Tim Leunig and Hans-Joachim Voth

Smallpox did reduce height : a reply to our critics

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Smallpox did reduce height: a reply to our critics

Timothy Leunig and Hans-Joachim Voth [1]

Royal Holloway College, University of London

Stanford University.

Between them our critics span the entire range of this *Journal's* readership. On the one hand Razzell accuses us of 'the abandonment of traditional scholarly procedures'.[2] He argues that our plight 'will provide a salutary lesson for the new economic history. No amount of sophisticated statistical analysis will provide a substitute for careful study of original sources.'[3] In contrast, Heintel and Baten use far more sophisticated statistical techniques - including a continuous kernel density estimator and truncation point estimators - in an attempt to justify their claim that our 'conclusions are without empirical or statistical foundation.'[4] Because these two comments are so totally different we will look at each in turn.

I

A close reading of Peter Razzell's thoughtful comment reveals that he is - on the key points at least - in agreement with us. He agrees with us that smallpox was historically important, stating that 'Voth and Leunig have rightly pointed out the serious consequences of smallpox'.[5] He goes on to agree that our hypothesis is a good one, arguing that 'The authors are therefore undoubtedly correct in highlighting the possible significance of smallpox for average height.'[6] And for all his concern about methodology, he does not suggest that there is an alternative way to test this hypothesis except to use the tools of new economic history. Having investigated his specific objections to our work, we are confident, therefore, that this paper will convince him that our central conclusion, that smallpox reduced attained heights by around one inch, is correct.

Razzell's concerns stem from the reporting methods used by the Marine Society itself. As he states, 'it should be emphasised that "no smallpox" is a residual category, in that it is the absence of a marking for smallpox (the letter "P") that is the basis of the coding for this category.'[7] He is therefore right to suggest that the employment of negligent or hasty recruiting officers would almost certainly lead to some people being listed in the original records as not having had smallpox, even if they had in fact suffered from the disease. Similarly some boys must have been recorded as being unable to read and write, even if they could, in fact, do both. We would not want to dispute that such incidences must have taken place in the long history of the Marine Society.

Razzell assumes that such negligent recording of the characteristics of recruits must have been carried over to the Floud, Wachter and Gregory Marine Society dataset, which was the basis for our study.[8] On that basis, he then concludes that 'the great majority of Voth and Leunig's "no smallpox" cases probably consist of entries on blank column pages',[9] that is, pages in which all boys are (negatively) recorded as having avoided smallpox, as well as being listed as unable to both read and write.

The data show quite clearly that such a claim is false: rather than a 'great majority', only 38.7 percent of those recorded as having avoided smallpox are also coded as being illiterate.

We do not find it at all improbable that 38.7 percent of one of the nation's most deprived groups should have been illiterate.[10]

That is not to claim, of course, that the dataset is entirely devoid of the influence of negligent recruiting officers. Whilst 88.6% of those who were (positively) recorded as being literate were also (positively) recorded as having suffered smallpox, only 86.8% of those who were (negatively) recorded as being illiterate were coded as having had the disease. Although this difference is statistically significant,[11] it is also historically trifling: it implies that of the 26,359 boys in the dataset as a whole, just 169 are wrongly coded as having escaped smallpox, a mis-coding rate of 0.64%. It is clear that Floud et al have done an extremely impressive job in preventing the type of error found by Razzell in the original records from contaminating the computerised dataset.

Razzell claims that data problems 'are so fundamental, that a re-examination of their central conclusions is necessary.'[12] We have shown that the data problems are in fact trivial. Nevertheless, we can re-analyse our dataset to show that mis-coding 1 in 156 boys makes no difference whatsoever to our results. Razzell himself notes that, 'the genuine cases of "no smallpox" can be recognised by their occurrence on pages with some entries in the "Reads or Writes/Spox" column.'[13] Although the computerised dataset does not give the information in original page format, we are able to restrict our attention - and our regressions - to those boys who we know were recruited by conscientious recruiting officers, that is, to those boys who are positively recorded as being able to read, write, or both. By definition, this sample excludes all those cases unacceptable to Razzell. We look first at the full sample. Regressions 1 and 2 are reproduced exactly from Voth and Leunig 1996, while regressions 1A and 2A are identical except that the sample is restricted to the literate. None of our results are affected.

The magnitude of the smallpox variable does not change. While, inevitably, the t-statistics decline with the fall in sample size, the coefficients on smallpox remains statistically significant at the 99.9% level of probability, and the overall explanatory power of our two models is not affected.

Table 1 *The determinants of height, full sample*

	1	1A	2	2A
Smallpox	-0.95	-0.96	-0.96	-0.99
	(-16.1)	(-11.3)	(-16.7)	(-12.0)
Ageyears	1.76	1.77		
	(166.4)	(131.0)		
Age14			2.30	2.26
			(58.8)	(13.4)
Age15			4.38	4.34
			(109.9)	(86.2)
Age 16			6.39	6.37
			(132.8)	(106.3)
Age17			7.61	7.63

			(112.1)	(88.7)
Age 18			8.11	8.12
			(74.8)	(57.9)
Age 19			8.61	8.47
			(46.7)	(34.5)
Age20plus			8.66	8.79
			(23.1)	(19.2)
Read	0.29	0.12	0.28	0.10
	(7.1)	(0.7)	(7.3)	(0.6)
Write	0.61	0.58	0.56	0.53
	(15.4)	(14.2)	(14.6)	(13.4)
Living	0.091	0.095	0.080	0.084
	(50.2)	(39.5)	(44.9)	(35.5)
Intercept	20.54	20.16	44.06	43.85
	(78.8)	(52.0)	(198.4)	(125.4)
adj. R^2	0.613	0.610	0.638	0.634
S.E.	2.38	2.40	2.30	2.33

F	8,360.1	5,350.4	4,220.2	2,681.6
N	26,359	17,060	26,359	17,060
of which, with smallpox	23,182	15,113	23,182	15,113
without smallpox	3,177	1,947	3,177	1,947

Note: t-statistics are given in parentheses. The estimation technique is OLS

We can apply the same procedure to our sample of boys recruited between 1770-75, a period in which there were no changes in the minimum height requirement, and no possibility that the smallpox variable could be capturing contemporaneous changes in the standard of living. Again, regressions 3 and 4 give our original estimates, while equations 3A and 4A are the re-estimates of these equations based only on those who were positively recorded as literate. Once more, both the coefficients on smallpox and the overall power of the models remain unaffected. Again, the t-statistic on smallpox falls - significant now at the 8 and 6 percent levels respectively - a function of the decline in the sample size to levels we would not generally use.

Table 2 *The determinants of height, 1770-75 (year of recruitment)*

	3	3A	4	4A
Smallpox	-0.52	-0.53	-0.56	-0.57
	(-2.7)	(-1.7)	(-2.9)	(-1.9)
Ageyears	1.44	1.41		

	(26.9)	(19.5)		
Age14			1.70	1.41
			(9.0)	(5.5)
Age15			3.78	3.71
			(17.0)	(12.2)
Age 16			5.16	4.81
			(20.0)	(14.1)
Age17			5.76	5.576
			(15.2)	(9.8)
Age 18			6.41	6.86
			(10.7)	(7.7)
Age 19			7.24	6.96
			(11.7)	(8.8)
Age20plus			10.6	11.1
			(7.8)	(6.8)
Read	0.04	3.50	0.02	3.31
	(0.2)	(1.5)	(0.1)	(1.4)

Write	0.41	0.44	0.42	0.44
	(1.9)	(2.1)	(2.0)	(2.1)
Intercept	34.41	31.30	52.86	49.71
	(42.9)	(12.1)	(247.4)	(21.1)
adj. R^2	0.432	0.430	0.450	0.448
S.E.	2.37	2.34	2.33	2.31
F	189.4	99.5	82.1	43.5
N	991	524	991	524
of which, with smallpox	795	456	795	456
without smallpox	196	68	196	68

Note: t-statistics are given in parentheses. The estimation technique is OLS

In doing these tests we have taken Razzell's argument to its limit by assuming that every single boy who was recorded as both illiterate and having escaped smallpox was recruited by an incompetent recruiting officer, and accordingly we have excluded them from our analysis altogether. When we do this, the coefficient on smallpox does not change. These tests show that even were Razzell to be correct in his assertion that the computerised dataset contains the same errors as the original records, we would have no reason to change our conclusion that smallpox unambiguously reduced attained heights.

II

Heintel and Baten do not question the reliability of the Marine Society data. Rather, they suggest that, contrary to our findings, the data offer no evidence to suggest that recruits who had suffered from smallpox were shorter than those who had not. They claim that the data contradict our findings for at least three reasons. First, they argue that using the raw data to assess the modal height of any group of boys is unreliable, instead they tell the reader that a continuous biweight kernel density estimator is a better way to find the mode than looking at the data itself.[14] Second, they argue that a combination of marked social and economic change and changing minimum height requirements means that 'regression analysis over the entire period should not be undertaken'.[15] Finally, they state that, in selecting the period we used for our cross-sectional regression, 'Voth and Leunig disregarded all periods in which their hypothesis is not confirmed.'[16] We shall show that these criticisms are misplaced.

Heintel and Baten claim that their concern that the sample will suffer from both left and right hand truncation, that is, too few very short or very tall people, leads them to use a continuous biweight kernel density estimator in order to estimate the mode.[17] This is not right. As we stated in our original article, we used the mode as our measure of average height precisely because it is the most robust measure of central tendency available, and in particular, it is not affected by left and right hand truncation, because 'it is not influenced by the "tails" of the distribution'.[18] So long as the modal boy was able to join the Marine Society - and neither Heintel and Baten nor anyone else have suggested anything to the contrary - the mode is an absolutely unbiased estimator of the average height of boys joining the Marine Society. There is no need and no advantage to using any form of estimator when the data already provides a simple and perfectly unbiased estimator of average heights.

In addition to rejecting our use of the mode, Heintel and Baten also object to our using the whole sample to assess whether those who suffered from smallpox were shorter than those who had not suffered from the disease. They claim that in producing graphs based on the entire dataset, 'Voth and Leunig were comparing two widely separated birth cohorts, assuming that the only difference between the two groups was their exposure to smallpox.'[19] Instead, they argue, we should have taken into account both changes in living standards and the general rise in the minimum height standard over the period.[20] This is precisely what we did, and we are puzzled that Heintel and Baten should think otherwise. At the very beginning of our discussion of the dataset we noted both that the 'official minimum height requirement imposed by the Marine Society and the strictness of its enforcement changed over time.'[21] Immediately after plotting the heights of the full sample, we noted that 'the number of recruits affected by smallpox in our group varies considerably from decade to decade. In particular, as figure six shows, the disease was more prevalent during the first part of the period. Those who suffered from smallpox may have been shorter not only because they had survived a severe illness, but because they were also born in an earlier period, and so experienced a lower standard of living.'[22] Figure six charted the percentage of recruits who had experienced smallpox over time. To claim that we were unaware of either the changes in minimum height standards, or the dramatic changes in the standard of living in this period is not correct. Nor can we be accused of ignoring their effects, for we devoted the rest of our article to overcoming them. As we stated in that article, we use two methods to overcome any problem that smallpox may be acting as a proxy for a century in which the standard of living changed dramatically. First, we estimate a regression 'controlling for the standard of living'.[23] Having obtained these results, we noted that 'this result can be tested by using cross-sectional analysis. This not only eliminates the possibility that the changing incidence of smallpox is capturing contemporaneous changes in the standard of living or other, unobserved, factors, but by using a period in which there are no changes in the official minimum height standard, we are able to avoid the problem of changing truncation bias.'[24]

Heintel and Baten do not accept that our full-sample regression answers their concerns. In particular, they offer three criticisms.[25] First, they claim that the regression residual is always correlated with the co-variates, but they offer no evidence to back up this statement.

Second, they claim that changing minimum height requirements mean that we needed 'to discard completely the part of the sample below the greatest of the minimum height requirements and to run a truncated OLS.'[26] Given that we are interested only in the difference in the modal heights of those who did and did not suffer from smallpox, rather than in the absolute heights of either groups, the issue of left hand truncation bias is unimportant, so long as the modal boy is unaffected by the minimum height standard, a condition that is fully satisfied.

Finally, Heintel and Baten state that Voth and Leunig 'omitted a trend variable in their regression, a regression which covers over 100 years of remarkable social and economic change.'[27] They are right to say that we omitted a time trend, for such a variable would imply not only 100 years of remarkable social and economic change, but 100 years of *remarkably linear* social and economic change. Such an assumption is historically wrong. Instead, we included a variable, 'living', which captured changes in the standard of living by averaging the Schwarz index of real wages in London over the two decades prior to recruitment. This variable is far superior to the time trend proposed by Heintel and Baten because it does not impose the assumption of linearity.

In order to justify their statement that ‘Voth and Leunig disregarded all periods in which their hypothesis is not confirmed’[28] Heintel and Baten divide the period into sub-periods, apply their continuous biweight kernel density estimator to each, and finally compare the heights of those who have and have not suffered smallpox. Of the seven sub-periods, they disregard four as having inadequate sample sizes. On the basis of the remaining three, they conclude that ‘contrary to Voth and Leunig’s assertions, the mode of the smallpox sample is as likely to be below the non smallpox sample as above.’[29] We have a number of objections to this exercise.

First, their choice of sub-periods is inappropriate. Throughout the rest of their comment, they repeatedly state that it is important to ensure that the minimum height standard is constant throughout the period under consideration.[30] In doing so, they are echoing our position: as we noted in our original article, ‘by using a period in which there are no changes in the official minimum height standard, we are able to avoid the problem of changing truncation bias.’[31] Despite this, four of their seven periods include changes in the minimum height standard[32]. This is unacceptable, for the reasons that we set out and they reiterated.

They quote results for the three sub-periods for which they claim that ‘both smallpox and non smallpox cases are available in large enough numbers’[33] to yield sound statistical results. They state that 30 observations are a ‘large enough’ sample,[34] although they fail to give individual sample sizes for each of their - impressively normal looking - graphs. In reality one example is sufficient to demonstrate that their results are the product of applying an unsuitable methodology to very small sample sizes.

Heintel and Baten’s graph 5b, the height of 16 year-olds, 1785-1799, claims to show that those who had suffered from smallpox were *taller* than those who had not had smallpox, is based on a sample of just 22 boys recorded as suffering from smallpox.[35] These 22 boys were born over a 15 year period, recruited under four different minimum height standards and varied in height by 11 inches - an average of just two boys per height category. This is a remarkably weak basis on which to draw any inference: reallocating only three boys is sufficient to reduce the modal height to 53 inches, the height of the shortest boy, or to raise it to 63 inches, the height of the tallest boy. In more formal statistical terms, the confidence intervals on Heintel and Baten’s estimated height of boys who had not suffered from smallpox are extremely broad. Tellingly Heintel and Baten do not give any indication of the confidence intervals for their graphs 2-5, offering only the point estimators.

Comparing the actual data with Heintel and Baten’s graph 5b shows that that the two graphs bear no obvious relation to each other, demonstrating how hard their biweight kernel density function has to work to generate their results.

Figure 1 Height of 16 years olds who have not suffered smallpox, 1785-1799 - actual data

note: these graphs are produced on identical scales

Figure 2 Height of 16 years olds who have not suffered smallpox, 1785-1799 - as estimated by Heintel and Baten.

So what is left of Heintel and Baten’s cross sectional analysis? Only two of their graphs are based on sample sizes of 100 or more - which, as we argued in our original paper, is the minimum number that can be relied on to yield sound results in this context. These two graphs, the heights of 13 and 14 year old boys born between 1770 and 1784, do not suffer from problems associated with changes in the minimum height standard. It is no coincidence that when Heintel and Baten look at these samples - their figures 2A and 3A - they find that the modal height of those people who had suffered from smallpox was less than the modal height of those who had not suffered from the disease. This shows that, even when an inappropriate smoothing technique is used, so long as the sample size is sufficiently large, and the period under investigation does not suffer from changing minimum height standards, the result is clear and unambiguous: smallpox reduced attained heights.

The use of biweight kernel density estimators and truncation point estimators are - at best - statistically unnecessary and unsuitable, and the use of sample sizes as low as 22 cannot be a reliable basis for inference. We therefore remain convinced that the Marine Society data show clearly and unambiguously that those boys who suffered from smallpox were shorter than those who did not. Similarly our best guess as to the height loss caused by suffering the disease as a child remains one inch.

III

By showing that smallpox reduced attained heights, this paper, like our previous one, should be seen as confirming that anthropometric history is useful for economic and social historians. Were it not to be the case that those who suffered one of the worst diseases in human history ended up stunted, we would be forced to question how well height acts as an aggregate measure of nutrition, disease, work intensity and other factors that make up the 'standard of living'.

We also argue that there is a second sense in which this reply strengthens the claims of anthropometric history within economic history. We have been able to show that the work of Floud, Wachter and Gregory - and their research assistants - in compiling the Marine Society dataset is of an extremely high standard. That dataset is a very sound basis on which to draw conclusions about the changing heights and standards of living of boys in London in the late eighteenth and nineteenth centuries. Equally, the statistical techniques that we employ demonstrate that anthropometric history, whilst very clearly part of the 'new' economic history, is not the exclusive preserve of those with higher degrees in statistics.

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Footnotes:

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[1] The authors would like to thank James Foreman-Peck, Robin Mason and Avner Offer for their help in writing this reply. As ever, the authors remain responsible for any errors.

[2] (Razzell, p. 9 top)

[3] (Razzell, p. 9 top) He goes on to argue that there are ‘Similar Problems’ in the work of Wrigley and Schofield. It is company that we are happy to keep. (Razzell, p. 9, top)

[4] (Heintel and Baten, p. 9, bottom)

[5] (Razzell, p. 1 top)

[6] (Razzell, p. 1 middle)

[7] (Razzell, p. 5, top)

[8] (Razzell, p. 7 bottom/ p. 8 top), ESRC SN 2134 (Long-term changes in nutrition, welfare and productivity in Britain: physical and socio-economic characteristics of boys recruited into the Marine Society, 1770-1873).

[9] (Razzell, p. 8 top)

[10] Indeed, even when we limit ourselves to those recruits known to have been recruited by conscientious officers - i.e. those positively recorded as having had smallpox - we find that 34.8% of boys were illiterate.

[11] We constructed a logit model to ask whether recorded information on literacy was a useful predictor of whether a boy had suffered from smallpox. Where S is a dummy variable set to one if the boy had had smallpox (and to zero otherwise), and L is a dummy variable for literacy set to one if the boy could read or write (and to zero otherwise), we find that:

$$\log (s/1\text{-}s) = 1.8 - 0.17L$$

0.17 is statistically different to 1, and has a large Wald statistic of 18.6

[12] (Razzell, p. 1, mid)

[13] (Razzell, p. 6, top)

[14] (Heintel and Baten, p. 2, top)

[15] (Heintel and Baten, p. 7, top)

[16] (Heintel and Baten, p. 5, bottom)

[17] (Heintel and Baten, p. 2, top). They also claim that their visual inspection revealed ‘other deviations from normality’, although they decline to tell the reader what these may be.

[18] Voth and Leunig, ‘Did smallpox reduce height?’, p. 552

[19] (Heintel and Baten, p. 3, top)

[20] (Heintel and Baten, p. 3, middle)

[21] Voth and Leunig, ‘Did smallpox reduce height?’, p. 544

[22] Voth and Leunig, ‘Did smallpox reduce height?’, p. 546

[23] Voth and Leunig, ‘Did smallpox reduce height?’, p. 547

[24] Voth and Leunig, ‘Did smallpox reduce height?’, p. 550

[25] (Heintel and Baten, p. 6, all)

[26] This is the methodology used by Komlos in recent articles in this Journal. For important criticisms of this technique, see Floud et al. (Heintel and Baten, p. 6 bottom), Komlos, *Secular Trend*, see also Komlos and Kim, *Estimating trends*, Floud, Wachter and Gregory, ‘Measuring historical heights’.

[27] (Heintel and Baten, p. 7, top)

[28] (Heintel and Baten, p. 5 bottom)

[29] (Heintel and Baten, p. 5, top)

[30] they raise the issue seven times. (Heintel and Baten, p. 1, bottom; p. 3, top; p. 4 ,top; p. 6, middle; p. 7, top; p. 8 top; p. 9, middle)

[31] Voth and Leunig, ‘Did smallpox reduce height?’, p. 550

[32] Their sub-periods contain as many as five different minimum height standards. They make no attempt to justify this, and note it only in a footnote: ‘the division into subsamples was

independent of the amount of shortfall [i.e. changes in the minimum height requirement].' Heintel and Baten p. 4 & footnote 15, Floud, Wachter and Gregory, *Height, Health and History*, p. 164

[33] (Heintel and Baten, p. 5 top)

[34] (Heintel and Baten, p. 4, footnote 16)

[35] all of their sub-periods have sufficiently large numbers of boys recorded as having suffered from the disease.