Statistics Commission

Report No. 22

Census and population estimates

and

The 2001 Census in Westminster: Final Report

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Report by the Statistics Commission

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Foreword

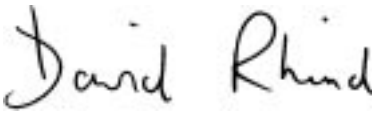
The decennial Census of Population has been the cornerstone of official statistics for generations. It has grown in cost and complexity as ever more has been demanded of it over the decades. The most recent UK Census, held in 2001, was a more sophisticated technical exercise than ever before and cost in excess of £250 million.

The Census provides a wide range of statistical information about people and households, for small geographical areas as well as at the national scale. In so doing, it supports local and national planning and enables reliable comparison between areas of the country – a key tool in the management of government policy. The count of the resident population also plays a critical role as a denominator in standard indicators such as 'GDP per head of population': these indicators drive regional policy and the allocation of European structural funds, and much else besides. It could be said that the Census provides a factual pivot around which social and economic policies develop, anchoring those policies to an underlying reality.

The 2001 Census was, in most respects and on the evidence available, a success. It produced robust local estimates across most of the UK. But for a relatively small number of areas, particularly some inner city ones, there is now evidence that the methods used were not equal to the challenges they faced. Substantial follow-up work has been required in these areas to produce revised, generally higher, estimates of the local population.

The Statistics Commission believes there are lessons to be learned for the future and this report seeks to draw these out. In the main these relate to England and Wales but some of our findings also pertain to Scotland and Northern Ireland. This report builds on the Commission's interim findings on the 2001 Census in Westminster published in October 2003. The report is in two parts: the first deals with what we have learned in general about Census and population estimates and the second is our final statement on the situation in Westminster, whose request for the advice of the Statistics Commission triggered our initial involvement. We are aware that government departments now have work in hand on some of the issues identified here but we hope that this report will help to draw attention to important issues and ensure further rapid progress.

The conclusions and recommendations in this report are those of the Statistics Commission alone. I would however like to acknowledge the help and advice of officials in the Office for National Statistics and other government departments who responded fully and openly to our many requests for information and also the contributions of many individuals and organisations who helped us to understand and weigh the evidence.



David Rhind, Chairman

PART 1

CENSUS AND POPULATION ESTIMATES:

AN OVERVIEW

Summary and recommendations

Introduction

It was well understood in the planning stages before the 2001 Census that the populations in some areas of the country, and some groups within the population, would be difficult to count. The resident populations of inner-city areas were one such group; it was anticipated that they might prove both hard to locate and hard to distinguish clearly from non-residents. The growing numbers of relatively mobile people – typically young men with less settled lifestyles – were another 'hard to count' group. A change in the definition of 'resident' for Census purposes – implemented following extensive consultation – meant that the Census form required more careful interpretation than in previous Censuses and this added to the technical challenge in the more hard-to-count areas.

In the face of these challenges and in the light of international experience, two key steps were taken by the Office for National Statistics. The first was to allocate some additional enumerators and other resources to the areas likely to present most problems. The second was to adopt the 'One Number Census' methodology, which anticipates some degree of under-enumeration in the initial Census count. The method involves conducting a large sample survey of households a few weeks after the Census, designed to establish the extent of under-enumeration in each area. Notional records are then created for all the people estimated to have been missed. Using this approach the Census estimates for each part of the country add up to the estimated total population – the 'one number' of the title.

The Statistics Commission was initially prompted to look into the effectiveness of this approach in early 2003 following strong expressions of concern from Westminster City Council that the Census population estimates for Westminster seemed to be too low. This was echoed by some other local authorities who similarly pointed to the considerable disparities between the Census estimates and the mid-year population estimates for the year before. The Commission assembled and analysed a great deal of evidence (referenced in Annex C) and discussed this with numerous experts.

We published our interim report on the Westminster case in October 2003 [1]. Work by the Office for National Statistics and others subsequently confirmed that the Census estimates for Westminster and some other areas had been too low and, in 2004 – although it was too late to change the Census tables – the mid-year population estimates for 2001 were revised for these areas. In the light of these developments, the Commission has now looked again at its earlier findings and extended its recommendations.

One of the recommendations of the Commission's interim report was that new population counts should be pursued, ideally in 2006, at least for the areas that proved most difficult to count in the 2001 Census. The Government response to that report spoke in terms of looking "at options for providing an effective mid-decade population benchmark for London, and possibly other large urban areas where population flows are high". We welcome this commitment and have broadened the recommendations of this report (see recommendation (iii)) to recognise the need for flexibility about the detail of the work that should be undertaken. However we are still of the view that substantive progress should be made by 2007.

Our final report on the Census in Westminster is included at Part 2 of this report whilst Part 1 develops the broader conclusions and recommendations. These have evolved through discussion with the Office for National Statistics (ONS), other government departments and experts outside government.

The debate about the figures for Westminster – and those for Manchester and certain other local authority areas – has been substantially resolved although, as the chronology below indicates, this has taken a long time. Discussions have now widened into a dialogue between ONS and many interested parties inside and outside central government about the way forward for population estimates and the future role of a decennial Census; we urge all parties to make these discussions constructive and we make our own recommendations below on some important aspects.

Key dates:

1997-1999	Census tests carried out
15 March 2000	Census Order approved by Parliament
29 April 2001	Census day
September 2002	First Census results released
December 2002	Westminster City Council first approached Statistics Commission
March 2003	ONS agree data matching process with Westminster City Council
July 2003	Westminster Data matching exercise began

October 2003	Statistics Commission Interim Report
March 2004	Government response to Commission's Interim Report on Westminster
July 2004	Initial results of Local Authority Population Studies, Westminster and Manchester data matching exercises released by ONS
September 2004	Final data matching reports/population studies reports published.

Common ground

The Commission believes that there is now substantial agreement on some important general points for the future and offers its own support for the following:

- At least one more decennial Census, in 2011, will be required.
- The 2011 Census will need to be conducted differently from that in 2001 and from any previous Census.
- In the context of making population estimates, the importance of data extracted from administrative records – for example NHS patient records – will grow steadily.
- A key objective for the 2011 Census will be to use available administrative records to improve the quality of the Census estimates, especially in hard-to-count areas.
- Another objective must be to test the viability of using data from administrative sources to improve mid-year population estimates and other demographic statistics for the years following the 2011 Census.
- To the extent that these developments prove successful, the central role of decennial Censuses will diminish and *may* eventually disappear.

The Office for National Statistics is currently leading a wide-ranging development programme to improve population estimates and plan for a 2011 Census. Whilst the Statistics Commission wishes this work well, we are not directly involved in it and are not seeking to comment on it at this time. The conclusions and recommendations in this report are aimed at government as a whole rather than just ONS.

Conclusions and recommendations

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- Inadequate address lists contributed to the problems identified with the 2001 Census.
- The estimation of international migration needs to be improved markedly.
- Government departments do not know enough about, or publish the rationale for, their own data requirements.
- Co-operation across the public sector is needed to improve population estimates.
- The wide consultation that ONS is currently undertaking is welcome and important; it needs to engage executives in local government etc as well as technical experts.
- Disclosure control methods are a source of major concern to users of Census statistics because they reduce the value of the data to users.

Recommendations

- Government departments, local authorities and other public bodies should commit to work closely together in the planning and execution of the 2011 Census.
- ONS should seek to draw together public sector expertise in demography and related disciplines from across the UK.
- Targeted studies or surveys should be pursued in selected areas ahead of 2011 with a view to improving population estimates for the most problematic areas.
- Improvement of the quality of migration data should be addressed urgently by the Home Office and ONS together.
- The creation of a robust and continuously updated national address register should be a priority for government and be led by the Office of the Deputy Prime Minister.
- Government departments should assess more systematically and publish their own requirements in relation to the Census.
- ONS should develop one or more alternative measures of population, in addition to 'usually resident', suited to the needs of different user groups.
- ONS should take account of the concerns of local bodies about the accuracy of population estimates through systematic consideration of, and response to, matters raised with them.
- ONS should lead government-wide consideration of a common approach on disclosure control methods, aimed at giving the user community the best possible data quality whilst reducing the risks of disclosure of confidential data to acceptable levels.

Conclusions

1. The inadequacy of the available address lists played a critical part in the difficulties encountered in the 2001 Census, specifically in some areas identified as 'hard-to-count'. It led directly to problems both with the initial enumeration and with the estimation of the numbers missed in the initial enumeration. The latter occurred where the under-enumeration was so clustered or extensive that the estimation process was not able to correct for it fully.

2. As well as denting confidence in the Census, the relatively large discrepancies in some areas, such as Westminster, between:

- the mid-year population estimates for 2000 and earlier years and
- the Census-based population estimates for 2001,

highlighted weaknesses in the regular annual processes for making the mid-year estimates. The estimation of international migration was shown to be a particular difficulty and this will continue to affect mid-year estimates in future unless substantial improvements are made. Following the National Statistics Quality Review of migration statistics (see Annex A), we understand that this problem is now being addressed. We believe that improvement to estimates of migration is essential, both to the Census and to many other issues of public interest, and will monitor progress in this area periodically.

3. The Statistics Commission suspects that many public bodies (government departments, local authorities and others) that use Census data to inform their decisions do not always have a good overview of the use they themselves make of demographic data – let alone the coverage, definitions and precision they actually require from Census data to support those uses. Particularly where Census data influence decisions on the allocation of public finances or the assessment of public services, the Commission believes that the effort required to research requirements thoroughly would be more than justified by the influence those requirements would have on central decisions about data collection and the subsequent fine-tuning of the evidence-base. Given the vast sums of public money distributed according to statistical formulae, these issues should not be treated as minor technical matters; and the user requirements should be published, so that they can be examined, compared and aggregated where appropriate.

4. Future population estimates, whether Census-based or produced by other means, will require much wider co-operation across central government and between ONS and local government than occurred in 2001 and previous Censuses. The growing difficulties with survey methods – in locating the selected sample of the population and in obtaining answers to survey questions – make traditional statistical methods more vulnerable to poor response. And, properly handled, the already rapid development of large administrative databases in central and local government potentially offers the opportunity to obtain better demographic data by blending administrative and survey data together whilst still protecting the confidentiality of individual records.

5. In view of these technical developments, a more multi-lateral approach to population estimates, involving a wide range of public sector organisations, is likely to offer the best way forward. This would allow the exploitation of local expertise and maximise the contributions that all can provide. We believe that, in future, local authorities, government departments and some other public bodies will need to offer direct support to the Office for National Statistics and make a substantive contribution to the work. Whilst public accountability for the resulting statistics will remain with ONS, other bodies must share responsibility for future success. The methodology to be adopted must be subject to consultation and be published in detail before it is used.

6. The Statistics Commission notes that planning for a 2011 Census, within the Office for National Statistics and the other Census offices, is well under way and work on wider aspects of demographic statistics is also progressing. We welcome the steps being taken to consult interested parties and in particular the publication of *A Demographic Statistics Service for the 21st Century* [2] and *Proposals for an Integrated Population Statistics System* [3] and more detailed information papers. We would note however that major consultation exercises also preceded the 2001 Census without always leading to the full engagement of local authorities and others. We would expect the multilateral approach proposed above to help address this.

7. Since the publication of our *Interim Report*, we have become increasingly aware of strong concern amongst the user community about the methods of 'disclosure control' adopted by ONS in publishing the 2001 results for small areas in England and Wales. This differed from the approach adopted in Scotland. In this context, disclosure control is the process of ensuring that statistics for small areas do not inadvertently disclose information about identifiable individuals. The concern expressed forcefully to us is that the methods used are so rigorous in their protection against the risk of disclosing personal information that they tend to undermine severely the value of the statistical data to users. The Statistics Commission recognises that a balance must be struck between:

- the public interest in making best use of data, in many cases collected at substantial public expense, and
- the public interest in maintaining the highest levels of confidentiality such that the risk of personal information being disclosed or inferred is minimised.

This issue is about balancing these different public interests and is thus more than a technical question. It also has wider policy relevance – in the context of Data Protection and Freedom of Information policy – and we believe that it needs to be openly debated and resolved at a national level leading to a common and widely supported approach. We are not aware of there having been any case of inadvertent disclosure of confidential information from previous Censuses, despite less restrictive methods being employed in them.

Recommendations

(i) Under the leadership of ONS, government departments, local authorities and other public bodies should commit to work together to develop a robust collaborative approach for the 2011 Census, particularly for dealing with hard-to-count areas. We would expect this to involve the exploitation of address and population lists from various government departments, from local authorities and other appropriate sources. The detailed local knowledge of local authorities about their own areas must be used to the full. Any statutory or policy constraints on data sharing for Census purposes will need to be resolved *as a matter of urgency* by the relevant government departments (including the Office of the Deputy Prime Minister, Department for Work and Pensions, Home Office and Department of Health); however the commitment to the protection of personal information collected for statistical purposes, as enshrined in the United Nations Fundamental Principles for Official Statistics and elsewhere, must continue to be respected. The Statistics Commission would like to see a formal and binding agreement in place between the various parties by the end of 2005.

(ii) Although the Office for National Statistics is the recognised leader in demographic methods within government, there are significant numbers of experts working in units scattered across central and local government, the wider public sector and academia, many with access to their own data and research. The central importance of population estimates in the allocation of public expenditure and in social and economic policy analysis argues strongly for a determined effort to pool this expertise wherever possible. We recommend that ONS should seek to draw together such expertise in demography and related disciplines from across the UK into an organised framework that would advise on the production of statistical estimates and the ongoing development of methodology. Whilst we have no detailed blueprint for how this might be done, the aim should be to draw in knowledge and resources from relevant bodies. Recognising that this can only be achieved through consensus, we would suggest that a goal of having new arrangements in place by the end of 2006 should be adopted.

(iii) Targeted studies or surveys should be pursued in selected areas ahead of field testing for the 2011 Census with a view to making improvements in the estimates for those areas where current population estimates are seen as less reliable, either because they proved problematic in the 2001 Census or because major population change is likely to have happened since. The Commission does not believe it is reasonable to expect such areas to wait until the results of the 2011 Census are available in about 2013 to obtain a more robust estimate. We would hope to see substantive progress on this by 2007.

(iv) The quality of migration data should be addressed urgently by the Home Office and ONS together. The implementation of the recommendations of the NAO review of Migration Statistics [4] and of the National Statistics quality review of International Migration Statistics (see Annex A) has already started but needs to be pursued as a high priority. The aim should be to have more reliable migration estimates by 2007, ahead of testing for the 2011 Census.

(v) The creation of a robust national address register should be a priority for the Office of the Deputy Prime Minister, ONS and other bodies that can contribute to the resolution of the technical and organisational obstacles that have stood in the way of progress with this in the past. In October 2004, Ministers at ODPM made clear that the Government recognises the importance of a national address register and the Statistics Commission has been informed that an announcement on the way forward is expected early in 2005. We note with interest that Northern Ireland already has what seems to be an effective address system and Scotland is planning one. We hope that all these systems can be made as consistent as possible across the UK. We think the aim should be to have a plan of action early in 2005 to inform Census planning.

(vi) Government departments and major public bodies should assess more systematically their own data requirements in the field of demographic statistics. The Census and population estimates are crucial to meeting their needs: any lack of clarity about those actual needs is likely to lead to unsatisfactory outcomes. The Statistics Commission believes that more formal analysis of requirements is likely to prove beneficial and influential. We recommend that these requirements, identifying the census variables required, the data accuracy needed, geographical resolution of the results, etc are published.

(vii) In consultation with users of the statistics, ONS should bring to fruition its work on alternative measures of population in addition to the 'usually resident population' and promote discussion of the use of these measures in resource allocation and other decision processes – for example, it may be that the cost of local authority waste disposal services and some aspects of crime prevention in cities would be more closely related to the 'working population' than the usually resident population. We urge that an in-principle decision be taken on alternative measures in 2005.

(viii) Whilst ONS must retain formal authority over population estimates, we believe ONS they should nonetheless take systematic account of the concerns of local authorities and other local bodies about the accuracy of Census and other population estimates for particular areas of the country. Local bodies have their own sources of knowledge and expertise and any evidence they can offer about the accuracy of centrally produced estimates should be welcomed and shared as part of the evidence on which future estimates will be based. ONS should ensure that

appropriate systems are in place for recording, considering and responding to concerns from local bodies. These systems should feed into an adequately resourced programme of evaluation which examines critically the quality of all population estimates on an on-going basis. ONS should maintain the capacity to revise the initial results in the light of the evaluation findings and make users aware of the potential for revisions. We recommend that the new arrangements be in place in 2006.

(ix) ONS should take the lead in building consensus about the disclosure control methods to be used in statistical work across the UK, in particular in the 2011 Census, and these methods should be made widely known and implemented before the Census is carried out.

Background

This section provides additional background to some of the conclusions and recommendations.

The One Number Census

The One Number Census (ONC) method used in 2001 integrates the initial Census count taken on Census day with estimates for under-enumeration in each Local Authority District based on the Census Coverage Survey, a separate exercise carried out a few weeks after the initial enumeration. This is done in such a way that the local figures sum to the national population estimate, which is the 'one-number' referred to in the title. Records are then created for individual people and households believed to have been missed in the initial Census enumeration, using all the evidence available. In theory, no revision to the figures should be necessary as any undercount will already have been corrected. In practice, some revision to the 2001 Census based population estimates did prove necessary in a relatively small number of areas. The ONC national population estimate was not however altered retrospectively and so the Census estimates for some areas are now different from the 2001 population estimates.

The importance of address registers

The Statistics Commission recognises that the decision to use the One Number Census (ONC) methodology in 2001 was based on the best available advice and research. The method appears to have worked well across most of the country and it seems likely that – in more difficult circumstances for fieldwork than ever before – the 2001 Census overall produced more robust estimates than its most recent predecessors. The problems that did occur would probably not have been apparent if only a more traditional Census (as in 1991) had been carried out in 2001.

Under the ONC method, the initial Census counts, made during the enumeration process, are augmented by estimates of the number of people missed in the initial count. In 2001, these estimates were derived from a separate Census Coverage Survey (CCS) conducted a few weeks after the Census itself. Further adjustments were then made to the resulting estimates to compensate for lack of statistical independence between the Census and CCS. Part 2 includes discussion of the calculations for Westminster and explains the nature of the dependency adjustments in more detail.

The 'address matching' studies for Westminster and Manchester and other local studies [5,6] carried out after the Census demonstrated that, despite the CCS and the estimation processes, the Census failed to account for between 11,600 and 14,600 addresses in Westminster, and smaller numbers of addresses in at least

seven other local authority areas. We understand that, across the UK, Census enumerators uncovered very large numbers of addresses that were not on the lists they had been given. These points highlight the weakness in the address lists with which Census enumerators and managers were working. Responsibility for creating address lists lies mainly outside ONS and this weakness is not a matter that ONS itself could readily have resolved, or can be expected to resolve now (see Recommendation (v) above).

The role of an address register will be even more critical in the 2011 Census in view of the fact that it is proposed to post Census forms to some households. The case for concerted action now to resolve the long-running difficulties with address lists is self-evident and overwhelming.

Improving annual population estimates

Concerns about the 2001 Census figures for Westminster were initially triggered by the considerable difference between the mid-year population estimates (MYE) prior to 2001 and the 2001 Census results. The figures appeared to show a 26 per cent fall in population between 2000 and 2001. Although much of the discrepancy has now been accounted for, the various studies have not explained it completely. ONS's analysis of such discrepancies for England and Wales as a whole indicated that more than half of the difference was due to:

- Over-estimation of the mid-1991 population figures in some areas. These over-estimated figures were then the basis for the mid-year estimates throughout the 1990s, allowing the error to be passed on year-to-year up to 2000. The initial over-estimation was apparently due to over-correction for assumed under-recording in the 1991 Census.
- Weak estimation of population change due to international migration (which is currently difficult to estimate accurately, due to the inadequacy of data sources).

Following the publication of local authority population studies, we now know that, in several local authority areas, an *additional* factor affecting the discrepancy was under-estimation of the 2001 population in the Census results.

The mid-year estimates for 2001, 2002 and 2003 have now been revisited and increased. Overall for England and Wales, additions of around 107,000 were made to 2001 population estimates which, whilst a large number, is still only 0.1 per cent of the population and affected only 15 of the 376 local authorities, all of which saw their estimates increased. A difference of 209,000 from the population estimates before the Census remains substantially unexplained. Unreliable migration estimates are seen by many experts as the most likely explanation for the unresolved component.

As with address registers, the measurement of migration is not a matter that ONS can resolve on its own. The National Statistics Quality Review of International Migration Statistics [7] and the NAO review of Home Office statistics [8] both identified some opportunities for improvement to migration data. Their recommendations, when implemented, will improve this element of the mid-year estimates which in turn will provide better evidence for Census quality assurance. The Commission is not currently able to judge whether these improvements will be sufficient to bring about the required level of reliability. This should become clearer over time. We find it disappointing that government's responses on this issue do not contain a clear timetable for implementing the recommendations.

Alternative measures of population

The question of alternative measures of population is one of the issues on which ONS is currently consulting both government and non-government users of statistics as part of preparations for 2011. ONS hosts meetings with advisory groups from both central government and local government to give them the opportunity to express views. It is critical to the success of exercises such as this that government and non-government organisations alike understand and can explain their own needs for data to inform their decision-making. We believe that some shortcomings in the consultation process occurred prior to 2001, in that discussion inside some bodies was largely conducted by technical experts and did not engage those involved in operational or policy matters. Given the importance of the Census to all such bodies, we urge them to set up improved processes for examining all the Census proposals for 2011 and providing feedback.

The use of administrative records

Whilst the prospect of population estimates based solely on administrative records currently appears to be a long way off, there is considerable potential to make greater use of the administrative information that is now available to improve the quality of population estimates and reduce the reliance on household surveys. We welcome the fact that ONS is planning to research the extent to which administrative data and other local authority sources of knowledge can be used to improve population estimates. We understand that a set of studies is planned for 2005/06 with two key strands:

- case studies of particular local authority areas or types of areas and
- investigations across England and Wales as a whole of the potential usefulness of particular administrative sources and their reliability in different areas.

The case studies will focus on factors that make population estimation particularly difficult, for example areas of rapid population growth. The research will examine whether sources not used at present could be used to assist in compiling the mid-year population estimates. We are clear that collaboration between various parties, inside and outside central government, will be essential to their success and we look forward to the findings of the studies.

CENSUS AND POPULATION ESTIMATES

PART 2

THE 2001 CENSUS IN WESTMINSTER:

FINAL REPORT

The final report

Conclusion

The One Number Census methodology may have a tendency to work imperfectly in the most hard-to-count areas such as Westminster, and did so in 2001.

Work undertaken by the Office for National Statistics and others in late 2003 and 2004 to reconcile lists of addresses for Westminster (and other areas) enabled improved, and higher, estimates to be made. These revised estimates are now regarded as final by ONS. The detailed analytical work behind the revised estimates has gone some way to restoring user confidence in the validity of the population estimates. That the additional analytical work was necessary points to the need to find improved methods and ensure appropriate public discussion of them for the future.

The Statistics Commission published its interim report on the 2001 Census in Westminster in October 2003 [9]. The conclusions and recommendations of that report are superseded by those in Parts 1 and 2 of this report.

The 2001 Census estimated the population of Westminster at 181,286. Westminster City Council argued that this figure was too low and presented various evidence to support its case.

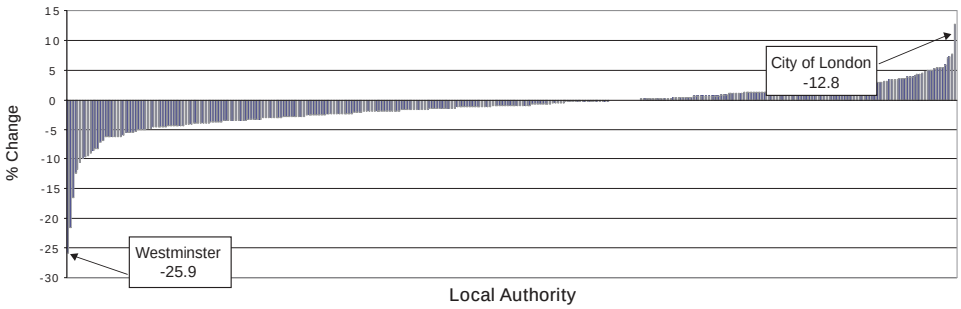
A substantial effort was made by the Office for National Statistics in advance of the Census to predict which areas would present special difficulties and to take precautionary measures. In the case of Westminster (and some other areas) there were however some greater than foreseen problems with the fieldwork which contributed to low coverage in the initial count and uncertainty in the estimates.

The Census figures are not straightforward counts. The initial Census counts, made during the enumeration process, were augmented by estimates of the number of people missed in the initial count. These estimates were derived mainly from a separate Census Coverage Survey (CCS) conducted a few weeks after the Census itself. Further adjustments were then made to the resulting estimates to compensate for lack of statistical independence between the Census and CCS. The calculations for Westminster are explained at Annex B.

Of the hundreds of local authority areas in England and Wales, the Census results for Westminster alone have been examined in detail by the Commission. We decided to look closely at this case both because Westminster approached the Commission for advice and because it is the extreme case when the difference between the previously published estimates of population (the mid-year estimates) and the 2001 Census figures are compared (see Figure 1).

Westminster was also one of the local authority areas with the lowest coverage in the initial Census count (Figure 2) and this increased the importance of the calculations needed to estimate the missing population, as explained at the end of this part of the report. It should be noted here that the more recent analytical work carried out by ONS has revealed that the true percentage coverage in Westminster was not 74 per cent as quoted in Figure 2 but rather was even lower at 68 per cent. However, in the interests of retaining comparability between the different areas, we have not amended Figure 2. Figure 3 shows how the estimates of Westminster's population differed at different points from immediately before the Census up to the latest estimate for June 2003.

Figure 1: Percentage population change 2001 Census vs original 2000 mid-year estimates English local authorities



Source ONS: www.statistics.gov.uk/census2001/downloads/Comparison_ONC2001_MYE2000.xls

This chart gives percentage differences comparing 2001 Census results with 2000 mid-year estimates for English local authorities. The differences are ranked from those where the Census results were most below the MYE to the converse.

Figure 2: Local authority areas with the lowest Census response rates – England & Wales 2001

Local authority area	response rate
Kensington and Chelsea	64%
Hackney	72%
City of London	74%
Westminster (true value 68%)	74%
Tower Hamlets	76%
Hammersmith and Fulham	76%
Camden	77%
Southwark	77%
Islington	78%
Lambeth	79%
Brent	79%
Newham	80%
Lewisham	81%
Haringey	83%
Slough UA	85%
Ealing	85%
Greenwich	86%
Ceredigion	86%
Luton UA	86%
Barking & Dagenham	86%
Redbridge	87%
Croydon	87%
Rushmoor	88%
Waltham Forest	88%
Merton	88%
Liverpool	89%
Wandsworth	89%
Enfield	89%

Source ONS: www.statistics.gov.uk/census2001/downloads/responserates.xls

Figure 3: Selected Westminster population estimates

Source (publication date)	Estimated population, thousands (year to which it refers)
ONS Mid-year population estimate (pre 2001 Census)	245 (June 2000)
ONS, One Number Census (September 2002)	181 (April 2001)
MORI Sample survey carried out for Westminster City Council (2003)	215 (December 2002)
ONS Mid-year population estimate (September 2003)	186 (June 2001)
	191 (June 2002)
ONS Mid-year population estimate (September 2004)	203 (June 2001)
	214 (June 2002)
	222 (June 2003)

Confidence intervals and the CCS

In publishing the Census population figures, the Office for National Statistics gave statistical confidence intervals for its estimates. It is important here to understand that a confidence interval does not represent the absolute upper and lower limits for the estimate. It is rather a range which will include the true value in about 19 cases out of 20, on the basis of probability. In the case of Westminster the published confidence interval was between 173,000 and 190,000. This range takes into account statistical variation due to the sample nature of the CCS. It does not take account of uncertainty due to weaknesses in the information about addresses etc. So the true range of possible values was considerably wider than indicated by these figures.

A simplified explanation of the calculation of the initial Census population estimate for Westminster follows at Annex B and further evidence is set out in Annex C.

Coping with hard-to-count areas

The Commission has some reservations about the judgements made in advance of the Census on the special measures to be taken to cope with the hardest-to-count areas such as Westminster. Though several London boroughs offered to help carry out the Census based on their local knowledge, the Office for National Statistics took the view that this would not be appropriate because authorities had a financial interest in the population count. Whilst statistical work must not be open to influence by anyone likely to benefit – or lose out – depending on the results, the loss of local knowledge exacerbated other problems.

It would be wrong, though, to give the impression that there was no co-operation between central and local government. Westminster offered paid leave to council staff to work as enumerators after discussion with ONS. Despite this, the Commission believes that discussions between ONS, the Local Government Association and local authorities, and actions arising from these discussions, could have gone significantly further and the more hard-to-count local authority areas could have been specially targeted in the Census Coverage Survey.

Westminster data matching and population study

Since the Commission's interim report, the Office for National Statistics and others have carried out considerable additional work on the 2001 population estimates. In particular, the Manchester and Westminster 'address matching' project examined the assumptions and data behind the ONC calculations for those areas and this led to important, corrections. This nature of the address-matching work is explained fully in the relevant ONS reports but, in simple terms, a series of exercises was carried out to compare the addresses identified by the Census and those contained in Westminster City Council's records (and similarly for Manchester). The exercises began with computerised matching of address records from council tax and electoral registers with those from Census records. This was followed by clerical matching of more complex and inconsistent addresses. After this process there remained a significant number of unmatched addresses from both WCC and Census records and a more extensive and detailed process was carried out that included, for example, matching flats in a block of flats where the numbering system had changed. The project eventually required a considerable amount of additional fieldwork. The project and its findings are described in detail in the ONS report published in September 2004 [10].

The address-matching project identified between 11,600 and 14,600 addresses missed from initial Census calculations across Westminster. Taking into account both the Local Authority Population Studies and other amendments to allow for younger men missed in the Census, an additional 21,660 was eventually added to the 2001 population of Westminster, taking the total to 203,300 for the 2001 mid-year

estimate. As well as the exercise carried out in Manchester, further analyses of key Census stages were conducted in another 30 local authority areas. Following the studies, population estimates were revised upwards in a total of 15 local authority areas, adding 107,000 to the 2001 Census-based population of England and Wales.

Address matching turned out to be a valuable technique but it is not without some weaknesses of its own. For example, it relies on comparison between Census records and local administrative records. Administrative records can identify households but they do not capture key characteristics of those households, such as whether or not the residents are 'usually resident' as defined for Census purposes. Thus it is possible that some households now counted in the population estimates are not 'usually resident' although efforts were made to minimise this problem.

Despite concerns of this kind, the Statistics Commission regards the revised estimates as the best available given all the evidence. We believe that they provide a better base for future mid-year estimates then the original Census estimates.

Westminster mid-year estimates

Figure 3 shows how the mid-year estimates have changed as a consequence of the ONS work (and compares them with the Census estimate and the results of a sample survey carried out by MORI for Westminster some 20 months after the Census). The original 2001 Census figure for the population was 181,000 while the mid-year estimate for that year, which was made in September 2004, was some 22,000 higher. We note that the most recent revisions to MYEs suggest a rapidly growing population in Westminster – by a further 19,000 people in the two years since the Census year.

The 'churn' in population in urban areas, and especially in central areas such as Westminster, is high, with up to a quarter of the electorate on the electoral register changing annually. We know that methods currently used for measuring migration into and out of the UK, and between local authority areas, are unsatisfactory and that this has been a long-standing problem in making estimates. Particularly unreliable are the estimates of international emigration and immigration into and out of Central London. Without improved methods, the process of updating the annual population estimates is manifestly liable to error. Add to this the difficulty of knowing whether people are 'usually resident' and the merits of seeking other ways to complement the Census become very evident.

Conclusions

The factual basis of this report has been checked with the Office for National Statistics and with MORI. Matters of judgement are however solely the responsibility of the Commission.

It is impossible to know the population of Westminster on Census night in 2001 with certainty. The accuracy of all estimates depends on the methods used and the local circumstances. The evidence we have seen convinces us that the One Number Census methodology tended to work imperfectly in the most hard-to-count areas in 2001.

The initial Census result of 181,300 came as a surprise to many in Westminster who had, until then, been working with a 2000 mid-year estimate of 244,000. The subsequent research and analytical work in 2003 and 2004 led to an improved estimate. This has gone some way to restoring user confidence in the validity of the process of producing population estimates, though the difference between the various estimates for recent years will inevitably be the source of ongoing concern.

Work undertaken by the Office for National Statistics and others in late 2003 and 2004 to reconcile lists of addresses for Westminster (and other areas) enabled improved, and higher, estimates to be made. This work was challenging and time-consuming. That it was necessary at all points to the need to find improved methods for the future.

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See also Annex C: References and Appendix A.

ANNEXES

ANNEX A

Overview of National Statistics Quality Review of International Migration Statistics

Recommendations

– an extract from:

Review of International Migration Statistics. NSQR Series Report No.23. Office for National Statistics, 2 September 2003.
http://www.statistics.gov.uk/methods_quality/quality_review/population.asp

Development of better estimates of total migration flows

The International Passenger Survey (IPS) has long been the 'workhorse' of international migration statistics, and the review's recommendations are that it be retained at least in the near-term as the main source for the estimation of total annual UK immigration and emigration. The partial uncoupling of the sampling of emigrants from the sampling of all outward travellers, as is already done for the sampling of the majority of immigrants separately from all inward travellers (in 'filter shifts'), would allow for design of a larger sample that would be partially outside of the constraints of the main IPS. It would also better provide for opportunities to experiment with alternate question formats for both immigrants and emigrants to capture respondents' uncertainty about how long they will or had expected to stay in the UK or abroad, and to evaluate non-response biases. Research into the combined use of, and checking against, alternate data sources is also needed to improve estimates of total immigration and emigration. These include other UK survey and general-population administrative data sources, Home Office administrative sources on non-EU immigrants, and other countries' UK-immigrant receiving statistics. Development of the IPS to estimate short-term as well as long-term migration would be expected to aid these matching efforts, and to aid in the synthesis of migration flow estimates with population stock estimates.

Expanded use of existing survey and administrative data sources for UK geography of migration

Substantial improvements to the estimation of the within-country geographical distribution of UK international migration may be achieved through the combined use of household (LFS) and port (IPS) survey data on immigration. For estimation of international migration at local authority levels, however, administrative data are needed to overcome the sample-size limitations of survey data sources. Again, they

are best used in combination with other (survey) sources. NHS patient register data are the best single potential source, covering both immigration and emigration of citizen and non-citizen populations. The NHS registers also have the advantage of already being used for the estimation of internal migration. Methodological research is needed, however, to adjust for coverage and response biases.

Use and development of survey and administrative data sources on persons subject to immigration control

The Home Office's administrative data sources have the potential to better address needs for statistics, at both national and local geographic levels, on the immigration and social and economic outcomes of persons subject to immigration control. Efforts to match estimates and definitions between these sources and those of large-scale surveys and the Census are also crucial for developing better statistics on this important component of all UK international migration.

New administrative data sources

Potential new administrative data sources, especially population registers and electronic arrival and departure recording, could radically reshape the empirical framework for international migration estimation. The time frame for their effect on international migration statistics is at least several years out. Planning for their design to best measure international migration, however, should begin much earlier.

ANNEX B

A simplified explanation of the calculation of the initial Census estimate for Westminster

The following illustrative calculations are based on the initial results of the 2001 Census and do not take into account the results of the Westminster population study and other adjustments which re-estimated the 2001 population to be 202,950 and Census coverage to be 68 per cent.

2001 Census estimate of the population of Westminster (29 April 2001)	181,286
Number actually counted in the Census as usually resident in Westminster	134,212
The number of people missed but added through estimation	47,074

Westminster had one of the lowest response rates among local authority areas and thus one of the largest proportions that had to be estimated. This paper sets out in simplified terms how the estimate of over 47,000 missed people was derived and considers the level of uncertainty associated with the process.

The essence of the Census Coverage Survey (CCS) is to estimate the proportion of people missed in the Census enumeration and increase the total count accordingly – referred to below as STAGE 1. There is then a second set of adjustments to deal with lack of independence between the Census and CCS – STAGE 2 below.

STAGE 1 – the CCS-based adjustment

The part of the CCS that is relevant to the Westminster estimate relates to the Central London Estimation Area (an area including Westminster but also City of London, Camden and Kensington and Chelsea). Sampling from every local authority area separately would have required a prohibitively large CCS, so it was common for them to be grouped in this way. This also had some advantages in designing the sample within the EA. A random sample of Post-Code Areas across this Estimation Area – containing about 2 per cent of the population – were visited in the CCS.

The Central London part of the CCS was not designed specifically to be representative of Westminster. This introduces a degree of uncertainty. If those areas of Westminster that were included in the CCS tended to have household characteristics untypical of Westminster as a whole, then the resulting population estimate could have been affected.

The CCS for Central London identified 8,686 residents, of whom 3,292 lived in Westminster. The details for these individuals were then matched against Census records to see which of them had been found in the Census enumeration and which had not. The Census enumeration records for people in the selected postcode areas were also checked to see which had been interviewed in the CCS and which had not. Thus individuals were identified as either having been counted in both the Census and the CCS, or just in the Census, or just in the CCS.

The results:

- Westminster residents counted in the CCS — 3,292 (100.00%)
  - – of which also counted in Census — 2,478 (75.27%)
  - – of which not counted in Census — 814 (24.73%)
- Westminster residents counted in the Census (in the CCS area) — 3,336 (100.00%)
  - – of which also counted in the CCS — 2,478 (74.28%)
  - – of which not counted in the CCS — 858 (25.72%)

From these results, a formula can be used to derive an estimate of the total population in the Westminster CCS area – including estimated numbers that were missed by both the Census and CCS. This is called the Dual System Estimator (DSE) and is calculated as:

$$\frac{3{,}336 \times 3{,}292}{2{,}478} = 4{,}432 \text{ (estimated total population in these postcode areas)}$$

The following sum gives the estimated number missed in both the Census and CCS

$$4{,}432 - 2{,}478 - 814 - 858 = 282 \text{ (missed in both)}$$

In practice, the Office for National Statistics used a more sophisticated approach that doesn't use the aggregate figures, as here, but rather works with more detailed figures for individual age and sex bands in each of the individual postcode areas. However the principle is essentially the same. The ONS approach resulted in slightly lower figures for the total numbers and the number missed: 4,416 total, 266 missed in both Census and CCS.

From the results above, it can be seen that an estimate of the coverage of the Census is 3,336 + 4,416 = 75.54% (using the ONS figures). *We have quoted this figure with two decimal places simply to make it easy to recognise later; it is not likely to be accurate to that level.*

Applying that assumption to the Census count for the whole of Westminster (134,212 counted residents less 6,172 in communal establishments who are not affected by this calculation, leading to 128,040 people) gives an estimate for the total of Westminster residents of:

$$\frac{128{,}040 \times 100}{75.54} + 6{,}172 = 175{,}672$$

Again ONS used a more sophisticated method of making this calculation and got a slightly higher result: 178,750. (The ONS approach involved fitting a regression model to the values for those postcode areas for which there were both Census and CCS counts and then applying that regression model to the postcode areas from which there were only Census counts. This makes best use of the available data).

Up to this point in the calculations, a very important assumption is made: that the probability of being counted in the CCS is the same whether or not the household was counted in the Census. This assumption is called 'independence'. In reality, the assumption of independence is unlikely to be justified. People who are not counted in the Census are generally more likely to be missed by the CCS than people who *were* counted in the Census. The independence assumption was initially adopted by ONS on the basis of simulation work during the 2001 Census design which showed that if coverage in the Census and CCS is good and dependence is not extreme, then an assumption of independence provides satisfactory estimates. This had to be revisited after the Census, when good coverage in the Census was not achieved in a number of areas. The estimation of the amount of dependence in an area is a critical step for those areas where Census coverage was low.

It may help in understanding dependence to think of the CCS as a thorough house-to-house search to identify people who live in an area. If this search finds everyone, then the assumption of independence holds – because their chances of being in the CCS are not affected by what happened in the Census. If the CCS misses some people but there is no particular tendency for these to have been people who were missed in the Census, then still independence holds. If however the people missed are disproportionately the same people as missed in the Census, then the independence assumption is invalid. Intuitively, it seems likely that some of those missed by the Census – those who wanted to avoid being identified for example – had more than an average chance of being missed by the CCS. So independence is not likely to be a totally valid assumption.

STAGE 2 – the dependency adjustment

The scale of correction needed to allow for lack of independence is difficult to estimate but in practice it is not a major effect in most local authority areas. However, the correction becomes very much more important when, as in the case of Westminster, the estimated Census coverage is so low.

To correct for the lack of independence, statistical methods dictate that a further adjustment should be made to the total calculated so far (ie 178,750). The adjustment by which the total will be multiplied is calculated as follows (using the Westminster figures cited above):

$$1 + (b - 1) \times (1 - 0.7527) \times (1 - 0.7428)$$

which is the same as $1 + 0.064(b - 1)$

where **b**, called the **odds-ratio**, is an estimate of how much more likely a person is to be counted in the CCS if he or she is also counted in the Census, compared with the case where the person was missed in the Census. The lowest meaningful value of **b** is 1, which would mean that the chances of being counted in the CCS are not affected by whether the person was counted in the Census – ie complete independence. The higher the value of **b** the more likely it is that a person missed in the CCS is one of the people missed in the Census too.

Note: ONS calculated both household level odds-ratios and person level ones and these do show some differences. This paper does not discuss this aspect as it is not directly relevant to the issues being considered. However, the step from household to person level ratios does involve another set of assumptions.

How the odds-ratio is calculated

The formula for calculating the odds-ratio **b** is easiest to follow if the figures computed above for Westminster are used to illustrate it – but it should be noted that this is just for illustration. The approach actually used in the Census did not involve this particular calculation – as explained further later. Using the Westminster figures to illustrate the formula it is:

$$b = \frac{2{,}478 \times (T - 2{,}478 - 814 - 858)}{814 \times 858}$$

T is a separate estimate of the population in the area – called the 'third estimate'. In practice this process has two steps; the first operates at the level of numbers of households and the second operates at the level of individual people. But the sum above illustrates the concept.

Now T is, by definition, difficult to estimate reliably. It is one of the quantities that the Census itself is intended to measure – so obviously it isn't known in advance. The way it was estimated for Census purposes was to take the average of two quantities that were known – the number of residential addresses held by the Post Office (adjusted by a factor to convert from addresses to households) and the number of households identified in the Census by the enumerators – and then to adjust the figure to give an estimate in terms of people rather than households.

It is clear that the odds-ratio b is difficult to estimate and introduces further uncertainty. It appears to the Statistics Commission that the difficulty of estimating b accurately tends to increase for the areas of the country where the Census coverage tends to be low. The reason for this is essentially that the circumstances which make an area 'hard-to-count' – such as unwilling households – also make it hard to be sure about the level of dependence. These areas are also the ones in which the dependency adjustment will have a relatively large effect on the final total. So not only is the calculation more uncertain in these areas, it is more important too.

It would be wrong to assume however that a high odds-ratio automatically leads to a large adjustment in terms of numbers of people added. A lot depends on the coverage in the initial enumeration. If the initial coverage is high, the odds-ratio will not have a large impact on the final estimate.

In practice, the odds-ratios used for the Central London Estimation Area were actually the values of b derived for the larger 'Inner London' area – on the grounds that the latter estimates would be more robust (the values used were 1.6 for the 'most hard-to-count' areas and 3.7 for the 'middling hard-to-count' areas when measured at the household level). This is a defensible step but, to the extent that Westminster is untypical of Inner London, it introduces still more uncertainty. Having calculated the necessary adjustments for the Central London Area as a whole, the 'extra population' was then allocated to the different local authority areas in proportion to the estimated amount of undercounting in the Census in each area. Thus there was never a specific value of b for Westminster on its own. But the net effect of these various steps was to produce an adjustment for Westminster which equated to a value of b of about 1.22 (measured at the person level) – that is to say a value near the bottom of the plausible range. Use of this dependency adjustment added some 2,500 people to the Westminster total. This took the 178,750 figure derived under the Stage 1 adjustments to 181,286.

Conclusions

The odds-ratio b is a measure of the extent to which an individual who was missed in the Census count was more likely to be missed in the Census Coverage Survey than someone who was counted in the Census. For those areas of England and Wales that had a high coverage in the initial Census count, the value of b did not make much difference to the final estimate. However in the Westminster case, where the coverage was exceptionally low, the estimated value of b was critical.

This is illustrated below by looking at the effect of setting b to alternative values. The last two columns give the level of response in the Census and CCS implied by the values of b. As b increases these figures start to become increasingly unrealistic, so a very high value of b is improbable.

b	extra people in Westminster	total estimated for Westminster to the nearest thousand	percent response in enumeration (people)	percent response in CCS of people missed from Census
1	0	179,000	75	75
1.22	3,000	181,000	74	70
2	11,000	190,000	71	59
3	23,000	201,000	67	49
4	34,000	213,000	63	42
5	45,000	224,000	60	37
6	57,000	236,000	57	33
7	68,000	247,000	54	29

The estimation of b is problematic, requiring a separate ‘third estimate’ of the resident population. This approach does not always produce sensible results. Much depends on the robustness of the various estimates that come into play in the calculations. The value of b for Westminster implied by the final Census estimate was towards the bottom of the range of plausible values.

Uncertainty about the value of b, and about other steps in the process, is not taken into account in the published confidence intervals and this lends an unjustified impression of precision to the official estimates.

ANNEX C

The population of Westminster in 2001:

A review of the evidence submitted to the Statistics Commission in 2003 by the City of Westminster, the Office for National Statistics and other parties

Philip Rees[1]

September, 2003; revised October 2003

The problem

The Office for National Statistics (ONS) undertook a full census of the population of England and Wales in 2001, published the first results on 30 September 2002 (age-sex tables and associated mid-2001 population estimates) and has since been rolling out a huge volume of outputs from the 2001 Census. ONS has used the 2001 Census statistics to revise radically the mid-year population estimates (MYEs) by age and sex for local authorities. For the City of Westminster the 2001 MYE population was 26 per cent lower than the previous mid-2000 estimate. Such a reduction had a drastic impact on the allocation of central government revenues for Westminster services.

The City of Westminster made strong representations to ONS for revision of the 2001 estimate, assembling a variety of evidence to support their claim that the population of the Borough had grown throughout the 1991-2001 decade, rather than declined to 1995 and grown since then (as indicated by the ONS revised MYE series). They took their complaints to the Statistics Commission in December 2002. Westminster commissioned work on the borough's population estimate by MORI survey company and from a group of academic experts. They continued a vigorous dialogue with ONS.

ONS have responded through letter, by meeting with Westminster representatives and by producing a report explaining how the Westminster census count and mid-year estimates were produced. They have continued to produce reports explaining the One Number Census methods, including a very recent paper on the allowances made for dependency in the Dual System Estimator (DSE) method. ONS have argued strongly for the robustness of their census count and their revision of Local Authority (LA) and Unitary Authority (UA) MYEs.

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Westminster and ONS are collaborating on an investigation of one aspect of the Census process: the possibility that substantial numbers of residential addresses were omitted from the Census enumeration in Westminster. ONS and Westminster have jointly funded and commissioned an address matching analysis by Manchester Geomatics. The Census address list is being matched against a master file constructed from eight address datasets. The files being used are AddressPoint™ (August 2000 and ONS 1998), Post Office Address Files (PAF 2001 release 4), Communal Establishments (LA records), Council Housing (LA records), Council Tax (LA records), Registered Social Landlords (LA records), Electoral Roll (LA records) and ONS Census additional records (confidential). The report is due for completion in December 2003.

This reports reviews the arguments marshalled by the Local Authority and the Office for National Statistics, using documentation submitted to the Statistics Commission by the interested parties and other organisations.

Summary of actions taken

The key actions taken by the City of Westminster were to protest about the 2001 Census count and the 2001 MYE for the Borough (City of Westminster 2002, Milton 2003, Rogers 2003a), to commission a MORI survey based population estimate (MORI 2003), to secure a MORI critique of the ONC (Mortimore 2002), to request a review of the issues from an expert panel (City of Westminster 2002b, Hobcraft *et al.* 2003) and to enter into a dialogue through meetings and correspondence with the Office for National Statistics (Wilson 2003a, 2003b, 2003c; Rogers 2003b).

The key actions taken by ONS were to prepare responses to the Westminster protest document in the form of letters (Pullinger 2003a, Pullinger 2003b, ONS 2003d, ONS 2003f) and *The Westminster Report* (ONS 2003c), seeking to explain why ONS felt that the ONC and revised MYEs were robust. They also pointed to the documents pertaining to the ONC, which have recently been augmented by the publication of the Dependency Method report (Abbott *et al.* 2003). ONS has reviewed the need to improve international migration statistics (Walton 2003, ONS 2003j) and has already carried out revisions (ONS 2003e). ONS has reviewed its future plans for the development of population statistics (ONS 2003b, 2003c, 2003g, 2003h; Cook 2003a, 2003b, 2003c), which has led already to revisions to the ONC informed mid-2001 population estimates (ONS 2003i).

The key joint actions by the City of Westminster and ONS were to carry out an address matching exercise, commissioning a trusted third party (Manchester Geomatics) to see if there was evidence of missing addresses (Pullinger 2003b, ONS 2003a).

The key agreement was an undertaking by ONS to modify the MYE in the light of robustly identified missing residential addresses. It is important though to be clear what ONS have proposed. John Pullinger, Director, Economic and Social Reporting at the Office for National Statistics, writes in his letter of March 2003 to C.T. Wilson, Director of Legal and Administrative Services, City of Westminster:

> 'As I stated during our meeting on 21st March, once the matching exercise is complete we will look at this evidence along with all other evidence available to us and make a judgement on that basis. If we conclude that there is clear evidence that the Census has missed significant numbers of households, and that these have not been adequately accounted for by the One Number Census process, then we would be prepared to make an adjustment to the population estimates.' (Pullinger 2003b, p.2, para 3)

Note that ONS consider that adjustment of the ONC at this very late stage of output production is not feasible.

The Statistics Commission has responded to Westminster's concerns (Statistics Commission 2003a) by holding a series of meetings with the City of Westminster (Statistics Commission 2003b), with the Office for National Statistics (Rhind 2003, Statistics Commission 2003d, 2003e, Diamond 2003), with the Office of Deputy Prime Minister (Statistics Commission 2003c) and the Greater London Authority (Statistics Commission 2003f, 2003g, 2003h).

Context

The first results of the 2001 Census of Population were published by the Office for National Statistics on the 30 September 2002 along with the mid-2001 (30 June/1 July) populations of Local and Unitary Authorities in England and Wales. These results consisted of tables of counts by age and sex.

The results were a surprise in that they were considerably lower than the users of those statistics expected on the basis of the Mid-Year Population Estimate series from 1991 to 2000 grounded in the adjusted 1991 Census. The total population of the UK was 58,789 thousand (ONS 2002), whereas the pre-Census population estimates for mid-2000 had been 59,756 thousand with a one year national projection for mid-2001 of 59,987 thousand. The difference between the 2001 Census figure and the mid-2001 population was 1,198 thousand.

ONS, together with GROS and NISRA, adopted the 2001 Census as the base upon which to estimate the mid-2001 population of Local Authorities and Unitary Authorities. They revised the 1991 mid-year estimates back to a 1991 Census count base and away from the previous base of a rolled forward estimate based on the 1981 Census. The population estimate series was then revised between these census dates adjusting for the discrepancy in both the 1981-1991 decade (one third) and 1991-2001 decade (two-thirds).

The estimated population of every LA and UA in the country was changed, mainly downwards. The new population estimates are an important part of the method used by the Office of Deputy Prime Minister (ODPM) to allocate 75 per cent of local government revenues that come from national taxation. The City of Westminster's population estimate in 2000 prior to the 2001 Census was 246 thousand, while its 2001 Census population was 181 thousand, 26 per cent fewer. This had the potential consequence of reducing of Westminster's local government annual allocation by around £60m. The reduction in allocation has been moderated by the floor mechanism used by the Office of the Deputy Prime Minister (ODPM), which resulted in a minimum increase of 3.5 per cent for Financial Year 2002/3.

The City of Westminster was naturally extremely concerned about the decrease in its estimated 2001 population. Westminster Council officers and councillors took their concerns to the Office for National Statistics and have conducted a dialogue with the ONS, asking for an explanation of the decrease and a revision of the population estimate. The City of Westminster also approached the Statistics Commission in December 2002 and asked them to investigate their concerns with the ONS 2001 Census results and 2001 mid-year population estimates for Westminster.

The Statistics Commission requested both written documentation and oral evidence from the City of Westminster and the Office for National Statistics, and received documents and oral evidence from other parties, including the Greater London Authority, Manchester Geomatics, MORI polling/survey company and a group of academic experts commissioned by the City of Westminster to review the problem. Appendix A lists the documents submitted in evidence and provided for this review. They include documents in the public domain and confidential transcripts and notes of meetings between the Statistics Commission and the parties involved. Appendix B provides a glossary of the numerous acronyms and technical terms used in the report.

Arguments by the City of Westminster

The principal arguments in favour of *a higher population estimate* for the Borough put forward by the City of Westminster are as follows (City of Westminster 2002, p1):

- their own estimate, based on Council Tax records and the Electoral Register, gives a figure of 231 thousand
- the Electoral Roll has increased by 26 per cent since 1991
- the National Health Service (NHS) Patient Register count of patients has increased by 19 per cent
- between 1991 and 2001 8 thousand new residential properties were built
- the number of domestic dwellings increased by 8.6 per cent between 1991 and 2001

- the primary school roll has increased by 28 per cent and the secondary school roll by 15 per cent
- a survey-based estimate by MORI opinion polling organisation in late 2002, prepared for Westminster Council, produced a population estimate of 215 thousand.

Further, the City of Westminster identified *specific features of their borough's treatment in the 2001 Census* which meant that the population was not properly counted:

- ONS failed to devote sufficient resources to administering the 2001 Census in the Borough which has large numbers of houses in multiple occupation, hostels, hotels, gated buildings or buildings with a concierge, asylum seekers and student halls of residence.
- As a result, many residential addresses were omitted from the 2001 Census with one estate being completely missed, one MP's residence being missed and instances and enumerators failing to list fully all residential addresses in enumeration districts.
- The allowance for dependence in the ONS One Number Census (ONC) methodology was too low for the Central London Estimation Area, and alternative allowances would have led to higher estimates (Hobcraft *et al.* 2003, p.8)
- Westminster's reduction in population from expectation was so extreme that it would not be expected statistically (MORI report). Westminster had expected a Census population within ±5 per cent of 245 thousand (the old mid-2000 estimate) less the average reduction in the population (about 2 per cent) in the ONC, say 5 thousand. This would have yielded, at a minimum, a population count for Westminster of about 228 thousand. The ONC number for Westminster was 181 thousand.

In addition, the City of Westminster contended the following about *ONS procedures*:

- ONS should not have abandoned its own figures, based on the International Passenger Survey, of immigration to Westminster.
- ONS had failed to explain why young men were 'missing' from the 1991 and 2001 Censuses in such numbers in young adult ages.
- ONS had not taken up offers by the City of Westminster of substantial help in the enumeration process by council staff (justified by the Borough's concentration of hard to enumerate areas and people).

Arguments by the Office for National Statistics

The Office for National Statistics has *addressed Westminster's concerns* by engagement with the City of Westminster either directly through correspondence or meetings or in evidence to the Statistics Commission responding to the points made by Westminster Council:

- ONS have used a large number of administrative records in the Quality Assurance process which compared the One Number Census with a plausible range of estimates based on these other records, including the previous set of mid-year estimates and patient registers (used by Westminster).
- ONS point out the Council Tax records do not necessarily provide a good basis for estimating the number of usual residents because in Westminster many homes are second homes and the occupants are usually resident elsewhere.
- School rolls do not necessarily reflect the population of children resident in the Borough when schools draw pupils from both inside and outside the borough.
- The survey based estimate by MORI assumed too high an average household size for imputed households as these are much more likely to be single person households than responding households. There was a very high 95 per cent confidence interval about the estimate of ± 60 thousand. The ONC figure fell within the MORI estimate range of 154 to 274 thousand.

ONS responded in some detail to the issues raised by Westminster Council about the *conduct of the census, the coverage survey and the One Number Census*:

- ONS admitted that there had been difficulties in recruiting census enumeration staff in Central London. They had welcomed Westminster's initiative to give council staff three days leave to undertake census officer or enumerator roles, and this suggestion had been widely used in London. ONS took the view that they could not accept Westminster's further offers of involvement in administering the census as this would lead to claims by other authorities of favoured treatment.
- ONS have agreed to fund, with the City of Westminster, an address matching exercise by Manchester Geomatics, which is currently proceeding. Address lists from a variety of sources are being compared with the census enumeration list to identify gaps. If evidence of missing residential addresses is firmly established, ONS have agreed to adjust the mid-year estimate population.

- ONS have explained and defended their innovative One Number Census procedures, designed by Professor Ian Diamond (then of Southampton University, now Chief Executive Economic and Social Research Council). They have provided, via the National Statistics website, large numbers of methodological papers including those of the Quality Assurance stage, in which ONC numbers by age and sex were checked against a range of plausible prior estimates. Note that these prior estimates were not used to adjust the ONC result.
- ONS contend that the ONC estimation methods could deal with outliers, when the response rate was low, through making an allowance for dependence.

ONS reviewed very critically, in the light of ONC results, *previous methods of post-census population estimation*:

- ONS now consider the International Passenger Survey (IPS) to be a flawed instrument for determining the LA destination of an immigrant, and a poor estimation of emigration. Migrants are a small sample within a larger survey focussed on visitors/tourists. The coding of destination 'central to London' to Westminster exaggerated radically inflows to the Borough.
- ONS are carrying out a review of International Migration statistics which will be published soon. This review should examine the question of how many young men emigrated and how the sex ratio in the young adult ages is affected. Evidence from the censuses of overseas destinations is to be examined. [Note: review published September 2003]
- ONS contend that they did welcome the Westminster leave for staff to enumerate but did not wish to extend LA involvement in order to maintain consistency of estimates across all LAs and UAs.

Strengths and weaknesses of the arguments and what we know about the problem at this stage

The arguments put forward by Westminster and ONS were reviewed by several different parties.

The City of Westminster commissioned three pieces of work:

- a technical paper by Roger Mortimore, Associate Director, MORI, entitled *The 2001 Census in the City of Westminster* (Mortimore 2002)
- a research study by MORI on *The Population of the City of Westminster* (MORI 2003)
- *An Interim Report of Independent Panel of Census Experts to Chief Executive, City of Westminster Council* by John Hobcraft and colleagues (Hobcraft *et al.* 2003).

The Greater London Authority contributed the following:

- extensive oral evidence to The Statistics Commission (Statistics Commission 2003f)
- GLA 2000 Round of Demographic Projections, as used in 'Towards the London Plan', which includes a variety of projections (Greater London Authority 2001).

Members of Parliament (Buck 2003, Flight 2003, Leigh 2003) have also commented on the conduct of the 2001 Census and the use of census populations in producing the 2001 mid-year and subsequent estimates.

It is useful to try to pick out some of the main points made in these additional reports, but in a generic fashion.

The administration of the 2001 Census

The Census organisations including ONS decided to use enumerator delivery of census forms and postback procedures for collection. These were tested out in the 1999 Census rehearsal. Postback had been used by other national statistical offices with success. The cost savings were considerable and enabled ONS to concentrate enumerator staff in hard to enumerate areas. There were, however, operational problems, some of which might have been anticipated such as forms and envelopes oversize for the standard UK postbox and overload at the Royal Mail. However, ONS staff and enumerators made an enormous effort to get the job done and a 94 per cent response rate was achieved (higher than anticipated).

With hindsight, it is possible to say that more local help should have been accepted from LAs with lots of hard to count populations. But this could only have been done with full prior agreement of all LAs, in order to maintain the level playing field of National Statistics.

The argument was also put forward that the Census Coverage Survey (CCS) should have been larger to cope with anticipated problems such as those that emerged in Westminster. Then LAs with hard to count areas could have had their own sample. But this is a conclusion from hindsight. The CCS was already the biggest ever household survey ever attempted in this country and the most successful in terms of response.

The ONC procedures of ONS and ONS consultation on the procedures

All parties were agreed:

- that the One Number Census procedures were necessary to handle the anticipated lack of response in the 2001 Census

- that the ONC was statistically robust as long as response rates were reasonably high
- that the matching exercise within the ONC had worked well
- that ONS had been correct to add a final dependence adjustment.

However, there were aspects which deserve some further explanation.

ONS has produced a large number of papers on the ONC and makes these available on the National Statistics website. They have also presented the methodology to census users, particular LAs, in a large number of meetings. This consultation built solid general understanding of the method, received some useful feedback and contributed to its widely perceived success. Even Westminster were supportive but, of course, felt that it had not coped well with their extreme situation. However, from the Westminster and GLA evidence it is clear that not everyone understands the details.

The Westminster Expert Panel report (Hobcraft et al. 2003) and the ONS's document *The Westminster: a Review of the Facts* (ONS 2003c) both present simple example computations of the data capture/recapture technique, while the MORI appendix to the City of Westminster's *Evaluation of the Accuracy and Reliability of the 2001 Census* quotes the standard formula used to derive the 100 per cent population from the 2001 Census:

$$E = CS/M$$

where E = estimated total population, C = population counted in the Census, S = population counted in the Survey and M = population matched in the Census and Survey. The derivation of the Dual System Estimator from the Hypothesis of Independence is explained in Appendix C. The Westminster results are reported in Table 1.

Table 1: Results from the Census and the Census Coverage Survey, Westminster, 2001

		Coverage Survey Counted	Missed	Totals
Census	Counted	2,478	858	3,336
	Missed	814	(266.5)	(1,080.5)
	Totals	3,292	(1,124.5)	(4,416.5)

Source: ONS (2003) *The Westminster Report: a Review of the Facts*, p.13.
Note: The figures not in brackets are observed counts. The bracketed figures are computed figures.

Now these figures are not simply the result of the application of the Dual System Estimator: M= 2478, C=3336 and S=3292, because E = (3336) (3292)/2478 = 4431.8 and the hypothesis of independence yields a different result for the count of persons missing in both Census and Survey. That calculation is (1124.5/4416.5) _ (1080.5/4416.5) which yields 275.1. There are several reasons for the difference: (1) the DSE is applied to sample postcodes and aggregated to the Estimation Area, (2) the DSE is applied to age-sex groups, (3) the DSE is applied to the Estimation Area not the individual LA, which is connected via a regression model and (4) a dependency adjustment is made, which takes into account differing response at the LA level. The Final Draft of the report on dependency adjustment has just been released (Abbott, Brown and Diamond 2003) and is under review by the Statistics Commission.

The main point to make from this discussion is that it is probably essential for the ONC team in the Office for National Statistics set out all of the algebra and arithmetic of the DSE and dependency computation for the City of Westminster LA in a completely transparent way. The chain of arithmetic calculation needs to be seen in its entirety. Now most users will find such an account challenging but statistically experienced LA officers should be able to follow the logic and check it using a spreadsheet and relevant supplied parameters. The ONC process is so important in providing the base for post 2001 MYE populations that such an extra step should be taken to ensure the trust in ONS's statistical estimates that Cook (2003c) rightly stresses is so vital.

Strengths and weaknesses of the various administrative data sources

There is a debate between Westminster and its experts on the one hand, and ONS and its staff on the other, as to the value of the administrative record indicators. Westminster argues that the chosen indicators show continuous growth through the 1991-2001 period. ONS argues that many of the indicators are prone to list inflation, mainly because removals from the lists lag behind additions.

ONS uses the following administrative sources or symptomatic indicators for Quality Assurance purposes, which are used to set up plausibility ranges for the 2001 ONC:

- previous mid-year estimates
- adjusted patient records
- child benefit records
- pensioner data
- schools Census data
- birth registrations
- extrapolated mid-year estimates.

Westminster uses the following as change indicators:

- original mid-year estimates (same as previous mid-year estimates)
- patient registers (same as adjusted patient records)
- electoral rolls
- Council Tax returns.

Let us review the arguments for the common indicators.

Previous/original MYEs

Westminster argues for retention of these, of course. But ONS had to revise the 1981-2001 MYE series as a result of the 2001 Census. That is one of the key purposes of a census – a reality check on population estimates. The Quality Assurance process led ONS to review and revise the 1991 MYEs because of the shortfalls in the 30-34 and 35-39 age groups for men, which had been inflated upwards in the 1991 estimates to agree with the national 1991 MYEs rolled forward from the 1981 Census.

Patient records/registers

The biases of NHS records are well known and include 'driftwood', the failure to remove migrants, 'dead-wood', people with duplicate records and 'ghosts', people who have died without being removed from the lists. All parties acknowledge these problems. However, there has been a programme by health authorities to clean their lists (because of financial distortions in GP payments) and Register accuracy improved over the 1990s. ONS reviewed this improvement prior to changing to a radically improved method of measuring internal migration. The 1997-98 review concluded, however, that the registration counts were not good enough yet to rely upon for population counts (Scott and Kilbey 1999). The relationship between the patient register count and the population count differs from place to place: Westminster houses a military population catered for by the Army Medical Service, adjusted for by ONS in their Quality Assurance procedures, and is likely to house a small minority of residents who use private medical services.

Council Tax records

Westminster argues that the council counts residential properties accurately and makes reasonable estimates of the average household size. A population estimate by Westminster City Council based on the dwelling count (occupied residences) for 2001 is 231,162. The MORI survey, which sought a complete enumeration of selected postcodes, produces a population estimate of 214,605 with a 95 per cent confidence band of 154,383 to 274,827.

ONS points out that the MORI method assumes too high an average household size for non-responding households. The likelihood of single member households being missed is much higher than multi-member households.

ONS also argue that not all the dwellings in Westminster contain usually resident households. Many households will occupy more than one residence (first home, second home). Westminster contains a much higher than average proportion of second homes. Table KS016 from the 2001 Census Key Statistics for Local Authorities records that 3.2 per cent of household spaces in England and Wales are vacant and 0.7 per cent are second residences or holiday accommodation. In Westminster the corresponding percentages are 6.5 per cent and 4.6 per cent.

ONS (2003h) have recognised in the document *A Demographic Statistics Service for the 21st Century* (pp. 19-21) that there are a variety of population bases/definitions suited to different purposes, such as delivery of services to all persons spending residence time in an area. Development of core population estimates based on a small, manageable set of different definitions is planned. Council Tax records might provide inputs to one of these alternative definitions but should not be used, themselves, to estimate usual residents as defined in the mid-year estimates.

The electoral register/roll (ER)

Again both parties recognise the difficulties in using the ER as a population surrogate. Westminster argues strongly for its use. ONS did not employ it in their QA. The reason was that the ER is very variable across LAs in coverage of eligible populations also vary.

Westminster argue that it is still an important indicator of change and show how it has grown over the 1990s (City of Westminster, 2002, Figure 2.1). The Parliamentary electorate grew by approximately 10 thousand over the 1991-2001 decade.

It is difficult to judge the merit of the respective arguments without a much deeper study of the relationship between the ERs and MYEs across the country. In 1995 citizens of EU countries (other than the UK) resident in the UK became eligible to vote in local and European elections and were added to the Electoral Registers. A proper comparison would need to look at the ER estimating the numbers involved.

The immigration issue

One of the justifications for the ONS revision of the 1991-2001 population estimate series was concern that the volume of immigration to the Borough had been consistently over-estimated. This view was strongly supported by the evidence presented by the Greater London Authority (Data Management and Analysis), who had taken the view that the OPCS/ONS estimates for Westminster based on demographic roll forward were consistently ahead of a housing capacity adjusted, multistate, cohort-component projection.

Immigrants to Westminster were probably over-estimated for two main reasons:

- The International Passenger Survey recorded a large number of intentions to migrate to central London, many of which were assigned to Westminster. The probability was that the knowledge of these migrants of the geography of London was vague and their actual destinations were much more widely spread.
- The method for assigning Asylum Seekers and Visitor Switchers (ASVS) to London as a whole and to London Boroughs was flimsy. The Home Office estimates that an arbitrary 85 per cent of ASVS migrants have London destinations on slim precise evidence. Country of birth data from the 1991 Census for the main ASVS countries is then used to distribute this 85 per cent to individual London boroughs.

The GLA has carried out a number of London borough projections from 1991 to 2001. The migration base of these projections is information on internal migration and immigration from the 1991 Census. Emigration was estimated by applying internal migration out-migration rates to resident populations and constraining these to gross emigration counts from the IPS. These inputs coupled with vital statistics over the decade and a housing capacity constraint produced projections closer to the ONC figure than any City of Westminster estimate (see Table 2 below). These projections slightly modified (Scenario 8.1) are the ones that the GLA consider provided the best estimate of Westminster's population prior to the 2001 Census and the ONC. Using revised 1991 MYEs would lower the population estimates for 2001 closer to the ONC number.

Table 2: Selected populations for the City of Westminster from the GLA 2000 round projections

Projection	1991	1996	2001
1B – using LPAC Housing Capacity Guidelines	187.7	203.8	212.8
2 – using 1993-98 migration trends after 1999	187.7	203.8	243.6
London Plan – Scenario 8.1	187.7	203.8	215.2

Recommendations

[*These are the personal recommendations of Professor Rees to the Statistics Commission*.]

The following recommendations are put forward for consideration by the Statistics Commission. They arise from the summary and evaluation of the arguments set out above and a review of all of the documents presented to the Commission.

1. Publish the body of evidence along with the Statistics Commission report

The Statistics Commission should assemble an edited set of all the materials in one coherent set of documents (less the confidential transcripts but including the summaries) in date order with permission of the parties as an archive of documents on the Statistics Commission website (in scanned PDF format). This evidence can be summarised in the Statistics Commission report with some editorial comments on the themes and arguments in each document, a revised version of this review and a set of summary recommendations by the Statistics Commission.

2. Encourage the parties to come to a sensible agreement on the results of the address matching exercise and how that might change the Westminster mid-year population estimate for 2001

The agreement of ONS to adjust the Westminster population estimate in the light of the address matching exercise should be supported. There is also likely to be a small revision as a result of the revision of the 2001 and 2002 mid-year population estimates announced in ONS (2003i).

3. Find that the ONC methods were statistically sound and fit for purpose

This conclusion will need to be confirmed by the additional consultancy on the ONC agreed by the Statistics Commission. In support of this conclusion, the following arguments can be advanced. The ONC was thoroughly researched at all stages. Statisticians outside ONS and users were consulted at every step. The volume of research papers produced and made available for scrutiny on the National Statistics website (http://www.statistics.gov.uk) is without precedent. In addition, the methods have been rigorously explained in a set of peer reviewed journal papers (Brown *et al.* 1999; Holt *et al.* 2001). In addition, Hennell (2003) has recently carried out an independent and rigorous review of the consistency of the explanations for the 2001 Census results and finds the ONS arguments on over-compensation for the undercount of young males in 1991 and on the underestimation of their emigration over the period 1981-2001 generally plausible.

4. Ask ONS to prepare a transparent account of the arithmetic of the Westminster ONC population

The principle of the ONC method is widely understood by most knowledgeable census users. The principle is that an estimate of the full population can be made if two estimators are available, as long as these estimators are independent. The details of its application to Estimation Areas and the imputation of adjustments to Local Authorities are probably less widely understood. Even ONS (2001) misses out crucial details that are needed to understand exactly what was done. The adjustment for dependency (where independence does not fully hold) have now been fully

explained (Abbott *et al.* 2003) but probably not widely understood. There is therefore a need for ONS to prepare a simple but fully explicit account of how the ONC estimate was achieved for a local authority (e.g. Westminster), in which the complete of chain of arithmetic is set out.

5. Support the investigation of how alternative population bases can be estimated and used

Part of the Westminster problem results from the need to support a population active in the borough that does not match the usually resident (in principal or first home) definition used in the census. ONS (2003h) proposes a set of alternative measures, the feasibility of which should be investigated, in conjunction with potential users, ODPM, the LAs, the NHS, for example.

6. Urge that swift consideration be given to the improvement of international migration estimates

ONS have already put forward a number of possible measures that could be taken (ONS 2003h, p.28). The evaluation of these measures can be done quite swiftly. They include introduction of landing cards for all incomers and embarkees, a successful practice in many other countries. This would probably need legislation to enact. Prior to this being passed the Labour Force Survey and the proposed Integrated Household Survey could be extended to include questions on emigration (from households that continue to reside in the UK).

7. Support the proposals for the development of a national address register

ONS (Cook 2003c) proposes to develop, in collaboration with other parties (GROS, NISRA, OSGB, OSNI, Royal Mail, LGA, ODPM, NHS) a comprehensive Address Register, agreed as the national standard. This would build on existing registers and the collaborative project that has enhanced the national postcode directory (the All Fields Postcode Directory enhanced by the Gridlink Project). This address register will help improve the operation of national surveys or mid-term Censuses and prepare the ground for the creation later in the decade of a national population register, should Parliament approve the creation of such a valuable information resource.

8. Support a feasibility study into a mid-term (2006) Census for London or for selected hard to enumerate local authorities

Such a mid-term Census would enable ONS to test the viability of their new population estimates, their new international migration measures and the utility of the national address register, well in advance of the next decennial census in 2011.

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APPENDIX A

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APPENDIX B

Glossary of abbreviations used

ASVS Asylum Seekers and Visitor Switchers
Important immigrant stream into the country. Visitor switchers are person who enter the country as visitors but then apply to stay.

CCS Census Coverage Survey
Large household survey administered shortly after the 2001 Census in order to estimate missing households and individuals.

DSE Dual System Estimator
The technique that uses two estimators (the Census count and Census Coverage Survey) to arrive at an estimate of the total population of the country at the time of the 2001 Census.

ER Electoral Register
A list of all persons who have the right to vote in one or more types of elections. It was traditionally a count in mid-October of each year (published the following mid-February) but now electors who have moved can register between the annual electoral enumerations.

ESRC Economic and Social Research Council
Funds social science research and postgraduate training in UK universities and recognized research institutions.

GLA Greater London Authority
The upper tier Local Government Authority for London. It has a team of experts who conduct demographic research on behalf of the GLA and London Boroughs.

GROS General Register Office Scotland
The government agency responsible for the population census and demographic statistics in Scotland. Collaborates closely with ONS and NISRA in the conduct and processing of the census of population.

IPS International Passenger Survey
A sample survey of incoming and outgoing passengers at the UK's principal airports and seaports. The survey contains a question about migration intention and destination (area within the country for immigrants or country abroad for emigrants).

LA Local Authority
The general term for unit of Local Government. The exact title and functions of LAs differ from one part of the country to another. For details, see “A Beginners’ Guide to UK Geography” on the ONS website (http://www.statistics.gov.uk/.

LGA Local Government Association
The organisation that represents the interests of local government.

MORI Market Opinion Research International
One of the UK’s largest market research and consultancy firms.

MYE Mid-Year Estimate
The estimated population of a territorial unit at midnight on 30 June/1 July.

NHS National Health Service
The public body providing health care for most of the UK’s population.

NISRA Northern Ireland Statistics and Research Agency
The government agency responsible for the population census and demographic statistics in Northern Ireland. Collaborates closely with ONS and GROS in the conduct and processing of the census of population.

ODPM Office of the Deputy Prime Minister
The central government department responsible for local government in England and Wales that allocates to Local Authorities the central government grant for support of local services and functions. The MYE is a very important component in the resource allocation formula used to distribute this multi-billion pound grant.

ONC One Number Census
The procedures used to produce a robust estimate of the census population and constituent households and individuals. The procedures are necessary because of the rising level of non-response in the decennial census.

ONS Office for National Statistics
The government agency responsible for the population census and demographic statistics in England and Wales. Collaborates closely with GROS and NISRA in the conduct and processing of the census of population. It also has responsibility for the quality assurance and co-ordination of national statistics for the whole UK and in reporting those statistics to national and international agencies.

OPCS Office of Population Censuses and Surveys
The government agency formerly responsible for the population census and demographic statistics in England and Wales. It was amalgamated with the Central Statistical Office in 1996 to form the Office for National Statistics.

PAF Post Office Address File
The database of addresses used by the Post Office/Royal Mail for delivery of mail to residences, organisations and businesses. Published quarterly and used widely by government agencies, local authorities and academic researchers.

QA Quality Assurance
The procedures for checking the validity of population statistics (e.g. from the ONC).

UA Unitary Authority
One of the categories of Local Government units.

UK United Kingdom of Great Britain and Northern Ireland
The full name of the country.

APPENDIX C:

Derivation of the dual system (DSE) estimator

The DSE formula is derived from the hypothesis of independence in probability theory. We first develop a notation to represent the estimation problem. Table 1 defines the variables.

Table 1: A notation for counts from the full Census and the Census Coverage Survey

Census	Census Coverage Survey Counted S	Not Counted s	Totals
Counted C	N(C,S)	N(C,s)	N(C)
Not Counted c	N(c,S)	N(c,s)	N(c)
Totals	N(S)	N(s)	N(T)

The variables and subscripts in the table are defined as follows:

N = number of people

C = counted in the Census Enumeration

c = not counted (missed) in the Census Enumeration

S = counted in the Census Coverage Survey

s = not counted (missed) in Census Coverage Survey

T = total

The accounting relationships for the row, column and grand totals embedded in the table are:

N(C) = N(C,S) + N(C, s)

N(c) = N(c,S) + N(C, C)

N(S) = N(C,S) + N(c, S)

N(s) = N(C,s) + N(c, s)

N(T) = N(C) + N(c) = N(S) + N(s)

The Hypothesis of Independence states that the joint probability of two events is the product of the probability of one event multiplied by the probability of the other event. Under the hypothesis of independence the joint probability of being missed in the census and in the census coverage survey is as follows:

$$P(c,s) = P(c) \times P(s) \quad (1)$$

where P = probability, P(c,s) is the joint probability of being missed in both census and survey, P(c) is the probability of being missed in the census and P(s) is the probability of being missed in the survey.

The number missed is therefore:

$$N(c,s) = P(c,s) \times N(T) = P(c) \times P(s) \times N(T) \quad (2)$$

The dual system estimator can be stated in this notation as:

$$N(T) = N(C) \times N(S)/N(C,S) \quad (3).$$

We need to derive equation (3) from equation (1).

It is easiest if we observe that the hypothesis of independence also means that we estimate the probability of being counted in both the Census and the Survey as:

$$P(C,S) = P(C) \times P(S) \quad (4)$$

and that:

$$N(C,S) = P(C,S) \times N(T) \quad (5).$$

Substituting the RH side of equation (4) for P(C,S) in equation (5), we obtain

$$N(C,S) = P(C) \times P(S) \times N(T) \quad (6).$$

We define the probability of being counted in the Census as:

$$P(C) = N(C)/N(T) \quad (7)$$

and the probability of being counted in the Survey as:

$$P(S) = N(S)/N(T) \quad (8)$$

so that the estimate of the number counted in both Census and Survey is:

$$N(C,S) = [N(C)/N(T)] \times [N(S)/N(T)] \times N(T) \quad (9).$$

Cancel N(T) on the right hand side, multiply both sides by N(T) and divide both sides by N(C,S). This yields

$$N(T) = N(C) \times N(S) / N(C,S) \quad (10).$$

This is the Dual System Estimator for the total population of interest.