Portuguese Journal of Social Science Volume 4 Number 2. © Intellect Ltd 2005.
Article. English language. doi: 10.1386/pjss.4.2.101/1

Measuring aggregate human capital in Portugal: 1960–2001

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Abstract

Recent studies conclude that human capital should be a high priority because it is a key growth input, particularly in an increasingly knowledge-based economy and an important lever of social cohesion policy. However, country-specific studies involving human capital and economic performance are scarce both for Portugal and for other countries. The small number of such studies is explained to a large extent by the increased complexity and difficulty of estimating continuous time series for human capital stock giving data paucity. This article tries to facilitate the emergence of further empirical works on the relation between human capital and long-term economic growth by providing an improved measure of the stock of human capital for the Portuguese economy from 1960 up to 2001.

Keywords

human capital
education
measurement
economic growth

Introduction

Many lines of economic research depend on having an accurate measure of individual human capital, which in turn require the measuring of investment in education and other inputs for human capital. Measurement problems are particularly acute in the case of human capital (Hanushek 1996; Sianesi and van Reenen 2003).

Many economists and policy-makers consider human capital as an important production factor, highly complementary with technological capital, and earlier studies focusing on cross-country growth performance over long periods generally yielded positive results (e.g. Barro 1991; Barro and Lee 1994; Mankiw et al. 1992). However, a substantial number of subsequent studies have not always supported this view (Benhabib and Spiegel 1994; Caselli et al. 1996; Pritchett 1995). De la Fuente and Doménech (2000; 2002) and De la Fuente et al. (2003) argue that these negative results derived from poor quality data used in those studies, which led to high measurement errors hiding in this way the connection between human capital accumulation and productivity growth.

Computing 'corrected estimates' of human capital stock, De la Fuente (2003) found that the productivity effects of human capital are substantial. In fact, in an earlier European Commission (EC) report (De la Fuente and Ciccone 2002) it is estimated that an additional year of average school attainment raises productivity in the average EU country by 6.2 per cent on impact and by a further 3.1 per cent in the long run through its contribution to faster technological progress. The first of these effects is considerably higher in the cohesion countries, reaching 9.2 per cent in the case of Portugal.

Theoretical models of human capital and growth are built around the hypotheses that knowledge and skills embodied in human capital directly raise productivity and increase an economy's ability to develop and to adopt new technologies. In order to explore its implication and open the way for its empirical testing, this basic hypothesis is generally formalized in one of two (not mutually exclusive) ways: (1) introducing the stock of human capital as an additional input in an otherwise standard production function linking the aggregate output to the stocks of productive inputs (generally employment and physical capital) and to an index of total factor productivity; and (2) including the stock of human capital as a determinant of the rate of technological progress (cf. Nelson and Phelps 1966).

Pack (1994) suggests nevertheless that the main flaw of empirical studies on economic growth derives from the fact that they have been tested earlier as Solow-style neoclassical growth models, rather than testing growth endogenous theory itself. Illustrating the scantiness of the few systematic tests of endogenous growth theory, Pack (1994: 69) stresses that cross-country regressions aiming at explaining growth rates provide 'rough orders of magnitude and indications of where to search for explanations of growth, but cannot articulate the connection between factor accumulation and economic growth'. He argues that the challenge for empirical work is to test the implications of the new theory against the economic evolution of individual countries using time series data.

However, country-specific studies are scarce (Pina and St Aubyn 2002). Some attempts to estimate the human capital contribution to individual country's economic growth are, in the case of Portugal, Dias (1992), Teixeira (1997), Pina and St. Aubyn (2002), Teixeira and Fortuna (2004) and Pereira (2004). At the international level this type of study is not abundant either, some examples being Chuang (2000) for Taiwan, and Laroche and Mérette (2000) for Canada. The small number of such studies is explained to a large extent by the increased complexity and difficulty of estimating continuous time series for human capital stock, which gives data paucity.

This article tries to facilitate the emergence of further empirical works on the relation between human capital and long-term economic growth by updating Teixeira's (1998) estimation of the stock of human capital for the Portuguese economy up to 2001.[1] It is presented here as an improved proxy of Portuguese human capital stock based on education attainment.

In the next section, we review a set of alternative measures for human capital stock by discussing the corresponding strengths and drawbacks. Section 3 focuses on the updating of human capital stock, presenting its methodological underpinning. A brief comparison between the present estimates and the available estimates at the Portuguese and cross-country level is provided in Section 4. Finally, Section 5 concludes the article pointing to further pathways for future research.

1 The work by Teixeira and Fortuna (2004), which analyses the long-term relationship between human capital, innovation capability and economic growth, uses the human capital stock detailed in the present article.

A review of alternative measures for human capital stock

A review of the measures of the stock of human capital used in empirical growth research reveals that human capital is mostly poorly proxied (Wossmann 2003). The main reason for the use of poor proxies of the stock of human capital is that in most empirical growth studies, the choice of the human capital proxy is hardly reflected upon and depends very much on data availability.

The choice of adult literacy rates as a proxy for human capital stock (e.g. Azariadis and Drazen 1990; Romer 1990) reflects, in most studies, the ease of data availability and a broad coverage of countries by the available data. However, they miss out most of the investments made in human capital because they only reflect the very first part of these investments. In fact, using adult literacy rates as a proxy for the stock of human capital implies the assumption that none of the additional investments over the basic education level directly adds to the productivity of the labour force.

An alternative proxy, school enrolment ratios (Barro 1991; Mankiw et al. 1992; Levine and Renelt 1992), tends to be considered a poor measure of the stock of human capital available for current production. Indeed, enrolment ratios are flow variables, and the children currently enrolled in schools are by definition not yet a part of the labour force. The accumulated stock of human capital depends indirectly on lagged values of school enrolment ratios, where the time lag between schooling and future additions to the human capital stock can be very long and can also depend on the ultimate length of the education phase. Enrolment ratios may not even accurately represent changes in the human capital stock, especially during the periods of rapid educational and demographic transition (Wossmann 2003). Specifically, they do not measure the human capital embodied in the entrants of the labour force in one particular year, but the human capital acquired by the then-current students who might enter the labour force at some time in the future. Moreover, the education of current students may not translate at all into additions to the human capital stock embodied in the labour force because part of current enrolment may be wasted due to grade repetition and dropping out. Finally, net investment flows would have to take into account the human capital content of the workers who are retiring from the labour force that year.

The educational attainment is clearly a stock variable and it takes into account the total amount of formal education received by the labour force. Therefore it has become the most popular and commonly used measure (Barro and Sala-i-Martin 2004; Barro 1997; 1999; Benhabib and Spiegel 1994). Well-known cross-country data on the levels of educational attainment and average years of schooling are those of Psacharopoulos and Arriagada (1986), Kyriacou (1991), Barro and Lee (1993; 1996; 2000), de la Fuente and Doménech (2000; 2002) and De la Fuente and Ciccone (2002). Concerning time series data, we have for Portugal the studies of Teixeira (1997; 1998), Pina and St Aubyn (2002) and Pereira (2004). These measures have recently been targets of major criticisms (Cohen and Soto

2001; Sianesi and van Reenen 2003; Wossmann 2003). On one side, specifying human capital by average years of schooling implicitly gives the same weight to any year of schooling acquired by a person - a year of schooling should be weighted differently depending on how many years of schooling the person has already accumulated. On the other side, it does not take into account differences in the quality of schooling across countries and time.

The money value of human capital stock (e.g. Laroche and Mérette 2000; Cohen and Soto 2001; Pereira 2004) overcomes some of the limitations of the years of education proxy. The human capital measure is constructed by combining data on years of schooling with rates of return estimated in micro labour studies which weight each year of schooling by its market return, i.e. by the earning it generates in the labour market. This measure is not widely applicable to international comparisons due to the limited availability of detailed wage data for most countries (Barro and Lee 2000). In the case of time series, the limited coverage is still more severe (in the case of Portugal, Pereira (2004), for example, presents only 16 observations). Additionally, there are potential problems with the available estimates of return to education because of biases through unmeasured characteristics like ability and because of the disregard for social benefits (Barro and Lee 2000). In the case of wages changing substantially, this measure tends to fluctuate unnecessarily (Mulligan and Sala-i-Martin 1995).

There has been considerably more work in improving international measures of human capital. International test scores of students (International Association for the Evaluation of Educational Achievement's (IEA), Third International Mathematics and Science Study (TIMSS) for the period 1994–1995) provide useful information on the quality of education. However, two shortcomings of these data may be pointed out. (1) The observations apply to different years and are most abundant for the 1990s; the sample sizes are also much smaller than those for average years of schooling. (2) They do not directly measure the educational capital held by a country's working-age population. The international adult literacy survey (OECD and Human Resources Development Canada 1998) is a very promising attempt to measure directly the skills of the labour force for international comparison. This measure is still in its earliest stages and covers only twelve OECD countries (it excludes Portugal). Additionally to its limited coverage it has been criticized because of measurement errors in modelling techniques (Barro and Lee 2000).

In this context, data on educational attainment still provide the best available information about the amount of human capital stock for a broad number of countries and for any one country over a period of time.

An update estimation of the Portuguese human capital stock

Portuguese economic growth has been comprehensively tackled with the outstanding research by Reis (1993) and Lains (1995; 2002; 2003b), concerning the period pre-1950s, and, for more recent time spans, Lains (2003a), Afonso (1999) and Afonso and Aguiar (2004).

However, studies explicitly concerned with the relation between economic growth and human capital for the Portuguese economy are rather scarce. The first ones emerged in the 1990s with the works of Dias (1992), Nunes (1993) and Teixeira (1997). Nevertheless, recently there has been a renewed interest in this line of investigation with the works of Pina and St Aubyn (2002), Teixeira and Fortuna (2004) and Pereira (2004). This recent spurt has been in part explained by the availability of a continuous time series for the Portuguese human capital stock based on educational attainment, which has been first introduced in Teixeira (1997; 1998).

Pina and St Aubyn (2002), based on Teixeira's (1997) work, introduced some methodological changes and adopted a more encompassing definition of human capital, considering data on formal training besides education. Their estimate covers the period 1977–2001. More recently, Pereira (2004) estimated three time series of human capital stock for Portugal, one based on educational attainment for the period 1960–2001, and the other two based on labour-market income for the period 1982–98. Similarly to Teixeira (1997; 1998), and contrary to Pina and St Aubyn (2002), the proxy refers only to formal education (not including formal training). Differently from Teixeira's and Pina and St Aubyn's studies, which consider 'adult active population' people over 25-years-old, Pereira (2004) uses a broader set of population (over 15-years-old, as does Barro and Lee 2000) and adjusts for population mortality.

It is important to point out that the inclusion of training as a component of human capital, as in Pina and St Aubyn (2002), does not significantly change growth regression results, as the authors themselves concluded. Additionally, the extension of the population set (adding the 15 to 24-year-olds) included in the estimation of Pereira by comparison with that of Teixeira's (1997; 1998) is not likely to produce significant improvements as the percentage of 15 to 24-year-olds in the total working-age population is small and declining over time (representing 21 per cent of the total in 2001), being still smaller as a percentage of the effective workforce. Concerning the adjustment for population mortality, Pereira (2004) uses a global average mortality rate for each period not being able (due to data constraints) of adjusting for mortality by age and schooling level, which would be the relevant issue regarding the estimation of the human capital stock for an individual country.

Given the above considerations, we opt for estimating and updating up to 2001 the work of Teixeira (1997; 1998) who estimated the Portuguese human capital stock based on educational attainments, i.e. the average number of years of schooling of the Portuguese adult working-age population. Thus, the following methodological description follows closely that in Teixeira (1998).

The estimation of the Portuguese human capital stock was pursued accordingly to the methodologies of Barro and Lee's (1993) original work and Kyriacou (1991). In a first phase, the data on the education attainment levels of the adult Portuguese population was compiled. This information was drawn from census statistics (1960; 1970; 1981; 1991; 2001) gathered by the National Statistical Institute (INE).

Using the perpetual inventory method it was possible to extrapolate, from the existing census figures, the proportion of the Portuguese population that achieved each of the education levels in intra-census adjacent years (see Table A1 of the Appendix). Starting with the census figures as a benchmark, the perpetual inventory method uses the school enrolment ratios (PRImary, SECondary and HIGher) to estimate changes from the benchmarks. Then, applying the formulas derived by Barro and Lee (1993) we were able to estimate the fraction of the adult working-age population (25 years old and over) from whom *j* is the highest level attained (*j=1* for total primary, *j=2* for total secondary and *j=3* for tertiary). As a result, we have census-based values of h_{jt} for 1960, 1970, 1981, 1991 and 2001, seeking to estimate the missing values.

$$h_{1,t} = \left(1 - \frac{L25_t}{L_t}\right) \cdot h_{1,t-5} + \frac{L25_t}{L_t} \cdot \left(PRI_{t-15} - SEC_{t-10}\right) \quad (1)$$

$$h_{2,t} = \left(1 - \frac{L25_t}{L_t}\right) \cdot h_{2,t-5} + \frac{L25_t}{L_t} \cdot \left(SEC_{t-10} - HIG_{t-5}\right) \quad (2)$$

$$h_{3,t} = \left(1 - \frac{L25_t}{L_t}\right) \cdot h_{3,t-5} + \frac{L25_t}{L_t} \cdot \left(HIG_{t-5}\right) \quad (3)$$

where:

L_t : population aged 25 years and over at time *t*;

$L25_t$: population aged [25, 29] at time *t*. It represents those who entered into the overall population aged 25 years and above, during the last five years;[2]

$h_{jt} = \frac{H_{jt}}{L_t}$: the proportion of the adult population for whom *j* is the highest level of educational attainment [*j*: total primary (1), total secondary (2) and higher/tertiary (3)];

$PRI_{t-\tau}$: the gross enrolment ratio for primary schools observed at time $t-\tau$;

$SEC_{t-\tau}$: the gross enrolment ratio for secondary schools observed at time $t-\tau$;

$HIG_{t-\tau}$: the gross enrolment ratio for higher schools observed at time $t-\tau$.

For the period in question, 1960–2001, census data corresponded to 11.9 per cent of the values for each education level. The perpetual inventory method allowed us to fill in more than 11.9 per cent of the values for primary education, 11.9 per cent in the case of secondary education and 9.5 per cent for higher education (see Table A1). To obtain the remaining missing values we use, similarly to Kyriacou (1991), a regression combining those two kinds of information previously referred to (census and perpetual inventory-estimated attainment levels). Differently from Kyriacou,

2 Barro and Lee (1993) neglected here any mortality for people aged 20–24 five years previously, and assumed that the survival probability for people who were 25 and over is independent of the level of educational attainment.

we introduced an additional explanatory variable to take into account population structure (and in this way be closer to the perpetual inventory method).

$$\ln h_{1,t} = -48{,}506 - 0{,}309 \ln\left(\frac{L25_t}{L_t}\right) + 0{,}854 \ln\left(PRI_{t-15} - SEC_{t-10}\right) + e_{1,t} \tag{4}$$

(-5,916) (-0,586) (4,988) $\overline{R}^2 = 0{,}818$

$$\ln h_{2,t} = -2{,}461 - 0{,}720 \ln\left(\frac{L25_t}{L_t}\right) + 0{,}702 \ln\left(SEC_{t-10} - HIGH_{t-5}\right) + e_{2,t} \tag{5}$$

(-1,129) (-0,721) (7,746) $\overline{R}^2 = 0{,}895$

$$\ln h_{3,t} = 0{,}382 + 0{,}478 \ln\left(\frac{L25_t}{L_t}\right) + 1{,}031 \ln\left(HIGH_{t-5}\right) + e_{3,t} \tag{6}$$

(0,143) (0,403) (8,631) $\overline{R}^2 = 0{,}927$

All regressions present a good fit. The output of these estimations is presented in the Appendix, Table A2.

In the following step we estimate the portion of the adult population disaggregating it into finer levels of education: incomplete and complete primary, secondary and higher education levels. Once again the starting point was the census data with reference to the individuals that attained one of the three levels of education by degree of completeness. The resulting conclusion ratios are reported in Table A3 in the Appendix. Subsequently, and in the same line of Psacharopoulos and Arriagada (1986) and Barro and Lee (1993), the estimates of human capital stock were assembled from the following formula:

$$\begin{aligned} H = {} & D_p\left(\frac{1}{2}\cdot h_{ip} + h_{cp}\right) + \left(D_p + D_{s1}\right)h_{is} + \left(D_p + D_{s1} + D_{s2}\right)h_{cs} + \\ & + \left(D_p + D_{s1} + D_{s2} + \frac{1}{2}D_{hig}\right)h_{ihig} + \left(D_p + D_{s1} + D_{s2} + D_{hig}\right)h_{chig} \end{aligned} \tag{7}$$

where

H: average years of schooling

Each percentage refers to the fraction of the population for which the j^{th} level of schooling is the highest level attained [$j = ip$ for incomplete primary, *cp* for complete primary, *is* for the first cycle of secondary, *cs* for the second cycle of secondary, *ihig* for incomplete higher, and *chig* for complete higher].

D_i: the duration in years of the *ith* level of schooling [$i = p$ for primary, *s1* for the first cycle of secondary, *s2* for the second cycle of secondary, and *hig* for higher].

For D_i we consider the official length for each level of education as it is reported by INE (1979/80): 4 years for primary, 6 years for the first cycle of lower secondary, 9 years for the second cycle of lower secondary, 12 years for upper secondary and 18 years for higher school.

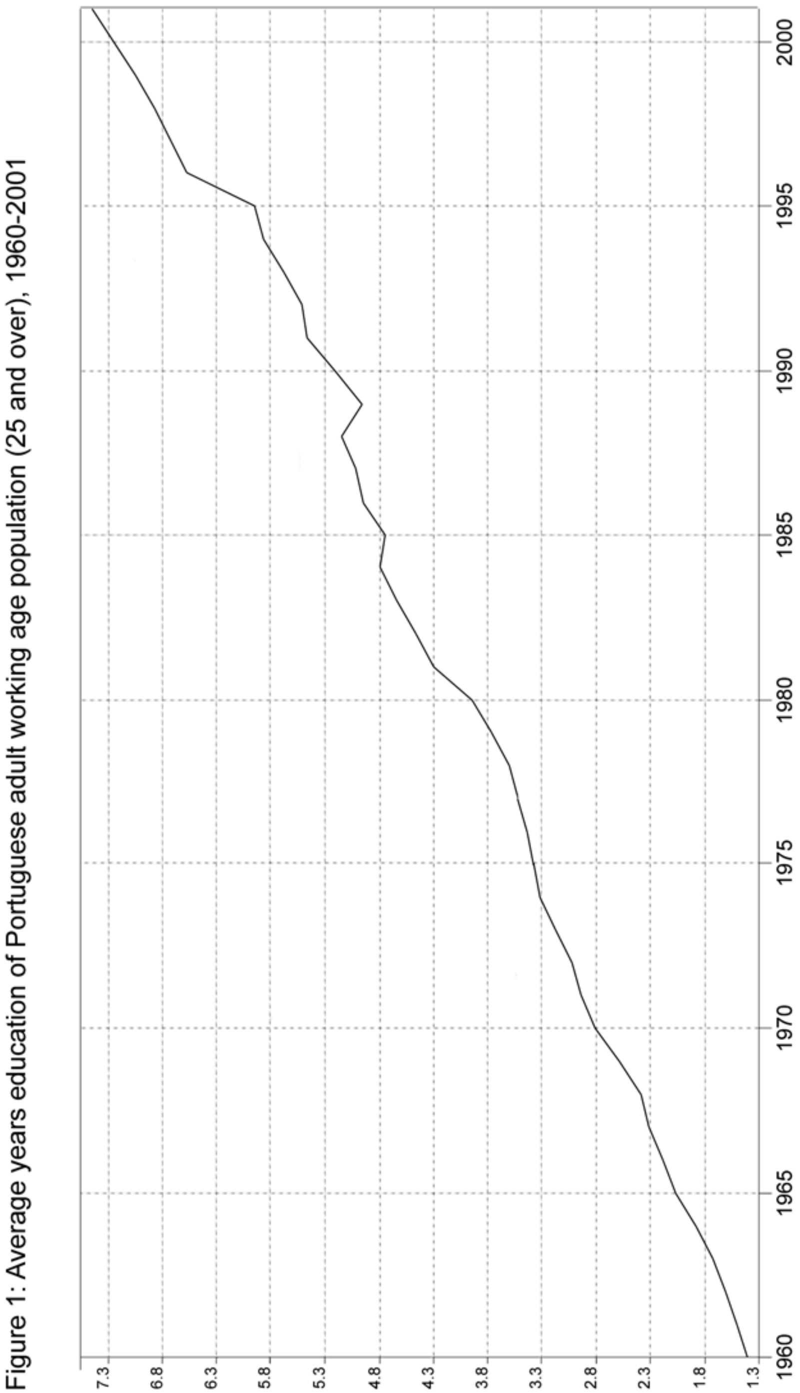

Figure 1
Source: See Table A4 in the Appendix.

The whole set of estimates for the Portuguese human capital stock is reported in the Appendix, Table A4. We estimate four measures of the average number of years of schooling of the Portuguese working-age population. At the first measure, *H*, we consider only the three main levels of education without distinguishing complete from incomplete levels. The other three estimates differ from each other relatively to the length of the first cycle of secondary school. *H'* considers that the individuals that do not complete any of the three education levels achieved at least half of the years [of education] officially required. *H''* the same as *H'* but considering incomplete secondary as those individuals that do not go further than the first cycle of lower secondary school. *H'''* the same as *H''* but now the relevant length of time is the second cycle of lower secondary school, which happens to be the compulsory education level in the Portuguese education system). The next figure presents the evolution of the proxy of the Portuguese human capital stock assuming this last hypothesis.

The examination of the Portuguese human capital stock evolution over these four decades highlights the remarkable pace of increase in the average years of education on the behalf of the Portuguese adult working-age population. From 1.4 average years of education in 1960, that reference group achieved 7.4 years of education by 2001. Notwithstanding the notable progress, it is important to note that the level is still well below the length corresponding to the present compulsory schooling level (9 years).

	1960–70	1971–80	1981–90	1991–2001
H (*average years of education*)	2.0	3.4	4.8	6.3

Table 1: Average years of education of the Portuguese working-age population (simple mean).

It is interesting to point out that this gradual increase in the stock of human capital was accompanied by substantial increases in returns to education, particularly after the mid-1980s (Hartog et al. 2001). Speculating on the causes behind the rise of the returns to education, Hartog et al. (2001) maintain that skill-based technological change seemed to be the chief explanation for a shift in the demand towards educated labour. This was primarily based on the fact that the shift in the use of more educated labour was due to changes taking place within the industries (consistent with technological change).

Comparison with other time series and cross-country estimates

Given the existence of other similar estimates for the Portuguese human capital stock, both based on time series (Pina and St Aubyn 2002; Pereira 2004) and cross-country data sets (Barro and Lee 2000; Cohen and Soto 2001; de la Fuente and Doménech 2002), it seems important to present and discuss the corresponding comparable figures.[3]

3 Pereira (2004) presents a similar but slightly more comprehensive comparison by computing the reliability ratios for the whole alternative estimates using Krueger and Lindahl (2000) approach.

4 In spite of this shortcoming, Pereira (2004) computed and presented the reliability ratios for both time series and cross-country estimates.

	Time series (continuous)			Cross-country (five or ten-year period)		
	Teixeira	Pereira (2004)	Pina and St Aubyn (2002)	Barro and Lee (2000)	Cohen and Soto (2001)	De la Fuente and Domenéch (2002)
1960	**1.36**	2.24		1.94	3.15	4.37
1965	**2.01**	2.55		2.24		4.62
1970	**2.74**	3.05		2.44	4.11	4.87
1975	**3.24**	3.54		2.79		5.29
1980	**3.91**	4.26	4.29	3.27	5.57	5.73
1985	**4.69**	4.91	5.03	3.57		6.06
1990	**5.15**	5.61	5.61	4.33	5.91	6.41
1995	**5.90**	6.52	6.60	4.54		
2000	**7.19**	7.31	7.47	4.91	7.28	

Table 2: Comparison between the estimated human capital stock and other time series (national) and cross-country (international) estimations.

Notes: Population groups vary as follows. Teixeira, Pina and St Aubyn (2002), Barro and Lee (2000) and de la Fuente and Doménech (2002) cover the population aged 25 years old and over; Pereira (2004) and Cohen and Soto (2001) cover the population aged 15–64 years old.

In the first stage, and in order to assess the main differences between our results and similar figures obtained in other frequently used cross-country data sets, we compiled the available estimates for the human capital stock with reference to Portugal.

Comparing with other time series estimates (Pina and St Aubyn 2002; Pereira 2004), our measure presents smaller figures, particularly in the initial periods. Notwithstanding this, as we can see in Table 3, the Pearson linear correlation coefficient is rather high between these three measurement procedures, nearby the condition of perfect correlation.

Regarding the parallel between our measure and those based on cross-country estimates, our proxy seems much more similar in levels to that of Barro and Lee (2000), at least for the period 1960–85. Beyond 1985, the corresponding estimates are rather distinct, with Barro and Lee's figures abnormally low. This departure is corroborated by correlation figures with our measure presenting the lowest correlation (although still high, 0.985) with Barro and Lee.

It is appealing in that the fact that, despite some relevant methodological differences, Cohen and Soto's and de la Fuente and Doménech's estimates present the highest correlation with our human capital stock proxy.

Using the reliability ratios presented in Crueller and Lindahl (2000) we can further discuss the relative advantages of the above-mentioned human capital stock proxies. We limit this analysis to time series estimates because, in the case of cross-country data, the amount of observations available does not permit us to carry out a serious comparative exercise of the respective reliability.[4]

The reliability ratio of an imperfect measure of average years of schooling, S^1 ($R1$) is computed as the ratio of the covariance between S^1 and an alternative imperfect measure S^2 to the variance of S^1. Formally,

		Time series (continuous)			Cross-country (five or ten-year period)		
		Teixeira	Pereira (2004)	Pina and St Aubyn (2002)	Barro and Lee (2000)	Cohen and Soto (2001)	de la Fuente and Domenéch (2002)
Time series	**Teixeira**		0.994	0.992	0.985	**0.986**	**0.997**
	Pereira (2004)			**0.999**	**0.993**	0.979	0.997
	Pina and St Aubyn (2002)				0.965	0.972	0.996
Cross-country	Barro and Lee (2000)					0.971	**0.988**
	Cohen and Soto (2001)						0.977

Table 3: Comparison between the estimated human capital stock and other time series (national) and cross-country (international) estimations - Pearson linear correlation coefficient.

Notes: Population groups vary as follows. Teixeira, Pina and St Aubyn (2002), Barro and Lee (2000) and de la Fuente and Doménech (2002) cover the population aged 25 years old and over; Pereira (2004) and Cohen and Soto (2001) cover the population aged 15–64 years old.

$$R_1 = \frac{Cov(S^1, S^2)}{Var(S^1)} \quad (8)$$

where
$S^1_j = S^*_j + e^1_j$
$S^2_j = S^*_j + e^2_j$
Being S^* is the true schooling and e the measurement error.

The computation of the reliability ratio assumes that e^1 and e^2 are uncorrected. This assumption is, however, very demanding because, in the case of the alternative time series estimates presented here, the corresponding measurement errors are likely to be correlated given that, to some extent, they rely on the same mismeasured enrollment data. Consequently, the reliability ratios derived from comparing such measures probably provide an upper boundary on the reliability of the data series (Krueger and Lindahl 2000).

The time series data have considerable signal, with the reliability ratio exceeding 0.90 for all data (excluding Pereira, which presents correlated error terms relative to Teixeira). This suggests that above 90 per cent of the variability in observed average years of education in the different data sets represent true levels. However, considering differences instead of levels, reliability ratios suffer a significant fall, particularly in Teixeira and Pina and St Aubyn when referred to Pereira. In changes, Pereira's data convey more signal than the other two measures of human capital stock. Indeed, between 25 per cent and 73 per cent of the variability in observed changes in years of education in Pereira's data represent true changes. For

Estimated time series in	Teixeira's reliability ratio (S^1)		Pereira's (2004) reliability ratio (S^1)		Pina and St Aubyn's (2002) reliability ratio (S^1)	
	S^2=Pereira	S^2=Pina and St Aubyn	S^2=Teixeira	S^2= Pina and St Aubyn	S^2=Teixeira	S^2=Pereira
Levels	0.906	0.923	*	0.953	**0.973**	0.962
Differences	0.096	0.158	**0.733**	0.253	0.529	0.037

Table 4: Comparison between the estimated human capital stock and other time series estimates - Krueger and Lindahl's reliability ratios.

** Violates classical assumptions. The reliability ratio is above 1.*

Teixeira the corresponding figures are 9.6 per cent and 15.8 per cent and in the case of Pina and St Aubyn, 3.7 per cent and 52.9 per cent.

Results based on reliability ratios suggest that Pereira's data might constitute a preferable proxy for the average years of education of the Portuguese working-age population. Yet, given the high likelihood of those three data series presenting correlated measurement errors and the fact that the Pearson linear correlation coefficients are very high for the whole set of data series, the relative performance and validity of these three proxies have to be tested against growth regression exercises.

Conclusion

This article aimed at providing an update up to 2001 of the stock of human capital for the Portuguese economy. With that it seeks to stimulate works on long-term economic growth and to endorse further investigation on the alternative roles of human capital on economic long-term dynamics.

The review of the different measures for the stock of human capital used in empirical growth research revealed that human capital is mostly poorly 'operationalized', being the choice of the human capital proxy/indicator hardly reflected upon and dependent very much on data availability.

Notwithstanding the increasing considerable work in improving international measures of human capital data, with the emergence of income-based human capital measures, measures which account for quality such as international test scores and those that account for different components of human capital such as the international adult literacy surveys, educational attainment still provides the best available information about the amount of human capital stock for a broad number of countries and for a country over a period of time.

The inspection of the evolution of the updated Portuguese human capital stock over the last four decades draws attention to its noteworthy rate of growth. In fact, from a meagre 1.4 average years of education, the Portuguese working-age population accomplished, by 2001, 7.4 years of education. Albeit the prominent progress, that level is still well below the length of the currently compulsory schooling level (9 years).

The exercise of comparing our human capital measure with other recent proxies revealed a rather high correlation (well above 0.90) among these measures. Nevertheless, results based on reliability ratios seem to give more credit to Pereira's (2004) data indicating that it might constitute a preferable proxy for the average years of education of the Portuguese working-age population. But reliability ratio computations are pervaded with classical assumption violations, which weaken the results achieved.

In our opinion, a more definitive comparison of the relative merits of the different proxies requires their use and appraisal in empirical growth regression estimations. This is simultaneously a challenge and a pathway for further research.

Appendices: Tables A1–A4

Table A1: Estimation, by perpetual-inventory method, of the fraction (*h*) of the Portuguese working age population attaining a given education level *i* (*i*=1 for primary; 2 for secondary; 3 for higher)

Year	*Enrolment ratios*				*Census data*			*From 1960*			*From 1970*			*From 1981*			*From 1991*			*From 2001*		
	PRI(t-15)	*SEC(t-10)*	*HIGH(t-5)*	*L25(t)/L(t)*	*h1*	*h2*	*h3*	*^h1*	*^h2*	*^h3*	*^h1*	*^h2*	*^h3*	*^h1*	*^h2*	*^h3*	*^h1*	*^h2*	*^h3*	*^h1*	*^h2*	*^h3*
1960	**0.852**	**0.071**	**0.023**	**0.139**	**0.228**	**0.033**	**0.010**	**0.228**	**0.033**	**0.010**	**0.307**	**0.079**	**0.012**									
1961	0.872	0.071	0.024	0.138										0.245	0.099	0.035	0.092	0.136	0.060	-0.257	0.674	0.187
1962	0.872	0.074	0.025	0.137																		
1963	0.908	0.076	0.026	0.135																		
1964	0.911	0.083	0.028	0.133																		
1965	0.964	0.089	0.031	0.132				0.313	0.037	0.013	0.382	0.076	0.015									
1966	1.003	0.099	0.035	0.130										0.331	0.095	0.035	0.198	0.127	0.057	-0.257	0.581	0.166
1967	1.045	0.110	0.037	0.129																		
1968	1.190	0.114	0.039	0.127																		
1969	1.240	0.137	0.041	0.126																		
1970	**1.260**	**0.153**	**0.043**	**0.108**	**0.460**	**0.080**	**0.018**	**0.399**	**0.044**	**0.016**	**0.460**	**0.080**	**0.018**									
1971	1.278	0.170	0.046	0.108										0.415	0.098	0.036	0.297	0.127	0.056	-0.265	0.503	0.152
1972	1.291	0.184	0.048	0.112																		
1973	1.297	0.202	0.052	0.112																		
1974	1.297	0.217	0.056	0.115																		
1975	1.279	0.229	0.063	0.118				0.476	0.059	0.021	0.496	0.076	0.021									
1976	1.299	0.240	0.067	0.128										0.498	0.107	0.040	0.394	0.133	0.057	-0.151	0.453	0.138
1977	1.286	0.248	0.071	0.132																		
1978	1.275	0.257	0.071	0.133																		
1979	1.259	0.277	0.077	0.134																		
1980	1.260	0.318	0.071	0.136				0.539	0.084	0.028	0.539	0.078	0.027									
1981	**1.246**	**0.347**	**0.085**	**0.119**	**0.546**	**0.126**	**0.045**							**0.546**	**0.126**	**0.045**	**0.455**	**0.148**	**0.060**	**-0.038**	**0.401**	**0.130**
1982	1.235	0.376	0.097	0.121																		
1983	1.242	0.424	0.092	0.123																		
1984	1.308	0.473	0.086	0.124																		
1985	1.459	0.465	0.083	0.126				0.597	0.122	0.035	0.601	0.088	0.032									
1986	1.494	0.512	0.092	0.128										0.609	0.129	0.051	0.522	0.183	0.064	0.114	0.367	0.124
1987	1.518	0.531	0.091	0.129																		
1988	1.511	0.562	0.094	0.129																		
1989	1.492	0.514	0.094	0.131																		
1990	1.400	0.560	0.106	0.131				0.629	0.165	0.044	0.648	0.107	0.039									
1991	**1.298**	**0.599**	**0.096**	**0.117**	**0.543**	**0.220**	**0.068**							**0.649**	**0.144**	**0.055**	**0.543**	**0.220**	**0.068**	**0.240**	**0.338**	**0.120**
1992	1.304	0.620	0.098	0.117																		
1993	1.340	0.675	0.097	0.116																		
1994	1.419	0.695	0.121	0.115																		
1995	1.369	0.712	0.134	0.114				0.648	0.188	0.051	0.665	0.136	0.046									
1996	1.377	0.754	0.161	0.114										0.659	0.175	0.060	0.590	0.243	0.071	0.364	0.327	0.117
1997	1.380	0.730	0.222	0.115																		
1998	1.395	0.726	0.244	0.114																		
1999	1.404	0.789	0.265	0.114																		
2000	1.384	0.860	0.284	0.114				0.676	0.215	0.061	0.692	0.169	0.056									
2001	**1.316**	**0.892**	**0.311**	**0.115**	**0.425**	**0.340**	**0.122**							**0.686**	**0.206**	**0.072**	**0.606**	**0.265**	**0.082**	**0.425**	**0.340**	**0.122**

Table A1 Notes:

L_t: population aged 25 and over at time t; $L25_t$: population aged [25, 29] at time t. It represents those who entered into the overall population aged 25 and above, during the last five years.

$h_{jt} = \frac{H_{jt}}{L_t}$ *: proportion of the adult population for whom j is the highest level of educational attainment [j: total primary (1), total secondary (2) and higher/tertiary (3)].*

PRI_{t-15}: the gross enrollment ratio for primary school observed 15 years ago;

SEC_{t-10}: the gross enrollment ratio for secondary school observed 10 years ago;

HIG_{t-5}: the gross enrollment ratio for higher school observed 5 years ago.

$$h_{1,t} = \left(1 - \frac{L25_t}{L_t}\right) \cdot h_{1,t-5} + \frac{L25_t}{L_t} \cdot \left(PRI_{t-15} - HIG_{t-10}\right); \; h_{2,t} = \left(1 - \frac{L25_t}{L_t}\right) \cdot h_{2,t-5} + \frac{L25_t}{L_t} \cdot \left(SEC_{t-10} - HIG_{t-5}\right); \; h_{3,t} = \left(1 - \frac{L25_t}{L_t}\right) \cdot h_{3,t-5} + \frac{L25_t}{L_t} \cdot \left(HIG_{t-5}\right)$$

Table A2: OLS estimation of the missing cases

Year	PS	SS	S	LL	lnPS	lnSS	lnS	lnLL	^lnh1	^h1	^lnh2	^h2	^lnh3	^h3
1960	0.781	0.048	0.023	0.139	-0.247	-3.042	-3.772	-1.974	-1.003	0.367	-3.175	0.042	-4.450	0.012
1961	0.800	0.047	0.024	0.138	-0.223	-3.055	-3.725	-1.980	-0.987	0.373	-3.180	0.042	-4.405	0.012
1962	0.799	0.049	0.025	0.137	-0.225	-3.019	-3.693	-1.991	-0.970	0.379	-3.147	0.043	-4.377	0.013
1963	0.832	0.050	0.026	0.135	-0.184	-2.987	-3.654	-2.003	-0.940	0.391	-3.116	0.044	-4.343	0.013
1964	0.828	0.055	0.028	0.133	-0.188	-2.899	-3.581	-2.014	-0.924	0.397	-3.046	0.048	-4.273	0.014
1965	0.875	0.057	0.031	0.132	-0.133	-2.859	-3.459	-2.026	-0.890	0.411	-3.009	0.049	-4.152	0.016
1966	0.904	0.064	0.035	0.130	-0.101	-2.745	-3.362	-2.038	-0.862	0.423	-2.921	0.054	-4.058	0.017
1967	0.935	0.073	0.037	0.129	-0.067	-2.616	-3.303	-2.051	-0.832	0.435	-2.821	0.060	-4.004	0.018
1968	1.076	0.075	0.039	0.127	0.073	-2.590	-3.254	-2.062	-0.774	0.461	-2.794	0.061	-3.959	0.019
1969	1.103	0.095	0.041	0.126	0.098	-2.349	-3.185	-2.075	-0.748	0.473	-2.617	0.073	-3.893	0.020
1970	1.107	0.109	0.043	0.108	0.102	-2.212	-3.138	-2.225	-0.510	0.600	-2.412	0.090	-3.917	0.020
1971	1.109	0.123	0.046	0.108	0.103	-2.094	-3.070	-2.225	-0.510	0.600	-2.329	0.097	-3.847	0.021
1972	1.107	0.136	0.048	0.112	0.102	-1.995	-3.034	-2.187	-0.570	0.566	-2.287	0.102	-3.792	0.023
1973	1.095	0.151	0.052	0.112	0.091	-1.893	-2.966	-2.187	-0.573	0.564	-2.215	0.109	-3.721	0.024
1974	1.080	0.161	0.056	0.115	0.077	-1.827	-2.887	-2.165	-0.611	0.543	-2.185	0.113	-3.630	0.027
1975	1.050	0.167	0.063	0.118	0.049	-1.792	-2.769	-2.135	-0.667	0.513	-2.182	0.113	-3.494	0.030
1976	1.059	0.173	0.067	0.128	0.057	-1.754	-2.701	-2.053	-0.794	0.452	-2.214	0.109	-3.384	0.034
1977	1.038	0.177	0.071	0.132	0.037	-1.729	-2.649	-2.028	-0.838	0.433	-2.214	0.109	-3.318	0.036
1978	1.018	0.186	0.071	0.133	0.018	-1.684	-2.642	-2.016	-0.863	0.422	-2.192	0.112	-3.305	0.037
1979	0.982	0.200	0.077	0.134	-0.019	-1.608	-2.567	-2.011	-0.882	0.414	-2.142	0.117	-3.225	0.040
1980	0.943	0.246	0.071	0.136	-0.059	-1.401	-2.639	-1.997	-0.914	0.401	-2.007	0.134	-3.293	0.037
1981	0.899	0.261	0.085	0.119	-0.106	-1.341	-2.464	-2.126	-0.725	0.484	-1.872	0.154	-3.174	0.042
1982	0.859	0.279	0.097	0.121	-0.152	-1.276	-2.336	-2.112	-0.759	0.468	-1.836	0.159	-3.036	0.048
1983	0.818	0.331	0.092	0.123	-0.201	-1.105	-2.383	-2.096	-0.797	0.451	-1.727	0.178	-3.077	0.046
1984	0.835	0.387	0.086	0.124	-0.180	-0.950	-2.453	-2.086	-0.808	0.446	-1.626	0.197	-3.144	0.043
1985	0.994	0.383	0.083	0.126	-0.006	-0.961	-2.492	-2.072	-0.782	0.458	-1.644	0.193	-3.177	0.042
1986	0.981	0.421	0.092	0.128	-0.019	-0.866	-2.390	-2.054	-0.813	0.443	-1.590	0.204	-3.064	0.047
1987	0.987	0.440	0.091	0.129	-0.013	-0.821	-2.398	-2.047	-0.822	0.440	-1.563	0.209	-3.069	0.046
1988	0.949	0.468	0.094	0.129	-0.052	-0.759	-2.366	-2.047	-0.833	0.435	-1.520	0.219	-3.036	0.048
1989	0.978	0.420	0.094	0.131	-0.022	-0.868	-2.363	-2.032	-0.849	0.428	-1.607	0.200	-3.025	0.049
1990	0.840	0.454	0.106	0.131	-0.174	-0.789	-2.248	-2.032	-0.891	0.410	-1.551	0.212	-2.907	0.055
1991	0.699	0.503	0.096	0.117	-0.359	-0.686	-2.346	-2.148	-0.760	0.468	-1.397	0.247	-3.063	0.047
1992	0.684	0.522	0.098	0.117	-0.380	-0.650	-2.321	-2.145	-0.770	0.463	-1.373	0.253	-3.036	0.048
1993	0.665	0.578	0.097	0.116	-0.409	-0.549	-2.330	-2.150	-0.770	0.463	-1.298	0.273	-3.048	0.047
1994	0.724	0.574	0.121	0.115	-0.322	-0.555	-2.113	-2.163	-0.727	0.484	-1.294	0.274	-2.830	0.059
1995	0.657	0.578	0.134	0.114	-0.420	-0.548	-2.013	-2.168	-0.746	0.474	-1.285	0.277	-2.730	0.065
1996	0.624	0.593	0.161	0.114	-0.472	-0.523	-1.826	-2.168	-0.759	0.468	-1.267	0.282	-2.537	0.079
1997	0.649	0.509	0.222	0.115	-0.432	-0.676	-1.507	-2.166	-0.751	0.472	-1.376	0.253	-2.207	0.110
1998	0.669	0.482	0.244	0.114	-0.403	-0.729	-1.411	-2.169	-0.739	0.477	-1.411	0.244	-2.109	0.121
1999	0.615	0.524	0.265	0.114	-0.487	-0.646	-1.329	-2.168	-0.763	0.466	-1.353	0.258	-2.025	0.132
2000	0.524	0.576	0.284	0.114	-0.646	-0.552	-1.257	-2.173	-0.800	0.449	-1.284	0.277	-1.953	0.142
2001	0.425	0.581	0.311	0.115	-0.857	-0.543	-1.168	-2.162	-0.876	0.416	-1.286	0.276	-1.855	0.156

Table A2 Notes: Estimates were calculated using the following regressions:

$$\ln h_{1,t} = -48{,}506 - 0{,}309 \ln LL + 0{,}854 \ln PS + 0{,}024t + e_{1,t} \; ; \ln h_{2,t} = -2{,}461 - 0{,}720 \ln LL + 0{,}702 \ln SH + e_{2,t} \; ; \ln h_{3,t} = 0{,}382 + 0{,}478 \ln LL + 1{,}031 \ln H + e_{3,t}$$

Table A3: Conclusion ratios by educational level

Year	CRPRIM	CRSEC	CRHIGH
1960	0.625	0.395	0.600
1961	0.625	0.395	0.600
1962	0.625	0.395	0.600
1963	0.625	0.395	0.600
1964	0.625	0.395	0.600
1965	0.625	0.395	0.600
1966	0.625	0.395	0.600
1967	0.625	0.395	0.600
1968	0.625	0.395	0.600
1969	0.625	0.395	0.600
1970	0.625	0.395	0.600
1971	0.630	0.411	0.621
1972	0.635	0.428	0.642
1973	0.640	0.445	0.664
1974	0.645	0.464	0.687
1975	0.650	0.483	0.710
1976	0.655	0.502	0.734
1977	0.660	0.523	0.759
1978	0.665	0.544	0.786
1979	0.670	0.567	0.812
1980	0.676	0.590	0.840
1981	0.681	0.614	0.869
1982	0.685	0.618	0.872
1983	0.689	0.621	0.875
1984	0.693	0.625	0.878
1985	0.697	0.629	0.881
1986	0.701	0.633	0.884
1987	0.705	0.637	0.887
1988	0.709	0.640	0.890
1989	0.714	0.644	0.893
1990	0.718	0.648	0.896
1991	0.722	0.652	0.899
1992	0.726	0.655	0.904
1993	0.730	0.657	0.900
1994	0.734	0.660	0.897
1995	0.738	0.662	0.894
1996	0.742	0.665	0.890
1997	0.746	0.667	0.887
1998	0.750	0.670	0.883
1999	0.754	0.672	0.880
2000	0.759	0.675	0.877
2001	0.763	0.678	0.865

Table A3 Notes:
CRPRIM: primary conclusion ratios; CRSEC: secondary conclusion ratios; CRHIGH: higher education conclusion ratios. In the computation of the conclusion ratios, census data (1970, 1981, 1991 and 2001) are the benchmarking figures. We further assume that these ratios varied uniformly over time, that is, for each year we apply the average annual change rates. The absence of data for the 1960–69 period forced us to presuppose that conclusion ratios assumed 1970's values.

Table A4: Estimates of the Portuguese human capital stock - average years of schooling of the Portuguese adult working age population

Year	H	H'	H''	H'''
1960	1.623	1.337	1.286	1.362
1961	1.729	1.425	1.374	1.450
1962	1.863	1.534	1.482	1.560
1963	2.009	1.653	1.599	1.680
1964	2.200	1.810	1.752	1.838
1965	2.403	1.978	1.919	2.008
1966	2.544	2.096	2.030	2.128
1967	2.690	2.215	2.143	2.251
1968	2.787	2.295	2.221	2.332
1969	3.018	2.484	2.395	2.528
1970	3.276	2.690	2.581	2.744
1971	3.423	2.823	2.708	2.880
1972	3.523	2.919	2.803	2.978
1973	3.672	3.058	2.937	3.119
1974	3.783	3.169	3.048	3.229
1975	3.886	3.279	3.162	3.337
1976	3.913	3.325	3.216	3.379
1977	3.994	3.414	3.310	3.467
1978	4.074	3.500	3.398	3.551
1979	4.239	3.664	3.563	3.715
1980	4.439	3.851	3.741	3.906
1981	4.781	4.179	4.061	4.239
1982	4.960	4.354	4.232	4.415
1983	5.144	4.518	4.383	4.585
1984	5.316	4.671	4.523	4.744
1985	5.248	4.616	4.473	4.688
1986	5.466	4.825	4.675	4.899
1987	5.527	4.886	4.733	4.962
1988	5.665	5.018	4.861	5.097
1989	5.453	4.841	4.698	4.912
1990	5.700	5.078	4.928	5.152
1991	5.982	5.322	5.150	5.408
1992	6.024	5.369	5.194	5.457
1993	6.198	5.530	5.343	5.624
1994	6.370	5.710	5.524	5.804
1995	6.463	5.811	5.624	5.904
1996	7.132	6.422	6.202	6.532
1997	7.263	6.559	6.339	6.668
1998	7.411	6.713	6.493	6.822
1999	7.579	6.886	6.666	6.996
2000	7.770	7.080	6.861	7.190
2001	7.985	7.296	7.076	7.405

Table A4 Notes:

H, *we do not distinguish complete from incomplete levels.*

H' *considers that the individuals that do not complete any of the three education levels achieved at least half of the years [of education] officially required.*

$$H' = 4 \times \left(\frac{hpi}{2} + hpc \right) + \left(4 + \frac{8}{2} \right) \times hsi + (4 + 8) \times hsc + \left(4 + 8 + \frac{6}{2} \right) \times hhigi + (4 + 8 + 6) \times hhigc$$

H'' *the same as* H' *but considers as incomplete secondary education those individuals that do not go further than the first cycle of lower secondary school.*

$$H'' = 4 \times \left(\frac{hpi}{2} + hpc \right) + (4 + 2) \times hsi + (4 + 8) \times hsc + \left(4 + 8 + \frac{6}{2} \right) \times hhigi + (4 + 8 + 6) \times hhigc$$

H''' *as* H'' *but now the relevant length is the second cycle of lower secondary school, i.e. the compulsory education level for Portuguese education system).*

$$H''' = 4 \times \left(\frac{hpi}{2} + hpc \right) + (4 + 5) \times hsi + (4 + 8) \times hsc + \left(4 + 8 + \frac{6}{2} \right) \times hhigi + (4 + 8 + 6) \times hhigc$$

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Suggested citation:

Teixeira, A.A.C. (2005), 'Measuring aggregate human capital in Portugal: 1960–2001', *Portuguese Journal of Social Science* 4: 2, pp. 101–120, doi: 10.1386/pjss.4.2.101/1

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