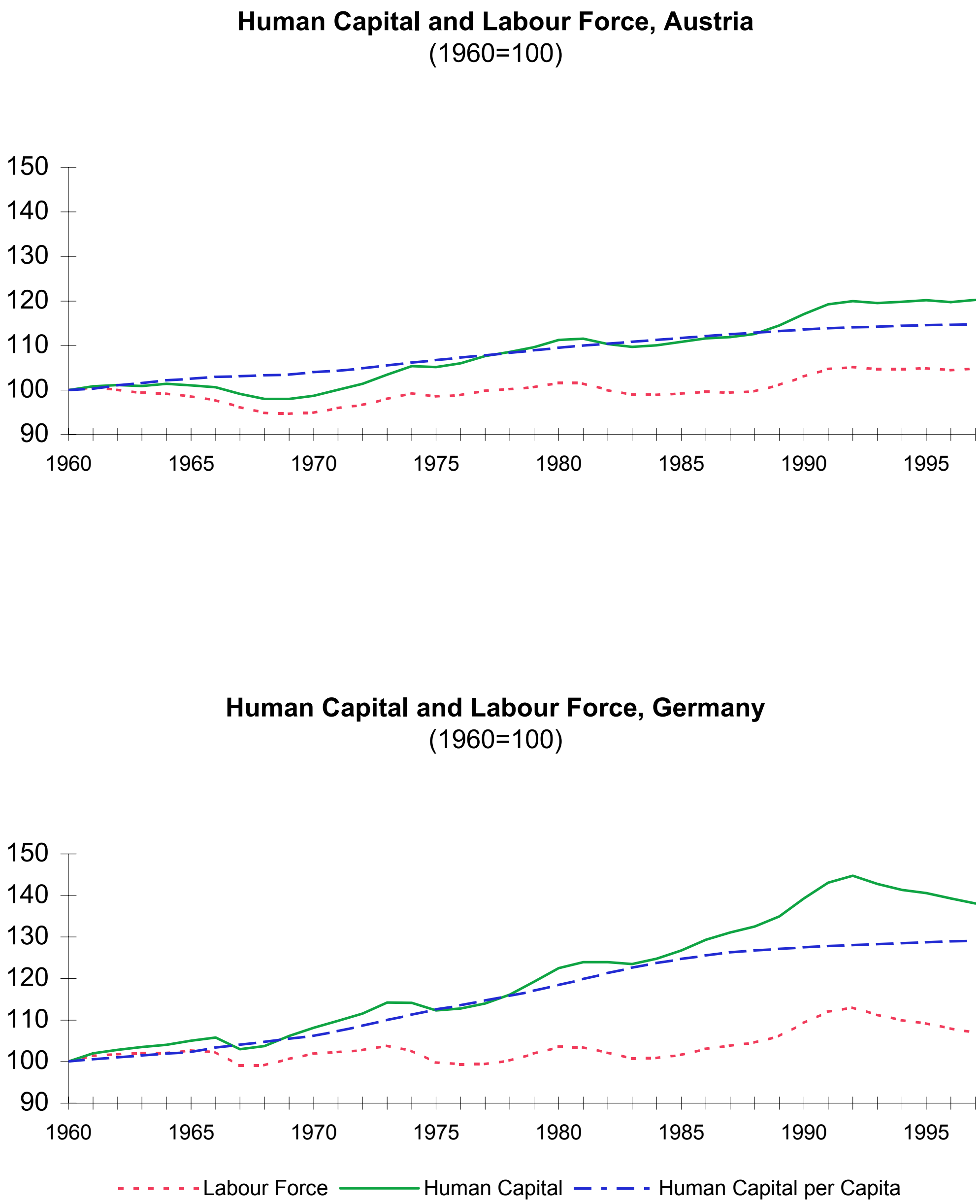
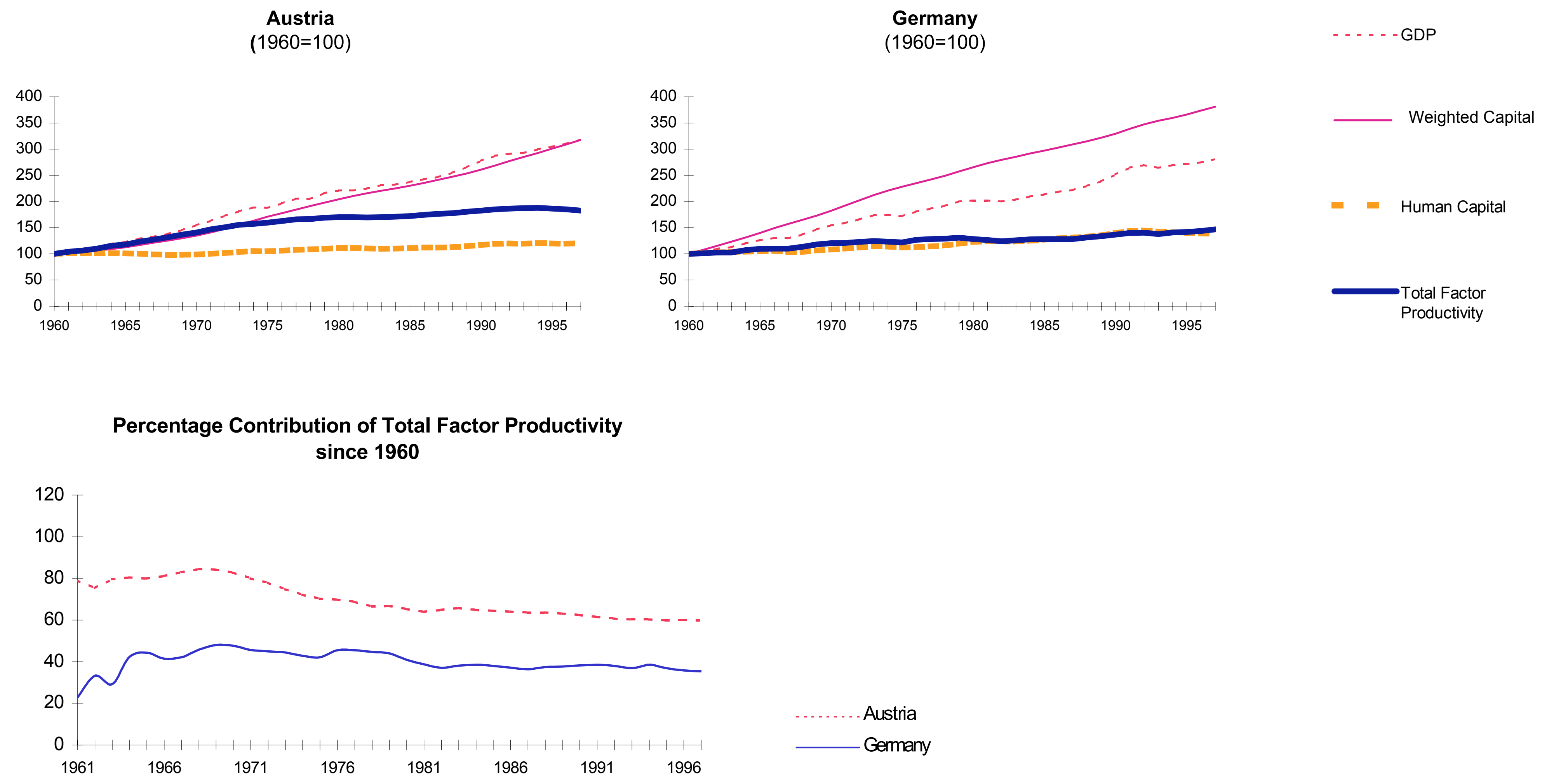


Figure 5

Gross Domestic Product, Physical and Human Capital and TFP



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