Human Capital and Economic Growth

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1. Introduction

A key problem in empirical studies on human capital and economic growth is how to quantify stocks and flows of human capital. The problem looms even larger in historical studies since conventional measures used in contemporary analyses often cannot be applied to the past. The first part of this paper examines a number of alternative approaches to quantify the stock of human capital in The Netherlands. In an earlier contribution (Albers and Groote, 1996) an estimate was made of the average number of years of primary education present in the working population. The present paper supplements these estimates by including secondary and higher education, and examines the difference these additions make. In addition, alternative measures of human capital are considered, including estimates based on education expenditure. The following sections discuss various theoretical issues pertinent to the empirical analysis of long-term economic growth, including a number of measurement problems. The final part of the paper examines the contribution of human capital to economic growth in The Netherlands using a growth accounting framework with alternative specifications, informed by neo-classical and endogenous growth theories. One should be careful not to use these models uncritically, since questions inspired by the agenda of the present may be less relevant to the study of the past. This paper intends to confront theory and empirics and thus to shed some light on the relevance of various growth models in a long-term perspective and explore the historical dimension of the process of economic growth.

2. Estimates of the stock of human capital in The Netherlands during the 19th century

The main problem is how to measure human capital. Even if one agrees on a theoretical concept of human capital, which is by no means straightforward, the problem remains how to make it operational. There seems no point in trying to be too sophisticated: historians should not be blamed for a failure to produce less precise statistics for the distant past than statistical agencies can come up with today. Nevertheless, one should consider at least the theoretical possibility that it may be possible to estimate human capital formation and stocks in the past as well as for the recent period. The Dutch case suggests that formal education in the nineteenth century can be quantified rather well, but that other measures such as skill levels present more difficulties. However, many of the shortcomings of measurement apply to recent estimates of human capital formation as well. In the growth literature all too often a shaky data set is used to run regressions of questionable validity.

The practical question still remains: how to quantify human capital? As a first step one is tempted to use the return on education as a measure of human capital, subject to all the well-known limitations.[1] These include, for instance, the validity of marginal productivity theory and the question how much human capital an unskilled worker has. Is it valid to assume that no human capital at all is attached to unskilled labour (See Mulligan & Sala-i-Martin, 1995, p.3)? In my approach one has to assume that an unskilled worker has a constant skill level across time and that there is perfect substitutability among unskilled workers. Only then can unskilled wages be used as a numeraire to seperate the labour and human capital components of labour income.

[1] In fact, this amounts to an inversion of the oldest attempts in human capital theory, which tried to explain differences in wage levels among indivuals by differences in human capital.

A first approach computes the human capital stock in 'physical' units, that is as years of education present in the total working-age population. An alternative is to define the human capital stock in monetary terms, using expenditure on education. Both concepts can in principle be applied to construct estimates of investment in human capital and of the human capital stock in a satellite account to the standard national accounts tables. Such satellite accounts have been devised in recent years for e.g. R&D investment and environmental damage. Bos (1996) gives a detailed formal elaboration of a human capital satellite account for use in present-day national accounting.

Bos (1996) rightly points out an important, yet often neglected implication of including human capital formation in an extended national accounts framework. The level of national income and hence the growth rate would change considerably should national accountants treat human capital formation the same way as fixed capital formation (as conventionally measured). Expenditure on education should be classed as capital formation rather than as final consumption expenditure by either the government or households; the present national accounts are not well suited to analyse accumulation processes within the household sector (Buiter & Kletzer, 1995). The appropriate measure of national income would change accordingly: in fact it can be shown that net value added would be lower. Changing the concept of capital thus also changes the rate of economic growth. As a consequence it may be wrong to include human capital as an extra factor of production in a production function or growth account without also changing the concept and measure of output used. Analogous to the famous Michaelson-Morley experiment in physics the length of the yardstick actually seems to change during the process of measurement. The growth literature usually does not address this question. This problem may be circumvented by presenting data on human capital in a satellite account to the official national accounts. This is one of the reasons human capital formation is not included in the core of the 1993 SNA, and in fact only few countries are at present working on the satellite accounts. In a sense the present paper is ahead of modern national accounting practice in many countries, perhaps a rare occasion in the field of broad 'historical national accounting'.

The first estimate of the human capital stock presented in this paper is a very direct application of the embodiment concept. Human capital is literally linked to human beings. The method followed in this paper was originally developed by Adrian Clemens, Peter Groote and me. (See Clemens, Groote and Albers, 1996, Albers and Groote, 1996).[2] Assuming the lifetime of humans (and therefore the lifetime of their human capital) to be finite, one can apply the perpetual inventory method to build a stock of human capital in essentially the same way as stocks of physical capital. An individual's human capital (the number of years of schooling) enters the stock when he/she finishes school, and leaves the stock at death or when he/she reaches the end of his/her working life. For the survival rates between the age of 12 and 65 I applied demographic key figures. Given the age structure of the population any changes in the average retirement age, which probably were not significant, would do little to change the outcome of the calculations. Labour force participation rates were also quite stable over the period examined. I assumed school enrollment to have been constant prior to 1800.[3] Unfortunately, the data do not allow a further differentiation of these demographic figures, e.g. to take into account differences in the survival rate between social groups with different levels of human capital (Barro and Sala-I-Martin (1995), p.455). It is a straightforward application of the perpetual inventory method,

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2 If only for the sake of historical accuracy it should be pointed out that we derived our methodology quite independently. It was only later that we found out about striking similarity to the satellite accounts to the national accounts which were developed at the same time.

3 Such an assumption is necessary to estimate the initial 1800 stock. From the mid 1850s onwards (roughly one asset life on), however, the estimate of H is independant of the initial assumptions.

widely used to compute stocks of tangible fixed capital, to investment in human capital. The gross stock of human capital was estimated as the weighted sum of past investment in human capital according to the following formulae.[4]

$$H_t = H_{t-1} + IH_t - RH_t \qquad \text{and} \qquad H_{t-1} = \Sigma_{i=l-1}^{l-1} IH_i$$

with: IH additions to the stock of knowledge, RH retirements of human capital and l the average lifetime of human capital

It is possible to estimate the annual flow of years of formal schooling entering the human capital stock from enrollment figures because of the abundant statistical source material on educational in the Netherlands.[5] The estimates of attainment levels (the stock of human capital) assume six years of schooling for primary education and four years for secondary education and higher education. All data on school attendance (including part-time education and sunday schools) were converted to full-time equivalents, corrected for absentees. There are, of course, a number of drawbacks to using formal education as a measure of human capital. The most important weakness is the exclusion of on-the-job training and of learning by doing.[6] Albers and Groote (1996) presented annual estimates of the total stock of years of primary schooling in The Netherlands over the period 1850-1913. These estimates were used for growth accounting exercises in an attempt to assess learning by doing effects indirectly. The present paper extends the period covered to 1800-1913 and adds estimates of the stock of secondary and tertiary schooling. To allow for the higher quality of post-primary schooling an, admittedly somewhat arbitrary, weighting has been applied. Following Maddison (1987, table A12) I attached a weight of 1.4 to secondary schooling, and a weight of 2 to tertiary schooling. These weights are consistent with an average rate of return of roughly 7% on an additional years' schooling (compare Psacharopoulos, 1994). Since primary education accounted for by far the largest share of the schooling stock over the whole period, the precise choice of weights attached to secondary and tertiary education, which matter far less in the aggregate, does little to affect growth rates of various measures of H (H1 to H3). Table 1 gives a summary overview of the enrollment ratio's used.

Many studies on human capital use school enrollment rather than attainment levels. This should be regarded a second-best option (Gemmell, 1996). The enrollment rate is a flow variable which is not suited to approximate the stock of human capital, which by definition is a stock variable (cf. Stevens, 1994). Enrollment ratios are a measure of investment in human capital, not of human capital stock. Estimates of educational attainment provide a better suited measure of the stock of human capital. Most studies on human

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4 For the sake of simplicity I did not use a more refined (bell-shaped or delayed linear) retirement pattern, which does little to change the growth rate of the stock (Albers, 1996). An alternative would be to use census data on attainment levels and run a perpepetual inventory model to interpolate between benchmarks (see Koman & Marin, 1997). For lack of census data on The Netherlands in the 19th century I could not use them as a check on the perpetual invemtory results.

5 Since I am here mainly concerned with devising a statistical measure of human capital formation the reader is refferred to Boekholt (1991) for a more detailed account of the institutional development of the educational system in The Netherlands .

6 In The Netherlands, technical and vocational training lagged behind other European countries (such as France and Germany) in the period studied, partly because of a lower degree of industrialisation.

capital use estimates of attainment levels derived from enrollment data either through variants of the perpetual inventory method or through some short-cut procedure (Barro & Lee, 1993, Kyriacou, 1992, Nehru, Swanson & Dubey, 1995). The stock estimates resulting from such questionable procedures suffer from implausible fluctuations and other flaws (see Bosca, De la Fuente & Doménech (1996) for a detailed and critical review). Extrapolation of early twentieth century enrollment rates in secondary and higher education does not take into account the age structure of the population, and differential participation rates. This means that regressions based on 20th century enrollment rates are biased towards giving too high a share to formal (in particular higher) education in the explanation of 19th century productivity growth. In an approach which has become very popular in the growth literature Mankiw, Romer and Weil (1992) use an extended Solow model with a specification allowing them to work with data on investment flows rather than capital stocks as a measure of capital input. In doing so, however, they have to impose a rate of technical progress which is the same for all countries. A more serious drawback is that the use of investment rates to approximate the rate of change of the capital stock can be justified only by the assumption of a steady state or by a linearization around a steady state. The assumption of a steady state implies an unchanging capital-output ratio and a fixed level of capital intensity. These assumptions are untenable in a historical context and the Mankiw-Romer-Weil approach therefore is ruled out for our purposes. One should, in addition, allow for differences in depreciation rates among various types of assets, which implies a changing aggregate rate of depreciation as the composition of investment and hence of the capital stock changes over time, in general accompanied by a secular decline in asset lives (compare Albers, 1996). In practice, the correlation between the investment rate and the rate of change of the capital stock turns out to be very low (see, for example Collins & Bosworth, 1996, pp. 145-146), a fact all too often overlooked in neat theoretical specifications. I therefore stick to estimating capital stock as the starting point for further analyses, an approach which does not suffer from the drawbacks mentioned above.

Table 1
Enrollment ratios, The Netherlands 1830-1913

year	primary education (H1) ratio to population aged 6-12	secondary education (H2) ratio to population aged 13-16	tertiary education (H3) ratio to population aged 17-22
1830	65.4%	0.8%	0.3%
1849	78.1%	0.7%	0.4%
1869	90.4%	1.7%	0.3%
1889	91.8%	3.7%	0.5%
1905	99.4%	5.8%	0.7%
1913	99.7%	8.8%	0.7%

Source: Knippenberg (1986), Van Stuijvenberg (1981), *Onderwijsverslagen*, various issues.
Note: primary schooling in full-time equivalents including attendance of sunday and repetition schools

An alternative method to estimate attainment levels of formal schooling would be to construct an estimate of the human capital stock from data on education expenditure, rather than enrollment rates, years of schooling etc.[7] There is ample information on education expenditure in The Netherlands covering the entire nineteenth century, enough to enable an estimate of the human capital stock in monetary terms. It is even possible to distinguish expenditure by type of school and expenditure category (general government, municipal authorities and private sources). I limit myself here to an aggregate expenditure estimate of the stock of total schooling (H1-H3). Table 2 summarizes education on expenditure in both current and constant (1913) prices. I used an index of teachers' wages to deflate education expenditure at current prices. Because of the dependance of schools on specialized labour inputs this index reflects changes in the costs of education better than, for instance, an index of consumer prices or a GDP deflator.[8]

Table 2
Total expenditure on education

year	current prices index 1913=100	constant prices index 1913=100
1807	2.0	4.0
1830	2.3	5.9
1850	3.0	6.2
1870	12.0	23.9
1890	32.5	45.1
1905	61.2	74.3
1913	100.0	100.0

Sources: Van der Voort (1995) for 1850-1913. Horlings (1995) for 1807 and 1830.
Deflators: project NR

The rapid growth of outlays on education is remarkable. In fact, expenditure increased far more quickly than school enrollment which means that the relative cost of education rose rapidly, due to, among other things, smaller class sizes, better pay for and better quality of teachers, and better standards of school buildings. The cost increases could be financed partly through more funds becoming available as a result of economic growth, and partly as a result of parliamentary Acts which improved both material facilities and teachers' wages, in particular from the 1880s onwards.[9]

The main drawback of any estimate of the human capital stock is that it is difficult to assess the real return to investment in education. Part of the increase in costs would have resulted in better material conditions for teachers and pupils, rather than a higher standard of education although no doubt wage rises did much to improve the quality of teaching. For similar reasons one may expect a year of schooling obtained in, say, 1880 to be of lower quality than a year's schooling in 1913. Indeed, the divergence between input and output measures of educational attainment is an important problem in contemporary discussions on measuring investment in education (Hanushek 1996). This may be a reason to prefer literacy rates as an assumed constant-

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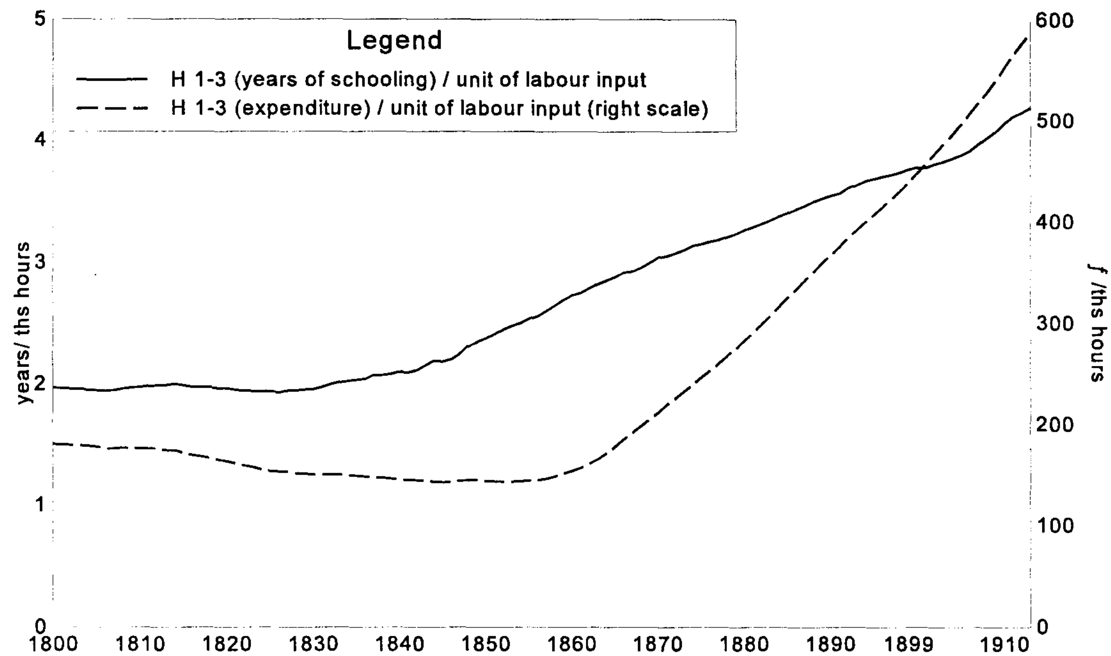
7 There is a close parallel here with the treatment of R&D as a factor of production. This can be measured by R&D expenditure or by other indicators, such as the number of patents granted.

8 Interestingly, recent literature on the subject often ignores this issue. Hanushek (1996), for instance, uses a GDP deflator to deflate changes in input costs.

9 During most of the nineteenth century the majority of Dutch schools were state schools, that is until schools affiliated to certain religious creeds were granted state subsidies (Boekholt (1991).

quality measure of educational attainment over years of schooling or expenditure. However, provided one uses an appropriate deflator, inefficiencies in the production of human capital may pose of less a problem in historical situations where both education expenditure and attainment levels increased appreciably over time, as in The Netherlands in the 19th century . From a theoretical point of view both 'physical' and monetary estimates of the stock of human capital may be applied. The quality and missing variable problems apply equally to both methods, while they both can serve as the basis for satellite accounts to the standard national accounts tables. Figure 1 shows the main results.

Figure 1
Stock of Human Capital per Unit of Labour Input, according to Attainment (H1-3) and Expenditure (H1-3) Data



Source: Authors' calculations.

The two alternative measures behave quite differently over time. The years of schooling measure began to increase at a faster rate in the 1820s and then levelled off during the 1860s. In contrast, the estimate of H1-3 in monetary terms first declined and then began to grow at a roughly constant rate from the 1860s onwards. This implies a significant increase in educational attainment in the 1830s and 1840s in terms of years of schooling which was not matched by a comparable rise in total real costs of schooling, a slightly puzzling result. According to the same yardstick diminishing returns to expenditure set in towards the end of the period covered here, as more costly inputs were not matched by a comparable rise in attainment. For the moment I choose not to dwell too long on the differences between the two measures developed and simply treat them as two alternative methods to capture the same phenomenon. Hours worked per person decreased only slightly in the course of the nineteenth century so the development of the stock of human capital per person employed was very much the same as per unit of effective labour input.

The main shortcoming of the way I tackled the issue remains that education stock may not be an entirely appropriate yardstick to measure the effects of human capital on economic activity. Practical abilities and the possibility to earn money were in many industries more important than formal schooling. In many cases there probably was a strong incentive to earn money rather than go to school. After all, schooling is only possible when subsistence is assured. Economic agents could so to say invest in being undereducated. It is likely that deskilling was more important to the early stages of industrialisation in a country such as the UK, with a firm manufacturing basis, than in the Dutch economy, which until well into the nineteenth century was much more dependent on agriculture and services. The Netherlands did not witness the same sudden increase in the demand for unskilled industrial labour as the United Kingdom and literacy levels increased steadily though at an uneven pace throughout the nineteenth century (Boonstra, 1993). For rural areas its is hard to assess the rewards to being educated and to being non-educated, but very sudden breaks in the demand for specific types of labour probably did not occur. In the large Dutch services sector literacy and education probably were of more use than in other sectors of the economy. To the extent that there is a trade-off between formal education and on-the-job-experience the estimates of the human capital stock presented here are biased towards an underestimate of its role in production. Mitch (1993, pp. 288-298) examined the issue of deskilling for Britain in the Industrial Revolution. The crucial distinction is between private (short-term) and public (long-term) returns to education. Mitch (1992) argued that in Britain private demand for education partly explained the increase in literacy during the nineteenth century. This reminds us that not only a better public provision of educational facilities mattered. Since I see no easy solution to this problem I will not attempt to quantify the effects of 'deskilling' on attainment levels.

This paper, however, is concerned mainly with the actual literacy rates and edcuational attainment levels in The Netherlands, not with an analysis of the demand and supply conditions which determined them. One might reasonably argue that it is better to focus on apprenticeships, on-the-job learning, learning by doing, and other kinds of informal learning, rather than on formal educational attainment (see Mitch (1993, pp.200-303) for this issue with respect to Britain). The problem then remains how to quantify informal learning which is much more difficult still then attempts to use variables based on formal education (cf. Crafts, 1995 who also is not able to solve this issue). For formal education at least quantitative data are available covering the whole economy.

3. Alternative estimates of human capital

Literacy is an obvious alternative measure to estimate human capital. I consider literacy rates problematic, however, because of the many pitfalls associated with measurement. A well-known shortcoming is the difficulty to make the distinction between the abiliy to read and to write. Moreover, information on literacy for The Netherlands in the 19th century is quite sparse, in itself enough reason to seek other measures of educational attainment.[10] The more general point that the relationship between literacy and productivity is far from straightforward applies just as strong to formal education. Nevertheless, perhaps the worst shortcoming of literacy rates is that they do not offer much of an explanation for differences in productivity performance in North-West European economies around the turn of the century. By the late nineteenth century the increase in

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[10] Of course, for other countries estimates of literacy may be better, while data on educational enrollment and attainment are scarce. In that case one is well advised to use the best set of estimates available. My considerations here solely concern 19th century Netherlands.

literacy would have become so significant, and the differences among countries so small, that no meaningful formal analysis can be based on literacy data. This is so for purely mathematical reasons. In the late nineteenth century, the literacy rate approached the natural upper limit over which it could not increase anymore, while at the same time secondary and tertiary education boomed. This runs counter to intuition to say the least as the variable can no longer capture the improvements in skills and educational achievement which clearly were there. With primary school enrollment and literacy approaching unity in, say, The Netherlands and Scandinavia there remains no room for differences in literacy rates to explain the observed productivity differences among these countries.[11]

Boonstra (1993), presents annual estimates of literacy for The Netherlands over the period 1820-1890. For the country as a whole male literacy rose from roughly 75% to 90%; female literacy increased from about 60% to nearly 90%. These figures are based on as yet unpublished research by Van der Woude (see Van der Woude (1980) for earlier literacy estimates at selected years).[12] The data were derived from a large sample of municipalities and use signing of the marriage register as a criterion for literacy. Underlying the aggregate trend are large regional disparities and a large gap between male and female literacy. Illiteracy among men was clearly lower. The relation between 'modern society' (or economic growth) and literacy is far from straightforward. The regional differences are linked both to economic structure and to the spatial distribution of religious affiliation. The latter factor worked for a large part indirectly, through the impact of the educational system. In the first quarter of the nineteenth century literacy was higher in the mainly protestant coastal provinces and showed a stronger rise in the subsequent period. Agrarian protestant provinces, such as Groningen, Friesland and Drenthe in the north of the country had the lowest share of illiterates until the middle of the nineteenth century. In that same period the economic core region (Holland, Zeeland and Utrecht) had slightly lower literacy rates. The differences in literacy rates among provinces remained roughly in the same rank order throughout the period covered, although the dispersion in absolute levels became less. The militia registers provide an additional source on male literacy. It has remained largely unexplored by present-day researchers although the figures were used in contemporary discussions on moral and economic development (Scheltema Beduin, 1891). In principle this source offers a more complete picture than marriage registers since practically all young men were examined for military service, whereas not all men married. Since the raw data have not yet been processed the information from the militia registers cannot at present be used to compare with Boonstra's (1993) estimates of literacy.

An interesting alternative is to consider the height of people as an indicator. Stature has been widely used in recent studies of the standard of living (Steckel, 1995). I examined the usefulness of height as a proxy for human capital using stature data from Drukker and Tassenaar (1996).[13] An advantage of this method is that comprehensive and comparable annual data are available over a long period. Data on stature might supplement the evidence on literacy. Indicators of stature, literacy, and average schooling attainment

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[11] One may stand this argument on its head and say that productivity levels in the aforementioned countries were very much the same around 1900, which may be interpreted as good educational infrastructure and similar eductional attainment supporting economic growth along broadly the same lines in all these Protestant countries. Since this is an entirely different approach I will not discuss it here.

[12] For the period 1600-1625 Van der Woude's (1980) figures suggest that in Dutch cities (excluding the South-eastern part of the country) male literacy was approaching 60% while female literacy was between 40 and 50%. Illiteracy subsequently declined steadily in the course of the seventeenth and eighteenth centuries (Boonstra, 1993).

[13] I thank the authors for their permission to use the data.

roughly moved together in The Netherlands until the 1840s. In general one would expect improvements in well-being to coincide with an increase of human capital, although it is of course highly uncertain how close the fit would have been. Nevertheless, faced with an absolute lack of data on formal education one could try to combine measures of literacy and height, the latter indicating potential and the former realization of human capital formation. In the case of The Netherlands such a shortcut will not be necessary for the nineteenth century since enough information on formal education is available to make alternative estimates possible. However, the method may still be applied to the pre-modern era for other countries, in the absence of other data.

However, with respect to the use of height data a number of important complications need to be mentioned. At first sight height may seem a promising indicator for physical ability. However, we should also in this case consider the trade-off between earning income and receiving education. People could chose to invest in 'being small' (that is: prefer high-paid, hazardous work in urban areas to living in healthier, traditional rural regions, or, alternatively, to receiving an education). To complicate matters even more, the caloric intake needed to attain a level of well-being depends on the intensity of labour (the caloric intake required by students, for instance, was less than for farm labourers). There were also profound regional differences in average stature within The Netherlands. These differences arose because of distinct patterns of economic development. The implications for stature are very difficult to assess with any degree of precision. Finally, from the 1840s onwards average stature showed little growth at a time when both schooling attainment and education expenditure were clearly on the rise. Stature therefore is likely to perform poorly in growth regressions from the mid-nineteenth century onwards, which suggests that length meay be a good indicator of human capital formation in pre-modern times, but perhaps not so useful for the more recent past. For the moment, the conclusion must be that for some periods height may be a good indicator of human capital, but that it is not in other periods.

Finally, other variables to approximate human capital formation, such as patents and R&D, often used in studies focusing on the post-World War II period, seem less useful to study Dutch economic performance in the nineteenth century. R&D expenditure by incorporated business was negligible and patents were not granted or protected in The Netherlands for most of the nineteenth century (Davids, 1995). Also, technology transfer from abroad in all probability played a much larger role in Dutch modernisation than any domestic innovation efforts. In fact, in the 19th century the Dutch were successful in adapting technologies from abroad while having a non too impressive record with respect to domestic innovations. Some of these considerations apply today, just as strong to a small open economy heavily biased towards the services sector.[14]

4. Growth theory and human capital

Does human capital account for real per capita GDP growth during the nineteenth century? The historiography provides a range different answers. Sandberg (1979), for instance, attaches much weight role to education as a determinant of productivity growth. For the archetypal case, Britain, some authors, for instance Mitch (1993) and Williamson (1996), are much more skeptical about the role of education in the English Industrial Revolution. O'Rourke & Williamson (1995) extend this skepticism to Scandinavia. In their regressions human

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14 See and Verspagen (1996) for theoretical considerations, Minne, 1995 for showing that Dutch output is more sensitive to foreign than to domestic R&D efforts, and Smits (1995) for a historical overview.

capital explains only a small part of economic growth. Broadly the same conclusion holds for the twentieth century, irrespective of the measure of human capital used, if the same regression specifications are used (see Benhabib & Spiegel, 1994, pp.151-154). Thus, even for the twentieth century human capital does not yield a particularly high coefficient in cross-section regressions using an augmented Solow model (a standard neoclassical growth model with human capital as an additional production factor). Since it is widely believed that human capital is an important factor in economic performance of countries in recent decades this observation puts the regression results for the nineteenth century in perspective.

It may be useful to review what growth theory has to say on the role of human capital. Developments in so-called endogenous growth theory have reinforced the interest among economists in human capital as a determinant of GDP growth, and as an explanatory variable in the convergence debate.[15] The reader is reminded that from the point of view of an economic historian, there is nothing really new in the mechanisms behind economic growth discussed in various strands of endogenous growth models. It is the mathematical form rather than the content that distinguishes endogenous growth models from the ideas earlier put forward by economic historians and growth accountants.[16] In my opinion it is, however, enlightening to make explicit the link between the two approaches.

In a traditional growth accounting approach one would expect education to be treated as an augmentation of labour input improving the quality of labour (see Maddison, 1995). There are two main alternative approaches to model the effect of human capital on economic growth in an endogenous growth framework (Spiegel & Benhabib 1994). The first is to treat it is an additional input in the production function (level effect). The familiar properties of the Solow model apply: a once and for all increase in investment (of either human or physical capital) changes the level of GDP, but not the long-term growth rate, which is determined by two exogenous variables: population growth and the growth of joint factor productivity. For this approach see e.g. Mankiw, Romer & Weil (1992) and Crafts (1995).

The second approach is to let joint factor productivity depend on the stock of human capital (rate effect). This approach argues that human capital is not just another production factor. To treat it is such would misspecify the role of human capital, which works mainly through technical progress and determines the ability to innovate and to use innovations from abroad (Nelson & Phelps, 1966). The effect of human capital on growth thus may work through intermediate channels which affect the rate of joint factor productivity growth. To the extent that physical capital formation is a necessary complement to the accumulation of human capital the two variables move together. The accumulation of physical capital is dependant on a sufficiently high level of human capital or, in other words, human capital may be inducive to the accumulation of other factors of production. In that case the inclusion of human capital as an additional factor of production in a growth account cannot be expected to receive a high coefficient. The importance of the embodiment of technical progress in physical capital may make this a particularly important case for the nineteenth century.

The answer to the question how much human capital matters, however, at least partly depends on its precise content. I think there is a crucial difference between accounting for economic growth in a technical sense and explaining economic growth in a more far-reaching sense of the word. This is more than a purely semantic question, since much of the confusion surrounding the subject probably stems from a certain ambiguity of terms. In an ultimate sense few would doubt the importance of education or human capital formation for

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15 The list of references one could give is very long. See Verspagen (1992) for a useful overview of recent developments in growth theory.

16 See, for instance, Maddison (1995). I therefore prefer the term 'endogenous' growth theory over 'new growth' theory.

economic growth. After all, the ability to learn and to use new production techniques and innovations depends on it. It is, however, uncertain how much human capital will explain if we include it in a regression analysis or production function approach as an *additional and independant* variable. If enrollment is rising, coefficients on labour growth variables will capture (part of) the effects of human capital stocks or investment (Gemmell, 1996, p.15). The initial productivity gap and levels of physical capital formation show up as by far the most robust variables in growth regressions (Levine and Renelt, 1992). They account for economic growth very well in that one can predict a large percentage of GDP differences using only these two variables. From a pragmatic point of view this may be all that is needed. Growth differences and productivity differences among countries can then be accounted for using data on a few key variables, although one could find it debatable whether or not it counts as an explanation proper. This probably is a different question than explaining economic growth from 'ultimate sources' in which innovation and learning play key roles.

It is possible, however, to distinguish the different concepts by making clear how they figure in any quantitative exercise or model. The outcome depends on the configuration of the regression, growth account or structural model used. The coefficient on human capital depends on a) the definition used and b) the formal specification. A number of questions arise concerning the specification of the production function. Is it flows or stocks that matter? Does a temporary shock to the system have permanent effects or not, or, to put it differently, is output trend stationary or difference stationary (cf. Sturm, Jacobs & Groote, 1995)? How does one take path dependencies into account? Do certain variables move together, so that one could include either one but not both simultaneously? As regards this last point, one should again consider the proposition that growth of the physical capital stock and of knowledge are interdependant, and in combination determine joint factor productivity growth. In Fagerberg's (1994) words: when both investment and education are included, the impact of each -in particular education- diminishes. The practical solution used is informed by theoretical considerations and vice versa. Measurement issues to a large extent determine the distinction between various strands of endogenous growth theories (Van de Klundert and Smulders, 1992, Crafts, 1995, Romer, 1994).

One may, for instance, be able to squeeze the residual in growth accounts considerably by changing the definitions of factor inputs. How much is left to variables such as quality of the labour force and 'technical progress' depends crucially on the definition of human and physical capital input. Much of the difference in the measured residual between what is sometimes labelled the Jorgenson and Denison approaches precisely stems from such definition questions (Baily & Schultze, 1990). A broadening of the definition of factor inputs will tend to reduce the residual (or joint factor productivity). This drives the results and not so much the mathematical formulation of the production function, be it Cobb-Douglas, another constant elasticity of substitution or a translog production function. Basically the same observations concerning the effects of mathematical formulations can be made with respect to the treatment of quality change and capital goods deflators in measuring physical capital input (Triplett, 1990, 1996, Hulten, 1990, Baily & Schultze, 1990).[17] If deflators fully take account of quality change and technical progress by definition no increase in capital productivity over time can be observed.

Along similar lines some strands of endogenous growth theory have essentially broadened the definition of capital and thus escape or at least reduce diminishing returns to a broad concept of capital. Some models allow for constant returns to broad capital (as in Rebelo, 1991, cf. Arthur, 1994 on diminishing versus increasing returns). The basic problem with the use of an enlarged definition of capital is the

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[17] This discussion used to be refferred to as 'resource cost' versus 'user value' approaches of measuring volume changes in physical capital.

appropriate weighting scheme to aggregate the different components of 'broad capital'. Other growth theorists impose diminishing returns to each individual production factors in augmented Solow models of the kind employed by Mankiw, Romer & Weil (1992). Crafts (1995) favours the use of augmented Solow type models over broad capital (Rebelo type) models, considering their plausibility in an historical context.

The specification of the functional form of the production function largely determines the results of growth regressions (Verspagen, 1995, p.124). First, from a purely theoretical point of view this would mean to use a very general functional form without many prior restrictions which allows for changes in the elasticities of substitution for the various production factors. In this respect at least the so-called translog production function is to be preferred over the standard Cobb-Douglas or other constant elasticity of substitution production functions (Jorgenson, 1995). In practice, however, a Divisia-Tornquist representation of a Cobb-Douglas production function, which makes it possible to allow for changes in factor shares over time, will yield results which differ only marginally from the ones obtained by using a translog function.[18] Second, in general one will get higher coefficients on human capital in cross-time than in cross-section regressions. Verspagen (1996) has shown that the weight one attaches to international knowledge spillovers depends on the use of a cross-section (BETWEEN in Verspagen's terminology) specification versus a time series (WITHIN in Verspagen's terminology). According to Verspagen at least part of the strong correlation Coe and Helpman (1995) find between international R&D spillovers and joint factor productivity growth results from their time series focus. Other studies, which use cross-section regressions, tend to get lower coefficients on international knowledge spillovers. For this reason one may expect the coefficient on the schooling variable in my (time series) approach to represent an upper bound while cross-section regressions of the type used by, for instance, O'Rourke and Williamson (1996) will tend to give a lower bound estimate of the effects of human capital formation on productivity growth.

5. The international context

Open economy forces played a major role in Dutch economic growth during the second half of the nineteenth century (compare Williamson 1996). This was the case for international trade, international capital flows, and technology transfer, but much less so for migration. For most of the period covered here The Netherlands pursued free trade policies with only low import and export duties, and the capital market was very much open to the outside world. Outmigration from The Netherlands, however, was limited compared with other European countries during the nineteenth century. In that sense The Netherlands certainly did not compare to Scandinavia (Cf. Williamson 1996) and outmigration therefore is unlikely to have contributed much to extra Dutch GDP growth relative to Britain or the United States. Migration flows did, however, account for a reduction of real income dispersion within the domestic economy since there was a constant inflow of migrants away from rural areas into the urban areas in the west of the country.

In the long run open economy forces of a kind different from the ones stressed in the Hekscher-Ohlin-Samuelson model were very important, too. These concern the impact of innovation abroad on the domestic economy. The literature on growth theory and empirical studies on long-term convergence remind us of the importance of innovation and technology diffusion for the process of economic growth (Coe & Helpman, 1995,

[18] The difference in estimated JFP- growth for The Netherlands in the period 1807-1913 amounts to less than 1%.

Maddison, 1995, Barro & Sala-i-Martin, 1995, Grossman & Helpman, 1991). Various endogenous growth models suggest the existence of strong inter-country linkages (so-called spillovers).[19] In these models countries can benefit from the purchase or imitation of technologies originally produced in other countries. Without other obstacles follower countries can benefit more from such international knowledge spillovers than lead countries. This perspective on the role of innovation and technology transfer is absent from the original Hekscher-Ohlin framework which implicitly assumes constant technology across countries, or at least a constant ratio of technological capabilities relative to the knowledge frontier. To the extent, however, that technology transfers are embodied in tangible capital goods, a proposition with particular relevance for the 19th century as I will argue below, Heckscher-Ohlin type models may work quite well.

The concept of technology spillovers fits in well with open economy models in general and may be relevant for the analysis of economic growth in nineteenth century Netherlands.[20] A significant part of productivity growth in the small open economy of The Netherlands no doubt originated from the effects of knowledge spillovers from abroad. The impact of technology spillovers can be conveyed through a number of different channels. It can be through embodiment in (imported) physical capital assets, through imports of foreign know-how, through increased levels of domestic human capital formation spurred on by an increase in technological possibilities, or through the promotion of domestic R&D. The relative importance of these mechanisms in all probability was different in the nineteenth century than in the recent past, which reminds us of the imprtance to adopt a historical approach.

From a theoretical point of view there is an important distinction between 'pure knowledge' spillovers and 'rent' spillovers (Griliches, 1979). Pure knowledge spillovers cannot be assigned to any particular firm or sector and cannot be appropriated. They are non-excludable and non-rival (Grossman & Helpman, 1994). Rent spillovers, on the other hand, can be appropriated for instance through patents. Rent spillovers can also be linked to specific input-output relations. For instance, one can distinguish an 'innovation producing' sector and 'innovation using' sectors. In a nineteenth century context one may think of steam pumping engines, invented and produced in the engineering industry and used in mining, among other industries.

Both types of spillovers matter for the relation between human capital and growth, but it is hard to disentangle their relative importance even at present, let alone in historical studies. Rent spillovers can be linked with specific products, sectors and economic actors. Rent spillovers work through migration of skilled technicians hired to operate new plant, through foreign investment and through foreign trade through import of best or good practice capital goods (cf. Salter, 1961). Rent spillovers, for a large part embodied in fixed tangible capital goods, in particular machinery and equipment, seem to have been the dominant force for nineteenth century capitalist economies. The impact of pure knowledge spillovers, on the other hand, has to do with the more general ability to adopt and adapt innovations from abroad. Pure knowledge spillovers encompass processes of learning not limited to any one sector of the economy. They are closely linked to aggregate human

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19 See Verspagen (1992) and Romer (1994) for an overview of endogenous growth theories.

20 The knowledge spillover literature, however, implicitly emphasises the (disequilibrating) impact of innovation spillovers whereas Hekscher-Ohlin type forces are usually analysed in a general equilibrium framework of the kind adopted by, for instance, O'Rourke & Williamson (1995). On this distinction see Heim & Mirowski (1987). An additional complication with the use of factor prices is that they have no unequivocal relationship with GDP per worker or GDP per capita. On the relation between factor price equilisation and convergence of GDP and productivity see Dollar and Wolf (1993).

capital, in a definition which should ideally capture more than formal schooling alone.[21] The size of the domestic human capital stock determines the ability to adopt innovation and the ability to catch-up. Different endowments of human capital and different rates of accumulation of phusical and human capital may account for persistent long-term growth differentials among countries (Lucas, 1990). This may help to account for the empirical fact that unconditional convergence does not take place (see Romer, 1994 and Quah, 1993).

It is likely that the relative importance of pure knowledge spillovers was smaller in the nineteenth century than today. For instance, The Netherlands (and indeed most other countries) had an almost complete lack of an institutionalized domestic R&D sector prior to World War I. It is quite difficult, however, to apply the theoretical distinction between rent spillovers and pure knowledge spillovers empirically. The same is true of the concept of total knowledge spillovers. Coe and Helpman (1995), for instance, examine the elasticity of output to both the domestic and foreign R&D stocks to estimate the size of international knowledge spillovers. Clearly, their methodology, even with human capital rather than R&D stocks, cannot be replicated in this paper for lack of comparable data.

A way to model international knowledge spillovers would be to include both the level of the human capital stock and the 'technological gap' with best practice techniques in the world economy (see Benhabib & Spiegel, 1994, pp.155-156). The growth of joint factor productivity is defined as a function of the external rate of technical progress, the growth rate of the stock of human capital in the domestic economy and the gap between the level of knowledge attained and the knowledge frontier (catch-up effect). In such a model a higher level of education enhances both the ability of a country to innovate and the implementation of knowledge developed abroad. Expressed in a more formal way:

$$\frac{dA}{dt} = \zeta + \eta * gH_i(t) + \Theta * H_i(t) * \frac{[A_{front}(t) - A(t)]}{A_i(t)}$$

The level of human capital thus determines the rate of productivity growth and the speed of catch-up in the short run. Note that the long-run growth rate of joint factor productivity is determined by the domestic accumulation of human capital and the exogenous growth of knowledge. This formulation is in the line of growth models which endogenise the effects of learning on growth, that is where H determines the growth rate of productivity directly (for instance Lucas, 1988). The specification chosen above defines a rate effect of human capital on growth. A different specification has the level of joint factor productivity as the dependant variable, rather than joint factor productivity growth. This alternative specification models level effects of human capital formation. The accumulation of human capital within a particular country affects the growth path in the short run. In addition, there is a catch-up term associated with international knowledge transfers but the asymptotic growth rate of the economy after convergence remains determined by the rate of exogenous technical progress and population growth. This is basically the result obtained using an augmented neo-classical production function with a catch-up factor. Lastly, note that this class of models may help account for the absence of global convergence. Human capital, a to large extent nontradeable commodity, determines whether or not convergence will take place in the long-run as countries with a bigger stock of knowledge grow

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21 Since it proved difficult enough to obtain estimates of formal schooling this paper, as stated earlier, does not attempt to include measures of other kinds of informal learning relevant to economic activity.

faster.[22] If knowledge levels among countries do not converge, persistent growth differences will be observed in the long run.

There is no estimate of the knowledge gap between The Netherlands and the technological leader in the period covered. There are no comparable data on the human capital stocks in other countries either, as stated above. In order to explore knowledge spillover models in international comparisons one should construct panel data with comparable estimates of the relevant variables for a number of countries. Consequently, it is not possible to explore this class of models in this paper. I therefore will use a different approach in the following and examine models which specify the relation between productivity growth and the accumulation of physical and human capital in the domestic economy (see Albers & Groote, 1996). This is necessitated by the focus on a single country, namely The Netherlands. The effects of international knowledge spillovers perforce are assessed indirectly. To the extent that they are embodied in the productive capacity of the fixed tangible capital stock the model will capture the effects of international knowledge transfers. Or, in other words, fixed capital accumulation and joint factor productivity (sometimes erroneously dubbed technical progress) must be interdependant. A high contribution of fixed capital formation to growth can be interpreted as a (capital embodied) form of catching up (compare De Long & Summers (1991, pp.467-468).

6. Growth accounts

This section examines the empirics of economic growth in The Netherlands during the nineteenth century. It uses the data on human capital, introduced above, and some theoretical insights discussed earlier. The growth accounts cover the period 1807-1913 and use a number of alternative growth models. First, I examine a standard neo-classical model with two factors of production: labour and fixed tangible capital. The second set of growth accounts concerns an augmented Solow model with human capital as an additional factor of production (see Crafts 1995, and Albers and Groote (1996) for similar exercises). Three alternative measures of human capital are examined: 1) years of primary schooling; 2) years of total formal schooling (H1, H2, and H3), and 3) the gross stock of human capital computed from total expenditure on formal education. The third set of models includes human capital in levels (average levels over the period examined taken as the log of the ratio relative to the absolute 1913 level).

The human capital data were discussed above. The series on the physical nonresidential capital stock are the outcome of joint research on fixed capital formation in The Netherlands in the period 1800-1913 conducted by Ronald Albers, Adrian Clemens, and Peter Groote (see Albers & Groote 1996). The estimates were made using a variety of sources, most important of which are tax data and government statistics. The perpetual inventory method was used to calculate capital stocks from data on the flows of nonresidential investment, retirements, and capital consumption. A further subdivision by type of asset, as pursued in Albers and Groote (1996), is not attempted since the focus here is on the role of human capital compared to physical nonresidential capital, not on the characteristics of disaggregated tangible capital stocks. Estimates of

[22] Of course, human capital is not wholly untradable and it certainly was not so in the 19th century as is shown by the many British engineers who helped to introduce British innovations to the European continent, especially in the early stages of industrialisation.

GDP, labour input, factor shares and skill premium used in this paper are the preliminary outcome of the research project 'Historical National Accounts of The Netherlands 1800-1913'.[23]

The standard growth accounts weight capital and labour with their share in national income. I redefined the factor shares (weights) for each production factor to estimate the augmented Solow model. A somewhat arbitrary third of profit income was assigned to human capital. I used estimates of the skill premium of wages to separate the contributions of 'raw labour' and human capital to total labour income.[24] The skill premium was assumed to be the reward for human capital, whereas wages for unskilled workers should reflect the renumeration of raw labour.[25] For conceptual reasons I prefer a Divisia index of factor shares, which allows for changing weights over the period examined, over the use of end-year weights (see Jorgenson, 1995).

Table 3
Factor Shares

	Standard Solow Model		Augmented Solow Model		
	K	L	K	L	H
1807	0.58	0.42	0.51	0.30	0.19
1854	0.50	0.50	0.46	0.35	0.19
1896	0.46	0.54	0.42	0.41	0.17
1913	0.57	0.43	0.52	0.31	0.17

Sources: project NR, estimates of skill premium by A. Vermaas/J.P.H. Smits, own computations

Table 3 gives an overview of the weights used for the growth accounts (see appendix 1 for a sensitivity analysis). The share attached to capital is much higher than in highly developed twentieth century economies, and more similar to the situation in some developing countries (cf. Mankiw, Romer & Weil (1992) who use factor shares without a solid empirical basis). The relative size of the factor shares also illustrates the extent of capital deepening that has taken place in The Netherlands over the last century and highlights the importance of not using present-day factor weights in historical studies. In addition, over the long period examined factor shares were far from constant over time, which vindicates the use of Divisia-Tornquist indices. The growth accounts were computed using the following production functions.

23 For data on capital formation in infrastructure see Albers and Groote (1996). Other national accounts data from Smits, Horlings and Van Zanden (1997).

24 Total labour income includes imputed wages to entrepreneurs and the self-employed. It can be shown that the skill premium of wages reflects the contribution of human capital to earnings in a world with perfect competition, where neo-classical marginal productivity theorems hold true (see also above).

25 A complicating factor is that unskilled wages may vary with age. I could, however, make no adjustments for this effect because of a lack of information on the age profile of earnings for unskilled workers.

Standard neo-classical growth model

$$Y = A(t) \cdot K^{\alpha} \cdot L^{\beta}$$

Y gross domestic product
K gross stock of fixed tangible capital
L labour (hours worked, corrected for unemployment)
A(t) variable denoting joint factor productivity (or residual)
α output elasticity of fixed tangible; $0<\alpha<1$: decreasing marginal returns to fixed capital
β output elasticity of labour; $0<\beta<1$: decreasing marginal returns to labour
$\alpha + \beta = 1$

Augmented Solow model with human capital as an additional factor of production

$$Y = A(t) \cdot K^{\alpha'} \cdot L^{\beta'} \cdot H^{\gamma}$$

Y gross domestic product
K gross stock of fixed tangible capital
L labour (hours worked, corrected for unemployment)
H gross stock of human capital
A(t) variable denoting joint factor productivity (or residual)
α' output elasticity of fixed tangible capital; $0<\alpha'<1$: decreasing marginal returns to fixed capital
β' output elasticity of raw labour; $0<\beta'<1$: decreasing marginal returns to raw labour
γ output elasticity of human capital; $0<\gamma<1$; decreasing marginal returns to human capital
$\alpha + \beta + \gamma = 1$

In order to quantify the impact of the growth of the production factors on productivity performance, it is necessary to establish comparative levels of output per joint input of labour and capital. One should realize that such estimates of joint factor productivity should not simply be confused with 'technical change', as is often done in the more theoretical and model-oriented literature. I prefer to use the more technical term 'joint factor productivity' instead of 'total factor productivity', since the latter term suggests that all relevant factor inputs are taken into account. A fundamental issue in growth accounting concerns the underlying production function The traditional Cobb-Douglas framework, which has been mostly used by growth accountants, assumes constant returns to scale and a constant substitution elasticity of unity. The Cobb-Douglas production function has been widely used as it is relatively easy to apply empirically. The coefficients on labour and (tangible and human) capital are fixed and correspond to the factor shares in national income. The translog production function which has been most extensively used by Jorgenson and others (see Jorgenson, 1995), is more flexible as it allows for changing substitution elasticities and non-neutral technical change. In practice, however, a Divisia-Tornquist index of the Cobb-Douglas function in discrete time, which uses the average of the factor weights for two points in time, may perform well enough.[26] The Divisia-Tornquist index allows for changing factor weights over time. In logarithmic terms joint factor productivity can therefore be estimated as follows:

[26] As it turns out the difference with the standard results in most cases amounts to a few percentage points only.

Standard neo-classical model:

$$\ln\frac{A_{t+1}}{A_t} = \ln\frac{Y_{t+1}}{Y_t} - (V_L)\ln\frac{L_{t+1}}{L_t} - (V_K)\ln\frac{K_{t+1}}{K_t}$$

with $v_L = 1/2\alpha_t + 1/2\alpha_{t+1}$, and $v_K = 1/2\beta_t + 1/2\beta_{t+1}$

Augmented Solow model:

$$\ln\frac{A_{t+1}}{A_t} = \ln\frac{Y_{t+1}}{Y_t} - (V_L)\ln\frac{L_{t+1}}{L_t} - (V_K)\ln\frac{K_{t+1}}{K_t} - (V_H)\ln\frac{H_{t+1}}{H_t}$$

with $v_L = 1/2\alpha_t + 1/2\alpha_{t+1}$, $v_K = 1/2\beta_t + 1/2\beta_{t+1}$ and $v_H = 1/2\gamma_t + 1/2\gamma_{t+1}$

with
- ζ denotes exogenous rate of technical progress
- η elasticity of domestic JFP growth to domestic accumulation of H
- θ elasticity of domestic JFP growth to technological catch-up
- H_i domestic stock of human capital
- A_i joint factor productivity in home country
- A_{front} joint factor productivity at the frontier (lead country)

Tables 4 through 6 display the resulting growth accounts.[27]

Table 4
Contribution of Production Factors and Joint Factor Productivity Growth to GDP Growth. Standard Neo-Classical Model

	gY	K	L	JFP
1807-1913	1.6 %	71.3 %	22.2 %	6.4 %
1807-1854	1.4 %	45.4 %	28.0 %	26.6 %
1854-1913	1.9 %	79.1 %	22.0 %	-1.1 %
1807-1828	1.4 %	36.5 %	27.3 %	36.2 %
1828-1854	1.3 %	50.4 %	29.8 %	19.8 %
1854-1896	1.8 %	74.1 %	24.0 %	1.9 %
1854-1877	1.6 %	86.9 %	24.0 %	-10.9 %
1877-1896	2.0 %	60.1 %	24.8 %	15.1 %
1896-1913	2.2 %	69.3 %	24.1 %	6.6 %
1896-1906	2.1 %	62.8 %	33.5 %	3.7 %
1906-1913	2.5 %	71.3 %	15.9 %	12.7 %

Note: JFP = Joint Factor Productivity; Percentages may not sum to 100 due to rounding.

[27] The periodisation reflects turning points (peak/peak) in the Dutch business cycle. I calculated turning points of the reference cycles on the basis of growth rates of real GDP data from Horlings, Smits and Van Zanden (1997).

Table 5
Growth Accounts with an Augmented Solow Model.
Contribution of Production Factors and Joint Factor Productivity Growth to GDP Growth using Alternative Measures of Human Capital, Percentage Points

Panel A: using years of primary schooling

	K	L	H 1 (years of schooling)	JFP
1807-1913	63.1 %	16.1 %	17.5 %	3.3 %
1807-1854	39.8 %	19.7 %	20.6 %	19.9 %
1854-1913	68.9 %	15.8 %	18.1 %	-2.9 %
1854-1896	64.4 %	17.6 %	19.9 %	-1.9 %
1854-1877	74.8 %	17.4 %	24.4 %	-16.5 %
1877-1896	52.1 %	18.7 %	13.2 %	16.1 %
1896-1913	60.8 %	18.1 %	14.0 %	7.0 %
1896-1906	54.4 %	25.3 %	15.2 %	5.2 %
1906-1913	62.0 %	11.9 %	14.0 %	12.1 %

Panel B: using years of total schooling

	K	L	H 1-3 (years of schooling)	JFP
1807-1913	63.1 %	16.1 %	17.9 %	2.9 %
1807-1854	39.8 %	19.7 %	20.0 %	20.4 %
1854-1913	68.9 %	15.8 %	19.2 %	-3.9 %
1854-1896	64.4 %	17.6 %	20.3 %	-2.3 %
1854-1877	74.8 %	17.4 %	24.2 %	-16.3 %
1877-1896	52.1 %	18.7 %	13.9 %	15.3 %
1896-1913	60.8 %	18.1 %	16.2 %	4.9 %
1896-1906	54.4 %	25.3 %	17.4 %	3.0 %
1906-1913	62.0 %	11.9 %	16.3 %	9.8 %

Panel C: using total expenditure on formal schooling

	K	L	H 1-3 (expenditure data)	JFP
1807-1913	63.1 %	16.1 %	13.4 %	-2.6 %
1807-1854	39.8 %	19.7 %	6.4 %	34.1 %
1854-1913	68.9 %	15.8 %	19.2 %	-3.9 %
1854-1896	64.4 %	17.6 %	40.3 %	-22.3 %
1854-1877	74.8 %	17.4 %	45.2 %	-37.4 %
1877-1896	52.1 %	18.7 %	29.7 %	-0.5 %
1896-1913	60.8 %	18.1 %	28.4 %	-7.4 %
1896-1906	54.4 %	25.3 %	32.8 %	-12.5 %
1906-1913	62.0 %	11.9 %	25.9 %	0.3 %

Note: JFP = Joint Factor Productivity; Percentages may not sum to 100 due to rounding.

Table 6
Growth Accounts with a Model using the Level of Human Capital, according to Alternative Measures. Contribution of Production Factors and Joint Factor Productivity Growth to GDP Growth using Alternative Measures of Human Capital, Percentage Points

Panel A: using years of total schooling

	K	L	H 1 (years of schooling)	JFP
1807-1913	63.1 %	16.1 %	14.7 %	6.1 %
1807-1854	39.8 %	19.7 %	16.7 %	23.7 %
1854-1913	68.9 %	15.8 %	14.9 %	0.4 %
1854-1896	64.4 %	17.6 %	15.8 %	2.2 %
1854-1877	74.8 %	17.4 %	17.9 %	-10.1 %
1877-1896	52.1 %	18.7 %	13.8 %	15.5 %
1896-1913	60.8 %	12.3 %	8.8 %	7.0 %
1896-1906	54.4 %	25.3 %	13.7 %	6.6 %
1906-1913	62.0 %	11.9 %	11.7 %	14.5 %

Panel B: using total expenditure of formal schooling

	K	L	H 1 (years of schooling)	JFP
1807-1913	63.1 %	16.1 %	13.4 %	7.4 %
1807-1854	39.8 %	19.7 %	13.0 %	27.4 %
1854-1913	68.9 %	15.8 %	13.9 %	1.3 %
1854-1896	64.4 %	17.6 %	14.0 %	4.0 %
1854-1877	74.8 %	17.4 %	14.6 %	-6.7 %
1877-1896	52.1 %	18.7 %	12.8 %	16.4 %
1896-1913	60.8 %	12.1 %	9.0 %	7.0 %
1896-1906	54.4 %	25.3 %	13.4 %	6.9 %
1906-1913	62.0 %	11.9 %	11.6 %	14.6 %

Note: JFP = Joint Factor Productivity; Percentages may not add to 100 due to rounding.

A number of interesting results stand out. First, over the whole period examined the growth of the physical capital stock was the most important driving force behind GDP growth. The contribution of joint factor productivity growth, on the other hand, explains just a small part of GDP growth, although JFP growth seems to have accelerated slightly shortly before World War I. Economic growth therefore seems to have had a strong physical capital using bias, even more so than suggested by the rougher growth accounts in Albers and Groote (1996).

Second, the inclusion of human capital (measured as years of schooling) in an augmented Solow model does little to change the results. Investment in human capital explains at most a fifth of economic growth, depending on the weight attached to human capital. Accumulation of fixed tangible capital remains the single most important source of growth, while the contribution of joint factor productivity is quite small. These results are quite robust to changes in the factor shares used (see appendix 1), although a higher factor share attached to H of course tends to push up the estimated contribution of human capital formation to economic growth.

Third, estimates of the human capital stock defined as years of formal schooling perform quite well in the growth accounts. Primary education accounted for by far the largest share of the total stock of years of schooling in the economy. The attainment data for H1 and H1-3 show very similar growth rates throughout. As a result the part of GDP growth assigned to each individual factor of production is quite similar using either (attainment) estimate of the human capital stock. Alternative estimates of the human capital stock based on schooling expenditure, however, yield highly implausible results with strongly negative joint factor productivity growth. Perhaps the price index used to deflate education expenditure still underestimates the rise of the cost of education, despite it showing a much faster rise than the aggregate GDP deflator.

Fourth, inclusion of human capital in levels in the production function does little to change the results. The importance attached to human capital in such a specification tends to be somewhat smaller compared to specifications where H is included in growth rates. Again, attainment variables perform rather well, while expenditure data now produce quite plausible results. All in all, there is no clear indication of level effects of human capital formation.

Fifth, for practical purposes the standard Cobb-Douglas framework does quite well to explain the pattern of economic growth in The Netherlands during the nineteenth century. The evidence suggest that factor accumulation is what mattered most. There seems to be little need to embrace slightly exotic growth models inspired by twentieth century experience, certainly not without critical reflection. The relative contribution of joint factor productivity growth to the increase of GDP does vary among subperiods. However, the average rate of joint factor productivity growth amounts to no more than some 0.1% per annum, which is surprisingly low by present-day standards. This would leave little room for disembodied technical change, organisational improvements, better resource allocation, etc.

Finally, the growth accounts suggest an important role for structural change and for the significance of differential productivity trends among sectors. Unfortunately, these effects cannot be discussed in more detail here. Suffice it to say that labour productivity in agriculture remained more or less the same in the 19th century, whereas labour productivity in services increased and industrial labour productivity showed up and downswings. Compositional effects may therefore to some extent explain the slightly odd swings in aggregate joint factor productivity growth rates observed, as well as bias downwards the overall rate of productivity growth.

We should perhaps not attach too much meaning to the exact percentages in the tables.[28] They give a wholly unjustified impression of exactness. Nevertheless, the results support interpretations which fit in with other literature. For instance, Abramovitz (1993) and Abromovitz and David (1996) argue that physical capital accumulation prominent role in the American economy during the 19th century since, in their view, technical progress had a strong physical capital-using bias. Only in the twentieth century did intangible (human) capital come to the forefront. For the nineteenth century, Abramovitz (1993) finds the contribution of physical capital to American economic growth to be far greater than the contribution of joined factor productivity growth (which is associated more closely with intangible capital). After 1870 the accumulation of physical capital became less dominant a source of growth in the United States, but its contribution remained dominant in explaining labour productivity growth until the turn of the century. Only then did the picture arise that is familiar from modern growth accounts: a contribution of physical capital to growth of about 20% (Maddison, 1987). The evidence for The Netherlands presented here supports these broad conclusions from the literature (see also Albers and Groote, 1996). The bottom line is that factor accumulation played the dominant role. In this respect at least, economic growth in The Netherlands in the 19th century and in East Asia in the second half of the 20th century seem akin (compare Collins & Bosworth (1996)).

It may be fruitful to distinguish three subperiods in a very tentative interpretation. The first covers the first half of the nineteenth century. It can perhaps best be characterized as a period of relatively capital-extensive pre-modern growth, with an important role for better resource allocation and structural and organisational change. This would explain the relatively large part of GDP growth attributed to an increase in joint factor productivity. The second period, from 1854 to 1896, marks the transition to a different pattern, and may be regarded as the first stage of modern economic growth. Infrastructural improvements promoted the national and international integration of markets, although in my opinion recent historiography sometimes lays too much emphasis on this point (cf. Horlings, 1996). Economic growth was driven by accumulation of physical capital, while labour input steadily increased. In this period technical progress and the international transfer of knowledge probably had a strong bias towards using fixed tangible capital. Joint factor productivity growth even was slightly negative. The contribution of physical and human capital to GDP growth in this period can be regarded as strongly complementary. Finally. the last period before the first World War marked the beginning of a gradual transition to a 'twentieth century' growth pattern, with a somewhat larger role for joint factor productivity growth, and a shift towards disembodied technical change which probably increased demand for schooling. The accelaration in joint factor productivity growth in the decades before World War I testifies to this. Here again, a parallel may be drawn to recent developments in (South) East Asia, where in recent years joint factor productivity growth has picked up as the maturing economies of the region become more susceptible to technology transfer (compare Collins and Bosworth, 1996, p.186). Of course, all of the above remarks should be regarded as no more than a highly speculative and uncertain first interpretation of the results.

One final caveat to the results tabulated above has to be mentioned. In estimates of joint factor productivity it is impossible to disentangle factor-augmenting technical change from the shape of the production function (and the assumed elasticity of substitution in particular). If the elasticity of substitution assumed is too high, JFP growth is underestimated (Rodrik, 1997). I have used Cobb-Douglas type production functions with constant returns to scale and and an elasticity of substitution between capital and

[28] Keep in mind that the time series approach for a single country is likely to give a higher coefficient on human capital than cross section regressions.

labour of unity. This approach implicitly assumes that technical change is Hicks-neutral. If the elasticity of substitution was, in fact, below unity *or* technical change was labour saving, the growth accounts would tend to underestimate JFP growth. The observed relative stability of the capital share over time despite substantial capital deepening can be consistent with either an elasticity of substitution lower than one, or labour-augmenting technical change (or some combination of the two). A possible underestimate of the contribution of technical change to growth would result in a bias proportional to the magnitude of capital deepening. However, when labour-saving technical change was accompanied by capital deepening, as seems likely, capital accumulation should still be given a prominent place. In my opinion the growth accounts therefore point to the right 'proximate; sources of growth , even if joint factor productivity growth is underestimated.

7. Conclusions

In this paper I present new estimates of the stocks of physical and human capital in The Netherlands covering the period 1800-1913. These data, in combination with recently updated historical national accounts statistics, are used in an analysis of Dutch economic growth during the nineteenth century. The paper proposes a number of alternative estimates of the human capital stock, and discusses their advantages and disadvantages.

The number of years of schooling in the working force seems a good candidate for a consistent, operational and quantifiable measure of the stock of human capital. For most of the nineteenth century, secondary and higher education accounted for only a small part of formal education attainment in The Netherlands. This suggests that an estimate of primary education attainment levels provide a useful first approximation of the stock of human capital. Research on other countries therefore may begin by focusing on primary education only. Alternative estimates of the human capital stock based on expenditure data provide much more difficulties. The growth accounts using these data yield highly implausible results. Literacy seems a less useful variable to study the impact of human capital formation on productivity growth at the macro-level. Because of the high literacy rates already prevailing in The Netherlands in the early 19th century little explanatory power results.

Various growth theories suggest that it may be fruitful to investigate the role of human capital and technology spillovers in economic growth. A review of the literature further suggests that the definition of capital input used and the choice of specification of a growth model may have important consequences for the results. Moreover, the interrelatedness of variables in growth accounts pose additional problems of interpretation. Unfortunately, at this stage it is not possible to carry out an international comparison using panel data on key variables. Consequently, the effects of international knowledge transfers on Dutch economic growth can only be assessed indirectly. The focus on economic growth within a single country (The Netherlands) over time probably gives an upper bound estimate of the role of human capital.

Finally, the role of tangible and intangible capital in Dutch economic growth is investigated using a number of different growth models. In general, joint factor productivity growth accounted for a much smaller part of economic growth than in OECD countries during the twentieth century. Technical progress in the nineteenth century seems to have had a strong fixed capital using bias. The application of alternative growth models with human capital as an additional factor of production does not radically change this picture. Human capital accumulation contributes positively to economic growth, but the impact seems to have been smaller than it is today. The contribution of human capital was of the same order of magnitude as that of raw labour throughout (roughly a fifth), whereas the accumulation of physical capital remained the main driving force behind economic growth during the nineteenth century. International knowledge spillovers seem to have been relatively small, and probably were to a large extent embodied in tangible capital goods. There is evidence of a slight acceleration of joint factor productivity growth towards the end of the period examined but 'extensive' economic growth seems to have been the typical pattern. In addition, the growth accounts also support the importance of structural change.

One of the main aims of the present paper was to investigate the possibility to make estimates of the human capital stock on the macro level for the nineteenth century. The estimates of the human capital stock in The Netherlands presented here are rather crude aggregate measures and I would happily leave improvements of my rough accounting measures to those more knowledgeable. Still, I do hope that the concepts and methods described here may be useful to other researchers. In my view the construction of comparable data on human capital and key national accounts statistics for a number of countries should be high on the research agenda, even though this is a time-consuming and difficult task. It will, however, enable a more comprehensive use of panel data in empirical investigations of long-run economic growth. Only then can the role of tangible capital, human capital, technical change, and technology transfer be analysed in a broader international and historical context.

Appendix 1
Sensitivity of Growth Accounts with Human Capital to Changes in Factor Shares
(for Augmented Solow model)

Altern. 1*	Factor Share (%)			Contribution to GDP Growth (%)			
period	K	L	H	K	L	H 1-3	JFP
1807-1913	50.9	30.8	18.4	63.1	16.1	17.9	2.9
1807-1854	47.3	32.5	20.2	39.8	19.7	20.0	20.4
1854-1913	46.7	33.4	19.9	68.9	15.8	19.2	-3.9

* the version used for the more detailed growth accounts in previous tables

Altern. 2	Factor Share (%)			Contribution to GDP Growth (%)			
	K	L	H	K	L	H 1-3	JFP
1807-1913	49.3	24.9	25.8	61.1	13.0	25.2	0.7
1807-1854	45.8	25.8	28.5	38.5	15.6	28.3	17.6
1854-1913	46.7	27.0	26.3	68.9	12.8	25.4	-7.1

Altern. 3	Factor Share (%)			Contribution to GDP Growth (%)			
	K	L	H	K	L	H 1-3	JFP
1807-1913	53.4	30.8	15.8	66.2	16.1	15.4	2.2
1807-1854	49.9	32.5	17.6	42.0	19.7	17.5	20.8
1854-1913	50.2	33.4	16.4	74.0	15.8	15.8	-5.7

Note: This table shows the summary outcome of growth accounting exercises using various weighting schemes which assign between one half (maximum) and one fourth (minimum) of profit income to entrepreneurship and hence human capital, and for higher versus lower bound estimates of the skill premium. Percentages may not sum to 100 due to rounding.

List of symbols

Y	gross domestic product
P	population
K_j	gross stock of fixed tangible capital of asset j
L	labour input (hours worked, corrected for unemployment)
H	gross stock of human capital
H1	gross stock of primary schooling
H2	gross stock of secondary schooling
H3	gross stock of tertiary schooling
H1-3	gross stock of total formal schooling
IH	gross investment in human capital (gross additions to human capital stock)
RH	retirements (discards) of human capital
A	joint factor productivity
A_{front}	joint factor productivity at the frontier (lead country)
α	output elasticity of fixed tangible capital
α'	output elasticity of fixed tangible capital (profit income assigned to H)
β	output elasticity of labour
β'	output elasticity of raw labour
γ	output elasticity of human capital
ζ	denotes exogenous rate of technical progress (independant of H)
η	elasticity of domestic JFP growth to domestic accumulation of H
θ	elasticity of domestic JFP growth to technological catch-up
v_L	$1/2\alpha_t + 1/2\alpha_{t+1}$
v_K	$1/2\beta_t + 1/2\beta_{t+1}$
v_H	$1/2\gamma_t + 1/2\gamma_{t+1}$

subscript j denotes type of asset:

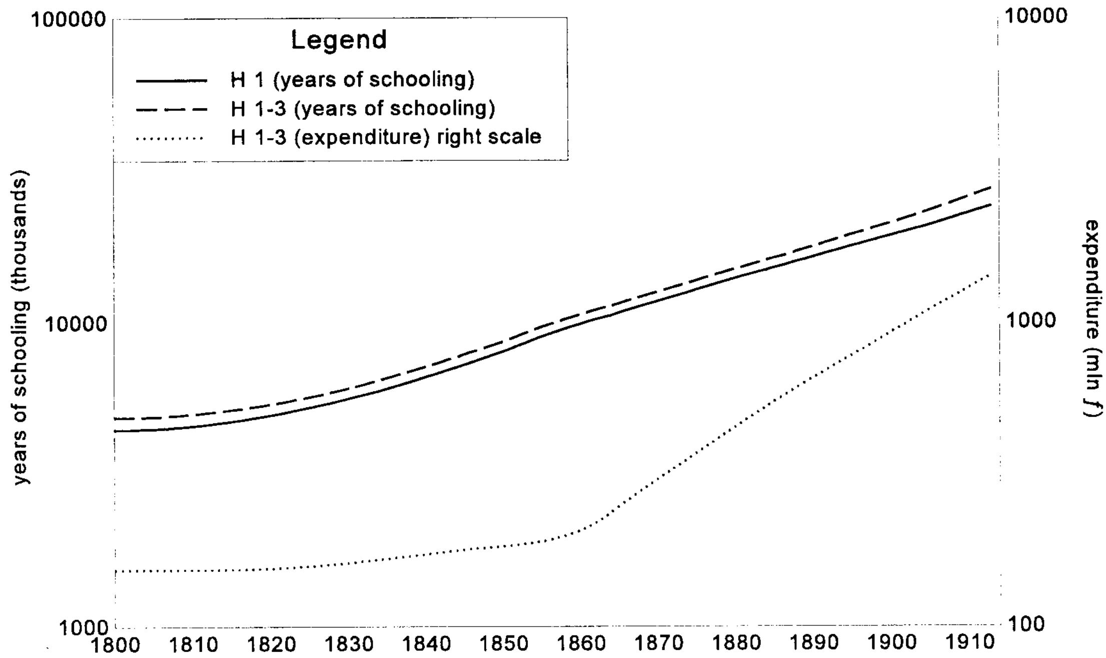
M	machinery and equipment
NR	nonresidential structures and dwellings
H	human capital

subscript i denotes domestic economy

t denotes time (years)

prefix g denotes annual compound growth rate

Appendix graph 1: Estimates of Gross Stock of Human Capital, The Netherlands 1800-1913



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