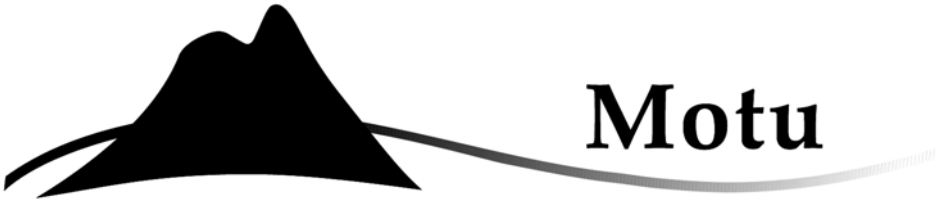


# Defining Areas
# Linking Geographic Data in New Zealand

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# Abstract

This paper develops a match quality statistic to quantify the trade-off between 'specificity' and 'completeness' when aggregating one regional aggregation to another. We apply this statistic to calculate the degree of mismatch between various regional aggregations for New Zealand using 1991 and 2001 Census Data. A program to calculate mismatch statistics is included as an appendix, as a Stata® ado file.



JEL classification
R1 - General Regional Economics
C80 General (Data Collection and Data Estimation Methodology; Computer Programs)

Keywords
Match quality; Geographic Aggregation;

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# 1 Introduction

Empirical researchers are often required to combine data series that are released at different regional aggregations. It is important to understand the degree of concordance between the different aggregations when using such data. This paper develops a match quality statistic to quantify the trade-off between 'specificity' and 'completeness' when combining data that are aggregated differently. We apply this match quality statistic to common New Zealand geographical aggregations and report key results. The aim of this paper is to provide information that will allow researchers working with regionally aggregated data to make informed decisions regarding the use of such data.

There are five commonly used aggregations for New Zealand geographical data: mesh blocks, area units, territorial local authorities (districts), regional councils, and aggregated regional councils. Another classification, based on travel-to-work data, is labour market areas (Newell and Papps (2001)). These various geographical aggregations partition New Zealand into different sub-units. The empirical section of the paper applies our match quality statistic to several key regional matches, and highlights the specific areas that are most problematic for each. We use the match quality statistic to investigate how best to group territorial local authorities to approximate labour market areas, a match that will be used in an upcoming Motu research project.

Our match quality statistic indicates that the match between territorial local authorities and regional councils is high. Franklin District, which overlaps Auckland Regional Council and Waikato Regional Council, is the main exception. The concordance between labour market areas and regional councils is also high. Northland, Waikato, Manawatu-Wanganui, Southland, and Otago are the regional councils with the worst matches. For the grouping of TAs to approximate LMAs, we choose to divide Wellington region into two sub-regions, and Auckland region into three sub-regions.

The plan of this paper is as follows: Section Two explains the geographical areas in use in New Zealand. Section Three discusses match quality and derives the statistic used to calculate the degree of mismatch between the

regions. Section Four discusses the empirical findings. Two aggregations are examined in more depth: TA to regional council (RC) and labour market areas (LMA) to aggregate RC. Section Five applies the match quality statistic to create a new regional aggregation, Aggregated TAs, for use in a forthcoming Motu project on regional labour market adjustment. Section Six briefly concludes.

# 2 Overview of Geographical Areas

The geographical aggregations used in this paper are outlined in Table 1. Two of these aggregations (mesh block and area units) are administratively defined by Statistics New Zealand, and two aggregations (TA and RC) are legislatively defined. There are two aggregated groupings (Aggregated TA and Aggregated RC). The other aggregation, labour market areas (LMAs), is a functional aggregation based on the geographical area where people live and work, using 1991 Census Data (Newell and Papps (2001)). This aggregation has high economic appeal for labour economics research as it is based on actual labour market behaviour of individuals.

The most disaggregated classification is the meshblock (MB) (over 41 000 MBs in New Zealand). MBs are then combined to form area units, the second most disaggregated classification. There are 1860 area units in New Zealand. The area units can then be combined to form any of the other classifications. The remaining classifications vary considerably in size: there are 74 TAs, 58 LMAs, 16 regional councils, 14 aggregated TAs, and 12 aggregated regional councils.

**Table 1: Types of Regional Aggregation**

| Name | Number | Description |
|---|---|---|
| Mesh Block (MB)[1] | 41376 (2006) | The mesh block is the basic 'building block' of higher aggregations. |
| Area Unit (AU)[1] | 1860 | Each AU is approximately the size of a city suburb. |
| Territorial Local Authority (TA)[1] | 73 (excluding Chatham Islands) | A TA is a legislatively defined government entity. Examples are Wellington City, Far North District. |
| Labour Market Area (LMA) | 58 | See Newell and Papps (2001). A labour market is the geographical area where people live and work. |
| Regional Council[1] | 16 | A regional council is a legislated local government entity[1]. Examples are Wellington Regional Council, Waikato Regional Council. |
| Aggregated RC[2] | 12 | The aggregated regional councils are regional councils (as above) with:<br>1. Marlborough, Tasman, Nelson and West Coast Regions aggregated together.<br>2. Gisborne and Hawkes Bay Regions aggregated together. |

1. For a more detailed discussion of the geographic classifications maintained by Statistics New Zealand and the changes over time, see the following website: http://www.stats.govt.nz/statistical-methods/classifications/default.htm
2. The Aggregated RC grouping is used in the publication of the Statistics New Zealand Household Labour Force Survey.

# 3 Quality of Match

The aim of this paper is to investigate how well each regional aggregation matches the other regional aggregations. There are four possible types of matches between classifications: one-to-one, many-to-one, one-to-many, and many-to-many. For example, combining area units to form one regional council is a many-to-one match, as many area units are used to form the one regional council. The four types of matches are outlined in Table 2.

Matches that are one-to-one do not cause difficulty when working with data, as the categories are perfectly comparable. Matches that are many-to-one will also be easily resolved, as data can be aggregated up to the new level. The other two categories, one-to-many, and many-to-many, are more difficult to resolve.

[1] Regional councils are generally larger than TAs, although there are four unitary authorities (regional councils that are identical to TAs): Gisborne, Malborough, Nelson, and Tasman.

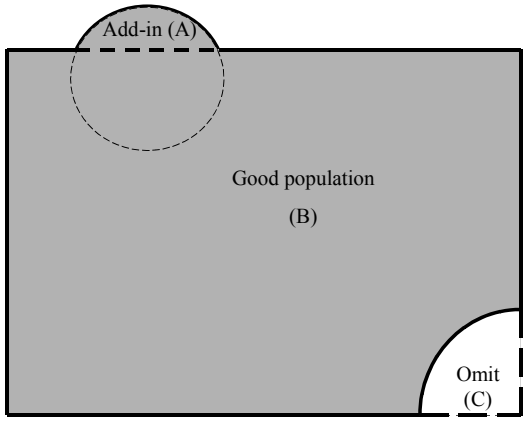
**Table 2 Relationship types between one geographical aggregation and another level of aggregation.**

| | Old category | New category | Geographical example |
|---|---|---|---|
| 1 | One-to-one | | Area unit to area unit. |
| | A10 | B10 | |
| 2 | Many-to-one | | Regional council to aggregated regional council e.g. combining West Coast, Tasman, Marlborough, and Nelson Regional Councils to form one aggregated regional council grouping. |
| | A10 | B10 | |
| | A20 | B10 | |
| 3 | One-to-many | | Regional council to territorial local authority e.g. Northland Regional Council into Far North District, Whangarei District, and Kaipara District |
| | A10 | B11 | |
| | A10 | B12 | |
| 4 | Many-to-many | | TA to labour market area. e.g. Waipara District is split between LMA 5 and LMA 6, and Rodney District is split between LMA 6 and LMA7. |
| | A10 | B11 | |
| | A10 | B12 | |
| | A20 | B12 | |

To motivate the match quality statistic developed below, consider the case of Franklin District. Franklin District straddles the border between Auckland Regional Council and Waikato Regional Council. Approximately 70% (14,400 people in 2001) of Franklin's population are in Auckland Regional Council, and 30% (37,200 people in 2001) are in Waikato Regional Council. If Franklin District is allocated to Auckland Regional Council, then approximately 14,400 (2001 population) extra people are included in the population count for Auckland Regional Council, and 14,400 fewer people in Waikato Regional Council. If we impose a minimum requirement ("cut-off") for the proportion of a district's population that must be included in one regional council for it to be allocated to that region, say 90%, then Franklin District would not be allocated to Auckland Regional Council or Waikato Regional Council. In this case the entire Franklin population of 51,600 people (2001 population) would be unallocated. This suggests that there are three factors that will influence the quality of match: mismatch occurring due to add-ins, mismatch occurring due to omissions, and mismatch occurring due to non-allocation.

Figure 1 illustrates the issue. The rectangle in Figure 1 represents a region, for example a regional council. The circle represents a sub-region, for example a TA. The shaded area (with extra area 'A' and without area 'C') is the population that is counted for that region. The actual population of the region is 'B+C'. Note that Area C will be the add-in population for a neighbouring region, and Area A will the omission population for a neighbouring population. To include the TA in the regional council, we can impose a requirement that there must be a certain proportion (the 'cut-off' value) of the TA's population contained in the regional council . If the proportion is below this value, then the TA will not be counted in the region's population, and will be either counted in an adjoining region or unallocated. For each region, it is possible to calculate the degree of mismatch resulting from add-in error and from omission error.

**Figure 1: Illustration of match quality statistic**




The match quality statistic for each region are calculated as follows:

*Add-in match quality* statistic for the region = $1 - m_1$, where $m_1 = \frac{A}{B+C}$ is the degree of mismatch due to add-in population, as a proportion of the actual population.

*Omission match quality* statistic for the region = $1-m_2$, where $m_2 = \frac{C}{B+C}$ is the degree of mismatch due to omitting population, as a proportion of the actual population.

If a sub-region is omitted from a region, it is either included in an adjacent region's population count (hence contributing to add-in error for that region), or may be unallocated (i.e. not including in any region's population count), depending on the cut-off value. As long as the add-in area (area C in Figure 1) is not larger than the actual population, the add-in match quality statistic is in the range [0,1], with 1 indicating a perfect match and 0 indicating a zero match. This is always true if the cut-off value greater than 0.50[2], a condition that is imposed in all subsequent calculations. The omission match quality statistic is always in the range [0,1], with 1 indicating a perfect match and 0 indicating a zero match.

Nationwide (summing over all regions), it must be that all population that is omitted from one region is either added into another region or unallocated. Thus, the following identity holds:

$$1-\sum_j m_2^j\left(\frac{pop^j}{\sum_j pop^j}\right)=1-\sum_j m_1^j\left(\frac{pop^j}{\sum_j pop^j}\right)-\frac{\sum unallocated\ pop}{\sum_j pop^j} \qquad (1)$$

where $m_2^j$ is the omission mismatch for region j; $m_1^j$ is the add-in mismatch for region j and the last term calculates the nationwide unallocated mismatch, by summing the sub-regions which are unallocated at the cut-off level and dividing by national population.

[2] The condition can also be true for lower cut-off values, as long as the sub-region is small relative to the actual regional population. However, a lower cut-off value gives rise to an additional complication in that a sub-region can qualify for inclusion in more than one region. Restricting the cut-off to values greater than 0.50 ensures that sub-regions are allocated to at most one region. A value of zero for the add-in match quality statistics arises only in the case where an entire region accounts for half of a sub-region's population.

We define the nationwide match quality statistic to be the left hand side of this equality, viz.: $1-\sum_j m_2^j(\frac{pop^j}{\sum_j pop^j})$. The match quality statistic can be decomposed into an add-in mismatch component and an unallocated mismatch component. As the cut-off point determines how much population will be omitted, as the cut-off point increases (the match is required to be more specific), the nationwide match quality statistic will decrease.

A simple example is given below to illustrate how this statistic calculates the quality of match between regions. Table 3 shows how the population is distributed between three TAs and two RCs. We are interested in finding the quality of match between TA and RC. α measures the proportion of the TA's population that is contained in the regional council; 100% of TA A's population is in RC1, but TA B's population is split, with 95% in RC 1 and 5% in RC 2.

**Table 3: Example of match quality statistic**

| TA | Population | α | RC | Allocated RC if cut-off is ≤0.95 | Allocated RC if cut-off >0.95 |
|---|---|---|---|---|---|
| A | 30 | 100% | 1 | 1 | 1 |
| B | 95 | 95% | 1 | 1 | Unallocated |
| B | 5 | 5% | 2 | 1 | Unallocated |
| C | 120 | 100% | 2 | 2 | 2 |

When the cut-off point is ≤0.95, TA B is allocated to RC 1. This means that 5 extra people are included in RC 1, and 5 people are omitted from RC 2. However, if the cut-off is >0.95 (i.e. a very close match is required), we cannot allocate TA B to either RC 1 or RC 2, as neither alpha value for TA B reaches the cut-off. Table 4 below shows the total population, add-in population and omitted population for a cut-off of 0.9 and 1.00.

**Table 4: Population for match quality statistic**

| | Actual population | Allocated population | | Add-in population | | Omitted population | |
|---|---|---|---|---|---|---|---|
| RC | | Cut-off =0.90 | Cut-off = 1.00 | Cut-off =0.90 | Cut-off = 1.00 | Cut-off =0.90 | Cut-off = 1.00 |
| 1 | 125 | 130 | 30 | 5 | 0 | 0 | 95 |
| 2 | 125 | 120 | 120 | 0 | 0 | 5 | 5 |

With the information in Table 4, it is possible to calculate the add-in and omission match quality statistics for each region, and the overall match quality statistic.

**Table 5: Calculation of match quality statistics**

| Cut-off value | RC 1 | | RC 2 | | Total match quality | Total add-in match quality | Total unallocated match quality |
|---|---|---|---|---|---|---|---|
| | Add-in match quality | Omitted match quality | Add-in match quality | Omitted match quality | | | |
| 0.90 | 0.96 | 1 | 1 | 0.96 | 0.98 | 0.98 | 1 |
| 1.00 | 1 | 0.24 | 1 | 0.96 | 0.60 | 1 | 0.60 |

When the cut-off point is 0.90, TA B is counted as part of RC 1. This means that RC 1 has some add-in mismatch, and RC 2 has some omitted mismatch. When the cut-off is 1, the match is required to be exact between TA and RC. Hence, the add-in match quality statistic is 1 for both RC 1 and RC 2 (i.e. there is no add-in mismatch).

The total match quality statistic is 0.98 if the cut-off value is 0.90, and 0.60 if the cut-off is 1.00. The total match quality statistic can be decomposed into add-in match quality and unallocated match quality. When the cut-off is 1, all mismatch is due to unallocated mismatch, with a statistic of 0.60. This means that 40% of the population is not counted. When the cut-off is 0.90, all the population is counted, hence the mismatch is due entirely to add-in mismatch.

# 4 Empirical Findings

## 4.1 Data

This paper uses the above match quality statistics to quantify the quality of match between the five different regional aggregations based on population. We use 1991 and 2001 Census population, coded to 2001 area units. Area units that are outside territorial authorities (for example, in the ocean) or are on the Chatham Islands are excluded[3].

[3] We use 1801 of the 1860 area units, excluding 59 area units.

First, some overall summary statistics are displayed for each of the concordances. We present these results using a cut-off value of 0.90, and provide results for other cut-offs in the appendix. This is to give an overall impression of the quality of match between each type of aggregation. Two common aggregations are then examined in more detail: TA to regional council (RC) and labour market areas (LMA) to aggregate RC.

## 4.2 Overview of Results

Table 7 and Table 7 summarise the quality of match for 1991 and 2001 data. The tables give the overall match quality statistic for a cut-off of 0.90. Tables for a range of other cut-off values are in Appendix B. The values in the table are weighted by population. The range of the match quality statistic is [0,1] under the imposed restriction that the cut-off value is greater than 0.50, with 1 indicating a perfect match.

Area units are the basic 'building blocks' – it is possible to construct any higher level of aggregation starting with the AU. Hence, the match between area units and each of the other aggregations is 1 in all cases.

The matches that are poor (match quality statistic less than 0.50) are when the 'from' aggregation is larger than the 'to' aggregation. For example, going from regional councils to labour market areas is a poor match, with a match quality statistic of 0.0229 (for 2001). This is because each regional council is much larger than each labour market area.

Common data series are aggregated either in TA or aggregate regional council terms. The match quality statistic between TA and RC is 0.9858 (0.9847) in 1991 (2001). The match between TA and aggregated regional councils is the same. This indicates that none of the mismatches between TA and regional councils occur in regions that are combined in the aggregated regional council grouping (i.e. Gisborne and Hawke's Bay; Nelson, Tasman, Marlborough, and West Coast).

**Table 6: 1991 Concordance between Regional Aggregations, cut-off = 0.90**

| From | AU | TA | LMA | RC | AggRC |
|---|---|---|---|---|---|
| AU | 1 | 1 | 1 | 1 | 1 |
| TA[4] | 0.0025 | 1 | 0.7388 | 0.9858 | 0.9858 |
| LMA | 0 | 0.2474 | 1 | 0.9463 | 0.9665 |
| RC | 0 | 0.0444 | 0.0239 | 1 | 1 |
| AggRC | 0 | 0 | 0 | 0.9052 | 1 |

**Table 7: 2001 Concordance between Regional Aggregations, cut-off=0.90**

| **From** | AU | TA | LMA | RC | AggRC |
|---|---|---|---|---|---|
| AU | 1 | 1 | 1 | 1 | 1 |
| TA | 0.0019 | 1 | 0.7330 | 0.9847 | 0.9847 |
| LMA | 0 | 0.2289 | 1 | 0.9473 | 0.9683 |
| RC | 0 | 0.0446 | 0.0229 | 1 | 1 |
| AggRC | 0 | 0 | 0 | 0.9091 | 1 |

The LMA to individual TA match is very poor, with a match statistic of 0.2474 (0.2289) for 1991 (2001). Although LMA and TAs are not dissimilar in size (73 TAs vs. 58 LMAs), the low statistic indicates that there are many border overlaps. The LMA to aggregate RC match has a much higher match quality statistic, at 0.9665 (0.9683) for 1991 (2001). These results suggest that using aggregated regional council boundaries gives a good approximation to groups of labour market areas.

We investigate the TA to RC match and the LMA to aggregated RC match in more detail below to identify the specific areas that the overlaps occur.

## 4.3 Key Geographical Concordances

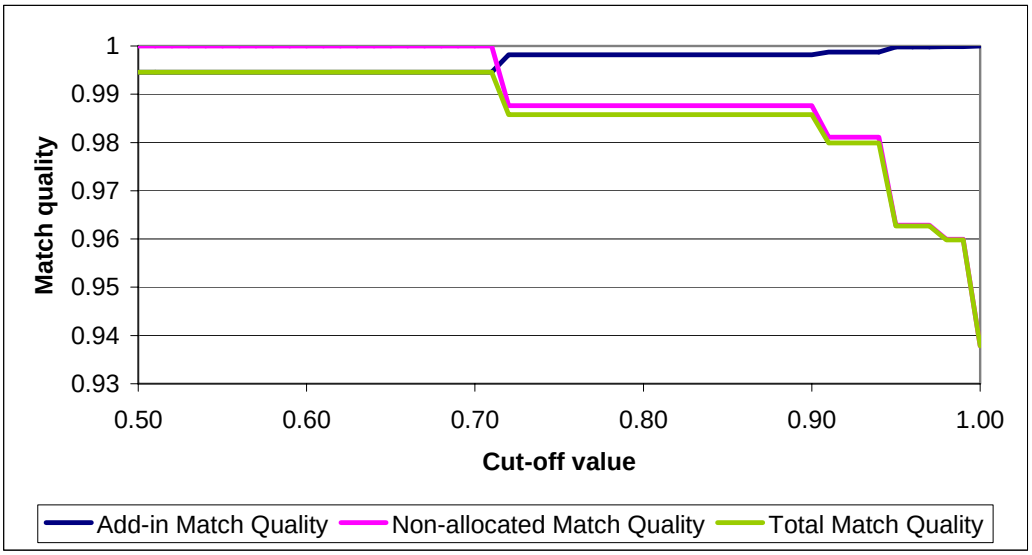
### 4.3.1 Territorial Authorities and Regional Council Concordance

The aggregate match quality statistic for TA to regional council is 0.9858 in 1991 and 0.9847 in 2001, using a cut-off value of 0.90. Figure 2 examines how the component match quality statistics changes as the cut-off

[4] One would expect that the match from TA to AU would also be 0 because of the difference in size between the two areas. However, there is one TA, TA 26 (Kawerau District, in the Bay of Plenty) that consists of only 1 area unit (AU 542600). TA 26 had a population of 8,340 people in 1991 and 6,975 people in 2001.

requirement changes, using 1991 data. The graph for 2001 is very similar and is contained in Appendix C.

**Figure 2: 1991 match quality of TA to RC, varying cut-off**




The total match quality statistic is highest using a cut-off less than 0.72. The total match quality statistic has value 0.9946 at these points. The overall match quality statistic then stays constant at a value of 0.9858 until a cut-off point of 0.91, before decreasing over the remainder of the interval. Appendix Table 8 gives the details of the population breakdown by TA and RC. This information can be used to explain the transition seen in the graph above.

When cut-off is less than 0.72, Franklin District (71% in Auckland Regional Council, 29% in Waikato Regional Council, 1991 values) is included in Auckland Regional Council. As all the national population is being counted, mismatch is entirely due to add-in mismatch, hence unallocated match quality is 1, and add-in match quality is 0.9946 (the value of the total match quality statistic). However, if the cut-off is higher than 0.72, Franklin District is not allocated to either regional council. As a consequence, the add-in match quality statistic improves, but unallocated match quality statistic worsens. The second jump in the graph is at a cut-off of 0.91. This is the critical cut-off for Waitaki District (90.7% Otago Regional Council, 9.3% Canterbury Regional Council, 1991 population). At a cut-off point lower than 0.91, Waitaki is included in Otago Regional Council. At higher cut-offs, Waitaki is unallocated, which causes the

distribution of the mismatch to shift again from add-in mismatch to unallocated mismatch. Finally, at a cut-off of 1 which is a requirement that the match is exact, all mismatch is due to unallocated population and there is no add-in mismatch.

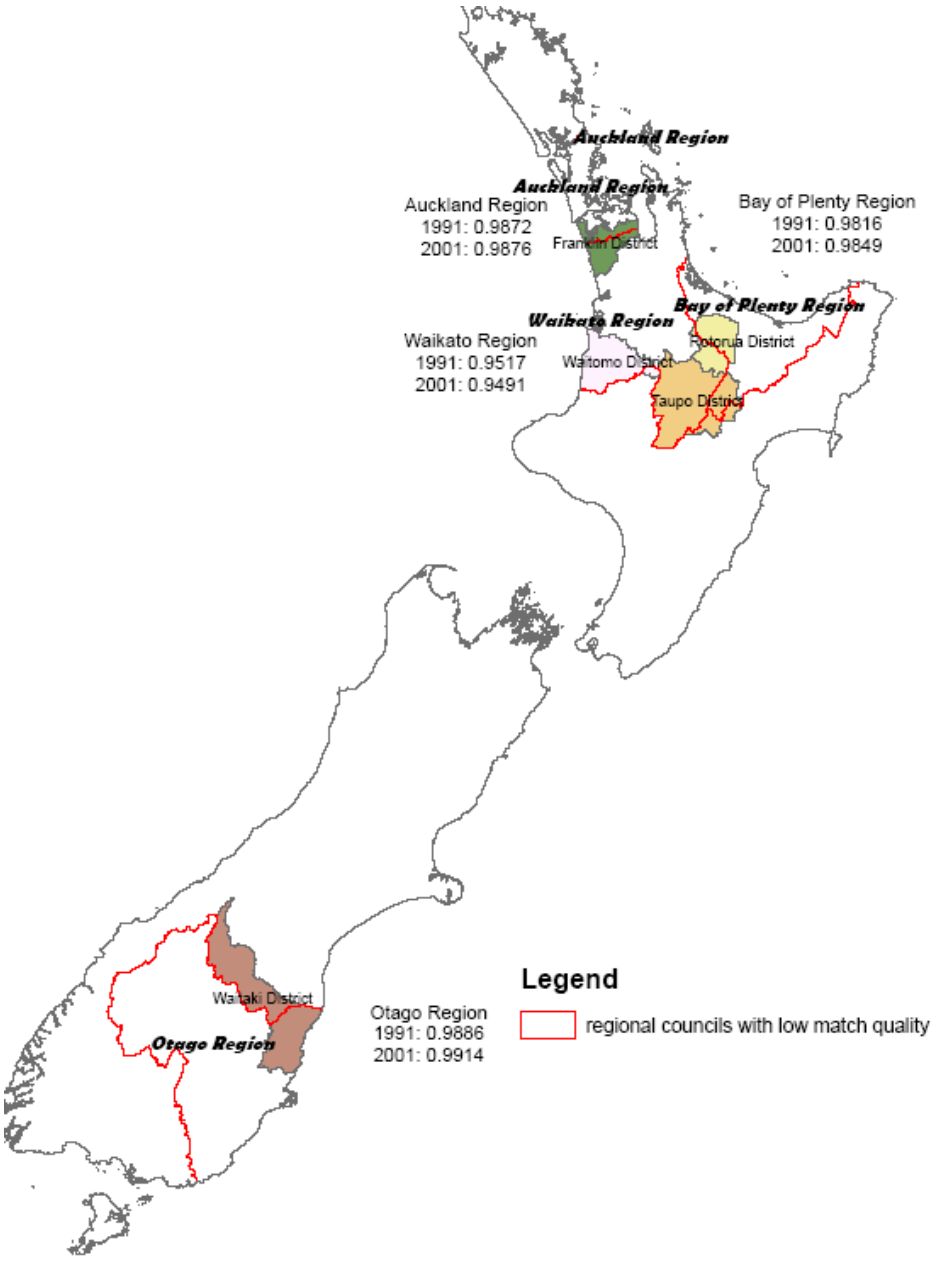
Figure 2 illustrates the trade-off between specificity (minimising misallocation, by using a higher cut-off level) and completeness (minimising omissions, as reflected in the size of the unallocated mismatch). At a cut-off value less than 0.72 all TAs are allocated, hence all the mismatch is purely from add-in mismatch. This is a complete match insofar as it utilises all the population data. However, there is considerable noise in such an allocation, with 28% of Franklin District's population allocated erroneously at this cut-off value. As the cut-off value increases the allocation becomes more specific as the add-in error decreases, but at the expense of completeness, as some population becomes unallocated.

Table 8 below lists the match quality statistics for each region, using the cut-off point that maximises overall match quality (cut-off = 0.71). The region's population (weighting factor) is also given. The table displays the omission mismatch statistic, add-in mismatch statistic, and a combined match quality statistic for each region. For example, Auckland Region has a match quality of 0.9872, with the mismatch entirely due to add-in mismatch, whereas Hawke's Bay has a match quality of 0.9995, with mismatch entirely due to omission mismatch. The national match quality statistic (weighted by population) is 0.9946 (0.9947) in 1991 (2001). Four regional councils, Auckland, Waikato, Bay of Plenty, and Otago, have a match quality statistic less than 0.99. These regions are shown in Figure 3, with the position of the TAs that contribute to the overlap.

The region with the lowest match quality statistic for both years is Waikato Regional Council, with a particularly low omission match quality statistic. This omission mismatch is due to the placement of Franklin TA. In 1991 (2001) 12,111 (14,424) people in Franklin District were counted in Auckland Regional Council instead of in Waikato Regional Council. These extra people contribute to the add-in mismatch for Auckland Region. Waikato Regional Council also has a slight add-in mismatch due to Taupo District. Over 99% of Taupo's population is in Waikato Regional Council, hence Taupo District is allocated to Waikato Regional Council, but as a result a small number of people

from Bay of Plenty Regional Council and Hawke's Bay Regional Council are miscounted (this totals 264 (250) people in 1991 (2001)). Bay of Plenty Regional Council has add-in mismatch (add-in match quality statistic is 0.9827 in 1991) due to the position of Rotorua District, which has 5.7% (3534 people, 1991) in Waikato Regional Council.

**Figure 3: Map of overlapping TAs for RCs with match quality statistic less than 0.99**



The only South Island Regional Council with a match quality statistic less than 0.99 is Otago Regional Council. This is entirely due to add-in error (omission mismatch statistic is 1 for both 1991 and 2001); Waitaki TA, is allocated to Otago, but has population split between Canterbury (9.3%, 1991) and Otago (90.7%, 1991). Although this results in a population omission from Canterbury, it is relatively minor and hence does not greatly affect Canterbury's omission match quality statistic.

**Table 8: Match quality statistic for TA to RC match, using a cut-off of 0.71**

| | 1991 | | | | 2001 | | | |
|---|---|---|---|---|---|---|---|---|
| Regional council | Add-in statistic | Omission statistic | Match quality | Share of national population | Add-in statistic | Omission statistic | Match quality | Share of national population |
| Northland | 1 | 1 | 1 | 3.76% | 1 | 1 | 1 | 3.75% |
| Auckland | 0.9872 | 1 | 0.9872 | 27.97% | 0.9876 | 1 | 0.9876 | 31.01% |
| Waikato | 0.9990 | 0.9527 | 0.9517 | 9.81% | 0.9990 | 0.9501 | 0.9491 | 9.57% |
| Bay of Plenty | 0.9827 | 0.9989 | 0.9816 | 6.05% | 0.9857 | 0.9992 | 0.9849 | 6.41% |
| Gisborne | 1 | 1 | 1 | 1.31% | 1 | 1 | 1 | 1.18% |
| Hawke's Bay | 1 | 0.9995 | 0.9995 | 4.10% | 1 | 0.9992 | 0.9992 | 3.83% |
| Taranaki | 0.9978 | 1 | 0.9978 | 3.17% | 0.9983 | 1 | 0.9983 | 2.75% |
| Manawatu-Wanganui | 0.9999 | 0.9986 | 0.9985 | 6.66% | 0.9998 | 0.9989 | 0.9987 | 5.89% |
| Wellington | 1 | 1 | 1 | 11.87% | 1 | 1 | 1 | 11.34% |
| West Coast | 1 | 1 | 1 | 0.94% | 1 | 1 | 1 | 0.81% |
| Canterbury | 1 | 0.9954 | 0.9954 | 12.99% | 1 | 0.9967 | 0.9967 | 12.89% |
| Otago | 0.9886 | 1 | 0.9886 | 5.26% | 0.9914 | 1 | 0.9914 | 4.86% |
| Southland | 1 | 1 | 1 | 2.96% | 1 | 1 | 1 | 2.44% |
| Tasman | 1 | 1 | 1 | 1.01% | 1 | 1 | 1 | 1.11% |
| Nelson | 1 | 1 | 1 | 1.08% | 1 | 1 | 1 | 1.11% |
| Marlborough | 1 | 1 | 1 | 1.04% | 1 | 1 | 1 | 1.06% |

### 4.2.2 Labour Market Areas and Aggregated Regional Councils

The aggregate match quality statistic for LMA to aggregate regional council is 0.9665 in 1991 and 0.9683 in 2001, using a cut-off value of 0.90. Figure 4 examines how the component match quality statistics change as the cut-off requirement changes, using 1991 data. The graph for 2001 is very similar and contained in Appendix C.

The overall match quality remains fairly constant for a cut-off point between 0.5 and 0.95, and then starts to worsen rapidly. This decrease in the

overall value of the match quality statistic is due to the increase in population that is unallocated. Appendix Table 9 details the population overlaps between LMAs and AggRCs, which can be used to interpret the graph above. The first decrease in the match quality statistic occurs at a cut-off of 0.68. This is the boundary value for LMA 6, which is split between Northland (32.9%, 1991) and Auckland (67.1%, 1991) Regional Councils. At a cut-off higher than 0.68, LMA 6 becomes unallocated, hence decreasing the unallocated match quality statistic. A cut-off of 0.77 is the boundary value for LMA 38, which is split between Manawatu-Wanganui (76.8%, 1991) and Wellington (23.2%, 1991). The next decrease occurs at a cut-off of 0.88, which is the boundary for LMA 57 (Southland: 87.5%, Otago: 12.5%, 1991). As the cut-off increases, the unallocated mismatch increases. At a cut-off of 1, all mismatch is due to non-allocation, giving an overall match quality statistic of 0.7944.

**Figure 4: 1991 match quality of LMA to AggRC, varying cut-off**

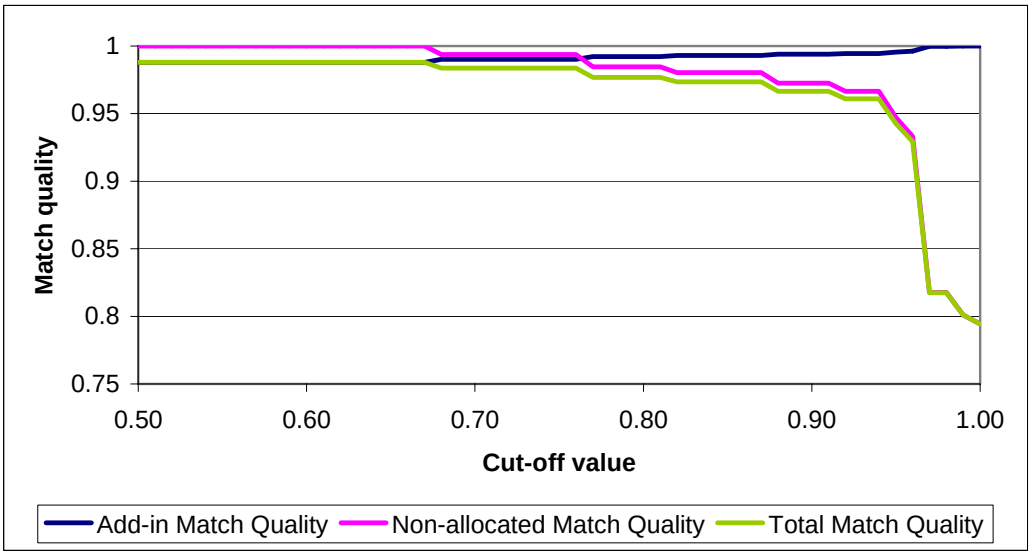
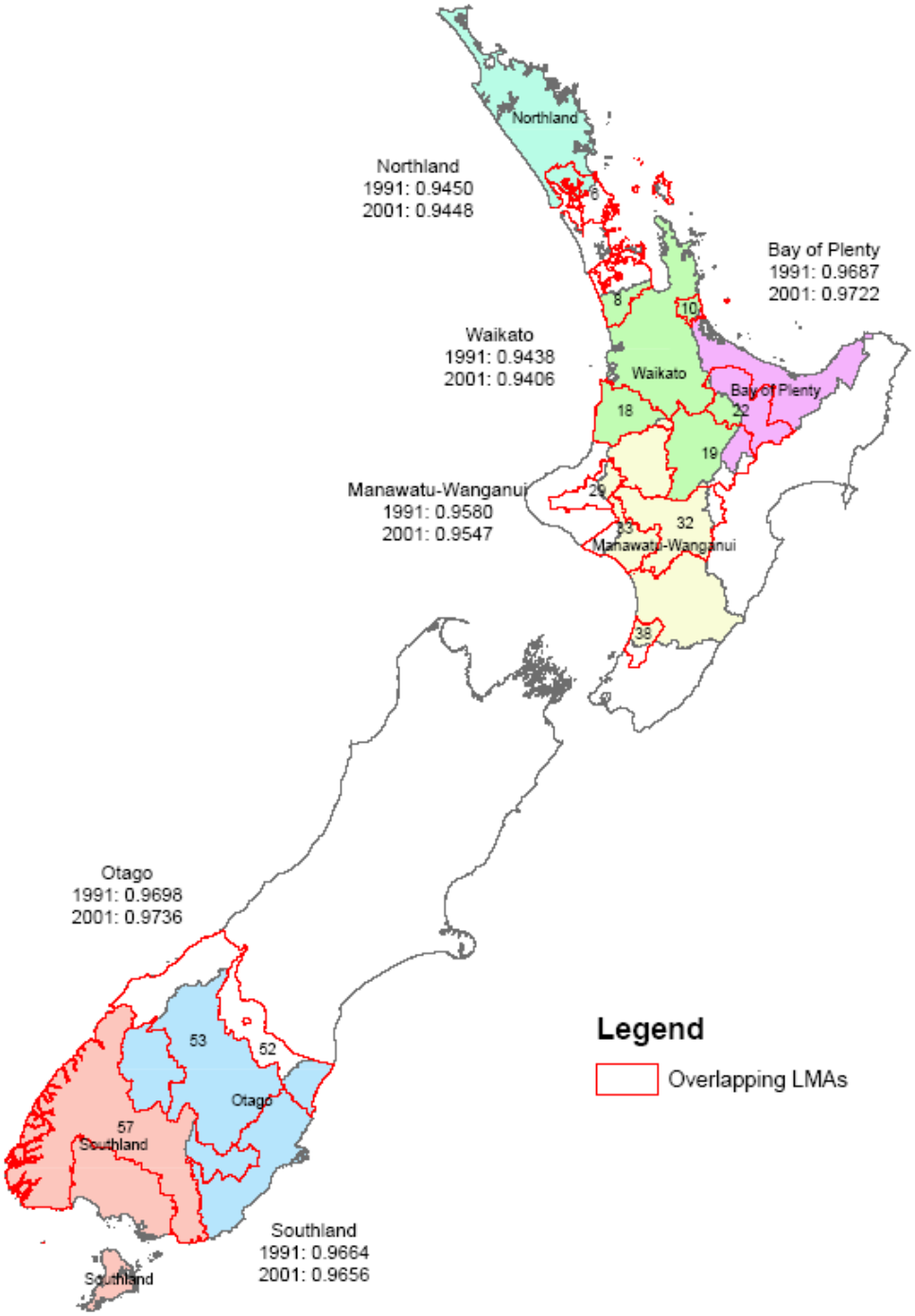



Table 9 details the decomposition of the match quality statistic into omission and add-in components by Aggregate RC. The table uses a cut-off value of 0.67, the value that maximizes the overall match quality statistic. The aggregate match quality using a cut-off of 0.67 is 0.9881 (0.9883) for 1991 (2001). As the table shows, the worst matches are in Northland, Manawatu-Wanganui, Waikato, Otago, and Southland Aggregate Regional Councils. The LMAs that contribute to the poor match in these Aggregate RCs are illustrated in Figure 5.

**Figure 5: Map of LMAs that overlap regional boundaries**




The low match for Northland Regional Council is due to LMA 6, which is split between Northland Regional Council and Auckland Regional Council, but allocated to Auckland. As a result, population is omitted from Northland (causing a lower omission match quality statistic of 0.9450, 1991). On the other hand,

Auckland has extra population, hence has add-in mismatch (0.9798 in 1991). Auckland Aggregate Regional Council has additional add-in error due to the position of LMA 8, which is split between Auckland and Waikato, and also allocated to Auckland. In total, there are 19,080 (22,158) people allocated to Auckland that in fact reside either in Northland or Waikato, in 1991 (2001). Waikato Aggregate Regional Council has add-in mismatch due to LMA 10, 18, and 19, all of which are allocated to Waikato, but contain some out-of-Waikato population as well.

The low match quality for Manawatu-Wanganui Aggregate Regional Council is due to both add-in and omission errors. Add-in mismatch is caused by two LMAs: LMA 33 and LMA 38. LMA 33 is split between Taranaki (4.4%) and Manawatu-Wanganui (95.6%), and added an additional 2064 (1935) people in 1991 (2001) to Manawatu-Wanganui. LMA 38 is split between Wellington (23.2%) and Manawatu-Wanganui (76.8%), causing an additional 7035 (7758) people in 1991 (2001) to be included in the Manawatu-Wanganui population count. The omission error is due to LMA 29, which is allocated to Taranaki, omitting 231 (171) people in 1991 (2001). For Southland, the low match quality statistic results entirely from add-in mismatch. This is because LMA 57 is allocated to Southland, although it contains over 3000 people who are in Otago Aggregate Regional Council. LMA 57 therefore causes some of Otago Aggregate Regional Council's omission mismatch. The main source of the add-in mismatch for Otago is from LMA 52, which is split between Canterbury (8.3%, 1991) and Otago (91.7%, 1991).

**Table 9: Match quality statistic for Labour Market Areas to Aggregated Regional Council match, using a cut-off of 0.67**

| | 1991 | | | | 2001 | | | |
|---|---|---|---|---|---|---|---|---|
| **Aggregate Regional Council** | **Add-in statistic** | **Omission statistic** | **Match quality** | **Share of national population** | **Add-in statistic** | **Omission statistic** | **Match quality** | **Share of national population** |
| Northland | 1 | 0.9450 | 0.9450 | 3.76% | 1 | 0.9448 | 0.9448 | 3.75% |
| Auckland | 0.9798 | 1 | 0.9798 | 27.97% | 0.9809 | 1 | 0.9809 | 31.01% |
| Waikato | 0.9910 | 0.9527 | 0.9438 | 9.81% | 0.9905 | 0.9501 | 0.9406 | 9.57% |
| Bay of Plenty | 0.9827 | 0.9861 | 0.9687 | 6.05% | 0.9857 | 0.9865 | 0.9722 | 6.41% |
| Taranaki | 0.9978 | 0.9807 | 0.9786 | 3.17% | 0.9983 | 0.9812 | 0.9795 | 2.75% |
| Manawatu-Wanganui | 0.9594 | 0.9986 | 0.9580 | 6.66% | 0.9558 | 0.9989 | 0.9547 | 5.89% |
| Wellington | 1 | 0.9824 | 0.9824 | 11.87% | 1 | 0.9817 | 0.9817 | 11.34% |
| Canterbury | 1 | 0.9962 | 0.9962 | 12.99% | 1 | 0.9973 | 0.9973 | 12.89% |
| Otago | 0.9887 | 0.9811 | 0.9698 | 5.26% | 0.9908 | 0.9828 | 0.9736 | 4.86% |
| Southland | 0.9664 | 1 | 0.9664 | 2.96% | 0.9657 | 0.9999 | 0.9656 | 2.44% |
| Marlborough, Tasman, Nelson, West Coast | 1 | 0.9974 | 0.9974 | 4.07% | 1 | 0.9975 | 0.9975 | 4.09% |
| Gisborne and Hawkes Bay | 1 | 0.9996 | 0.9996 | 5.41% | 1 | 0.9994 | 0.9994 | 5.00% |

# 5 Motu Project on Regional Labour Market Adjustment

This section illustrates the usefulness of the match quality statistic for aggregating TA data to approximate LMAs, an application of relevance to a forthcoming Motu research project The research project examines regional labour market adjustment, ideally using functional LMAs as the main unit of observation. The project will combine data from the Household Labour Force Survey (HLFS), the Quarterly Employment Survey (QES), and house price data from QVNZ. The HLFS data are readily available for aggregated RCs, and area unit coding is accessible to Statistics New Zealand for deriving estimates for other (similar sized) areas. QES data are available for aggregations of area units. House Price data are available for TAs.

One option would be to use the aggregated regional councils for which HLFS data are available, but this introduces concordance errors between both LMA and aggregated regional council, and between TA and aggregated regional

council. Further, as the project is looking at regional labour market adjustment, a weakness with using aggregated regional council boundaries is that large regional councils, such as Auckland and Wellington, each contain several distinct labour market areas, and analysis at the regional council level ignores any intra-regional labour market differences.

Our solution to this problem is to investigate how best to aggregate TAs to approximate LMAs. We group the TAs into 14 'aggregated TAs', generally following the aggregated regional council boundaries. We divide Auckland Region and Wellington Region each into two sub-regions. We use labour market boundaries as a guide as to where to allocate individual TAs when dividing Auckland and Wellington Regions. Appendix Table 1 contains the TA components of each Aggregated TA region. We carry out a similar analysis to the first part of this paper, identifying which TA groupings have the most overlap with LMAs. We find that the match with our Auckland TA groupings is particularly bad, because Auckland City TA is divided across two LMAs. We create an alternative aggregation of TAs, treating Auckland City TA as 'a city of two halves', and give it its own labour market. This alternative aggregation provides the best match with LMAs.

## 5.1 Match between Labour Market Areas and Aggregated Territorial Authorities

The aggregate match quality statistic for LMA to aggregate TA match is 0.8542 in 1991 and 0.8445 in 2001 using a cut-off of 0.90. The graph for 2001 is very similar and contained in Appendix C.

The highest value of the total match quality statistic is 0.9662, for a cut-off value less than 0.68. Appendix Table 10 details the population breakdown in each overlap of LMA and Aggregate Regional Council boundary. A cut-off of 0.68 corresponds to the boundary for LMA 6, which is split between Northland Aggregate TA and North Auckland Aggregate TA[5]. The next major drop in the match quality statistic is at a cut-off of 0.79, which corresponds to LMA8, which is split between North Auckland (21.6%, 1991) and South Auckland (78.4%,

1991). This LMA is the most populous LMA in NZ, with a population of 388,962 (474,762) in 1991 (2001). When this LMA is unallocated it therefore decreases non-allocation match quality considerably, as is evident in the graph. The match statistic is then fairly constant until a cut-off of approximately 0.97, where the high cut-off value causes several LMAs to become unallocated.

**Figure 6: 1991 match quality of LMA to AggTA, varying cut-off**

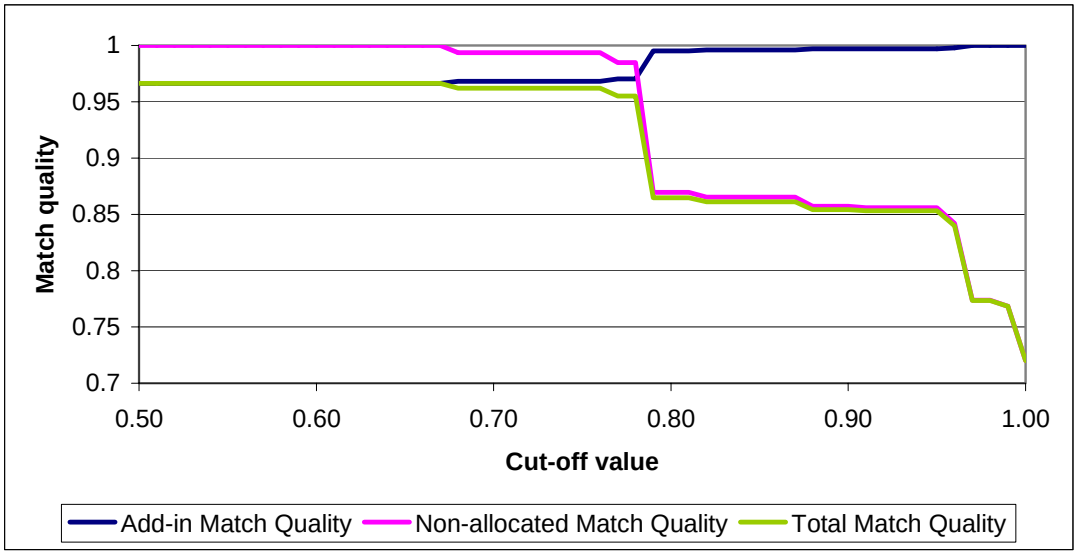
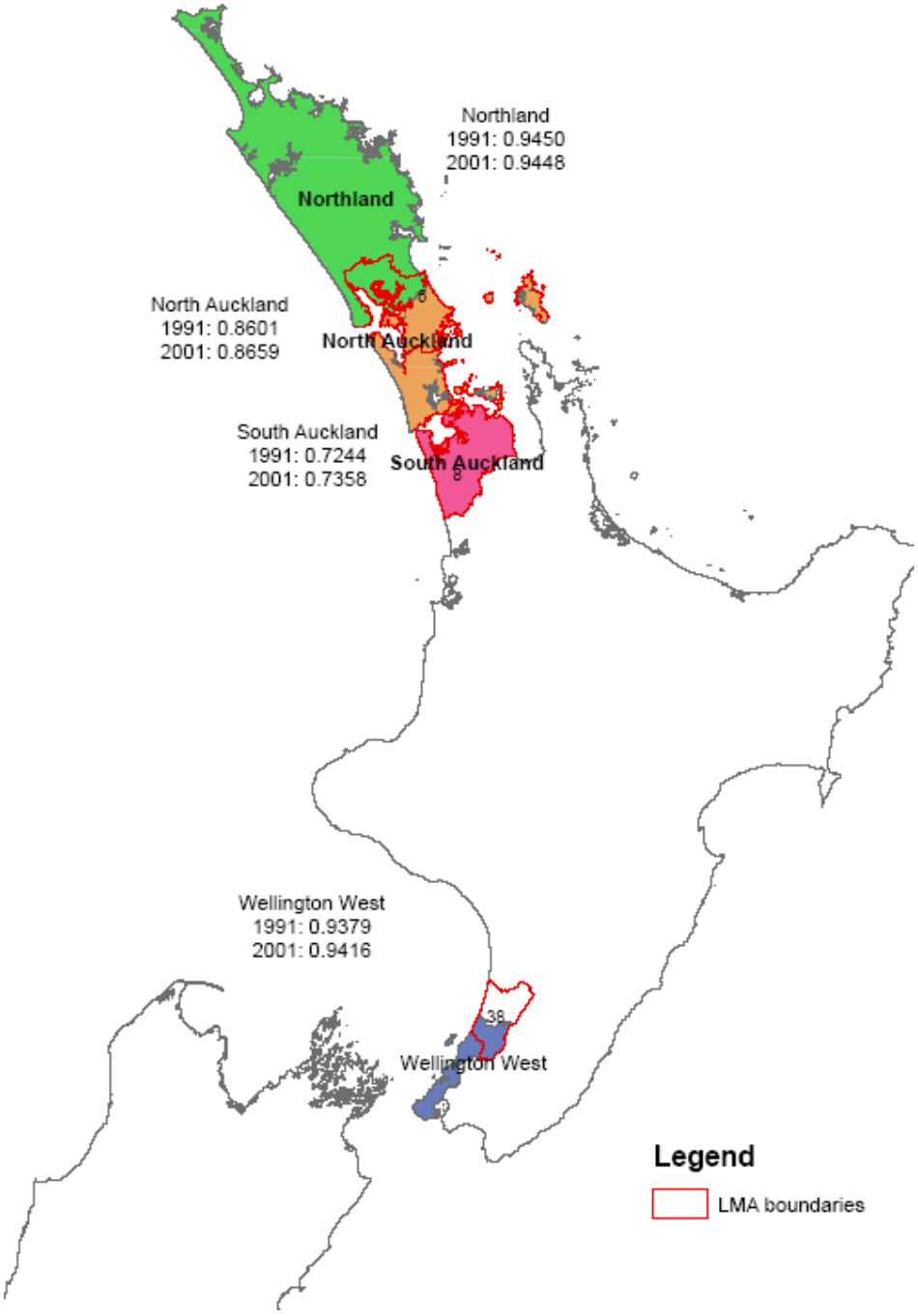



Table 10 lists match quality statistics for each aggregated TA, using the cut-off that maximizes the overall match quality statistic (0.67). At this cut-off, the aggregate match quality statistic is 0.9300 (0.9278) in 1991 (2001). The table details the add-in and omission decomposition for each aggregate TA. The aggregate TAs with the lowest match quality statistics are Northland (0.9418, 1991), North Auckland (0.8934, 1991), South Auckland (0.7244,1991), and Wellington West (0.9359, 1991). The two Auckland aggregate TAs alone comprise almost 30% of the national population, hence their values have a large impact on the national statistic. These overlaps are illustrated in Figure 7.

[5] Appendix A contains the details of the 'aggregate TA' grouping.

**Figure 7: Map of LMAs that overlap Agg TA boundaries with match quality statistic less than 0.95**




North Auckland has a low omission match quality statistic (0.8708 in 1991). South Auckland has a low add-in match quality statistic (0.7244 in 1991). The low match quality statistic for South Auckland and North Auckland

Aggregate TA is due to the position of LMA 8. LMA 8 straddles the border between North and South Auckland, with 78% (79%) of its 1991 (2001) population in South Auckland and 22% (21%) of its 1991 (2001) population in North Auckland.

Northland Aggregate TA has a match quality statistic of 0.9418. This is due to the position of LMA 6, which is divided between Northland (32.9%) and North Auckland (67.1%). Using a cut-off of 0.67, LMA 6 is allocated to North Auckland, hence contributes to omission mismatch for Northland and add-in mismatch for North Auckland. Wellington West Aggregate TA has a match quality statistic of 0.9359. This is primarily due to LMA 38, which is split between Manawatu Aggregated TA (76.8%) and Wellington West Aggregated TA (23.2%). This is because LMA 38 is split over two TAs: Horowhenua District, which is allocated to Manawatu Aggregated Regional Council, and Kapiti District, which is allocated to Wellington West Aggregated Regional Council.

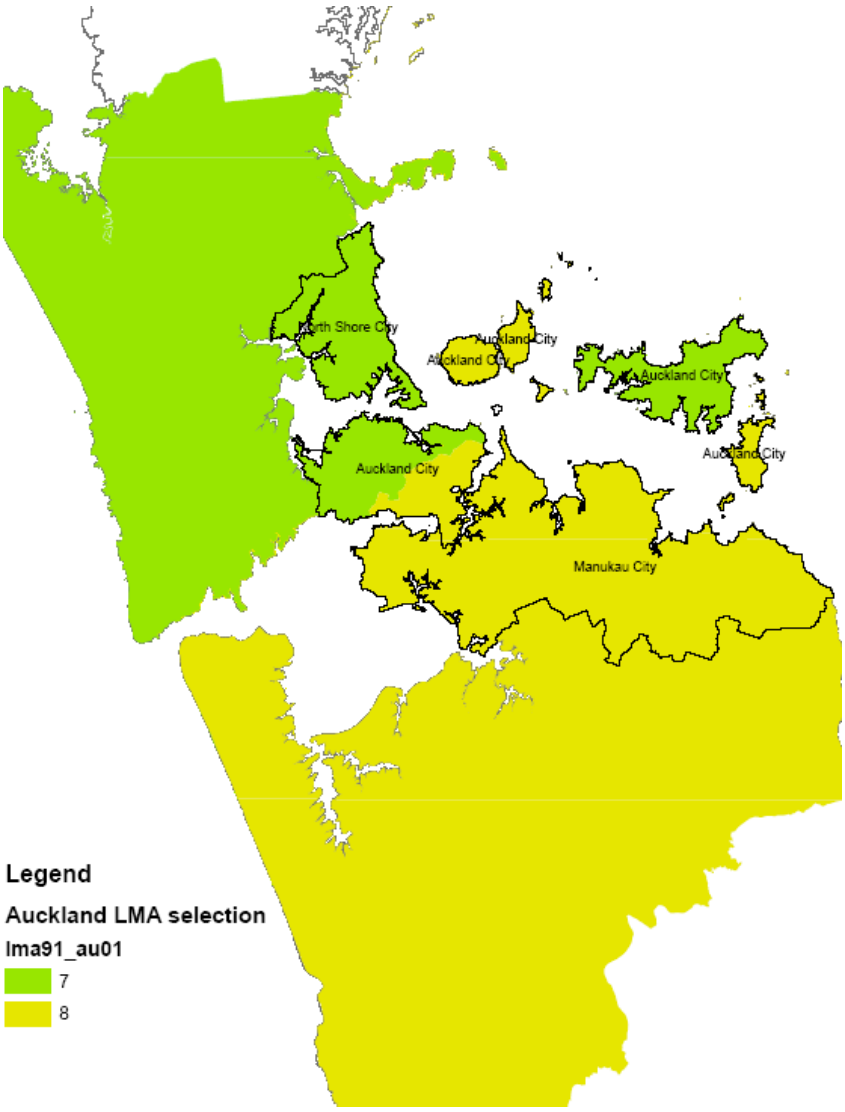
**Table 10: Match quality statistic for LMA to Aggregated TA match, cut-off of 0.67**

| | 1991 | | | | 2001 | | | |
|---|---|---|---|---|---|---|---|---|
| **Aggregate TA** | **Add-in Statistic** | **Omission Statistic** | **Match Quality** | **Share of national population** | **Add-in Statistic** | **Omission statistic** | **Match quality** | **Share of national population** |
| Northland | 1 | 0.9450 | 0.9450 | 3.76% | 1 | 0.9448 | 0.9448 | 3.75% |
| North Auckland | 0.9893 | 0.8708 | 0.8601 | 19.29% | 0.9903 | 0.8756 | 0.8659 | 21.35% |
| South Auckland | 0.7244 | 1 | 0.7244 | 9.04% | 0.7358 | 1 | 0.7358 | 10.05% |
| Waikato | 0.9917 | 1 | 0.9917 | 9.36% | 0.9911 | 1 | 0.9911 | 9.11% |
| Bay of Plenty | 1 | 0.9873 | 0.9873 | 6.15% | 1 | 0.9875 | 0.9875 | 6.49% |
| Gisborne & Hawke's Bay | 1 | 1 | 1 | 5.41% | 1 | 1 | 1 | 5.00% |
| Taranaki | 1 | 0.9808 | 0.9808 | 3.18% | 1 | 0.9812 | 0.9812 | 2.76% |
| Manawatu | 0.9595 | 1 | 0.9594 | 6.66% | 0.9559 | 0.9999 | 0.9559 | 5.89% |
| Wellington West | 0.9685 | 0.9694 | 0.9379 | 6.82% | 0.9723 | 0.9693 | 0.9416 | 6.79% |
| Wellington East | 0.9999 | 0.9575 | 0.9575 | 5.05% | 0.9998 | 0.9587 | 0.9584 | 4.55% |
| Marlborough, Nelson, Tasman, West Coast | 1 | 0.9974 | 0.9974 | 4.07% | 1 | 0.9975 | 0.9975 | 4.09% |
| Canterbury | 0.9991 | 1 | 0.9991 | 12.93% | 0.9994 | 1 | 0.9994 | 12.84% |
| Otago | 0.9980 | 0.9792 | 0.9772 | 5.32% | 0.9980 | 0.9814 | 0.9794 | 4.90% |
| Southland | 0.9664 | 1 | 0.9664 | 2.96% | 0.9657 | 0.9999 | 0.9656 | 2.44% |

## 5.2 Further Auckland Region Issues

The highest match quality statistic for the LMA to Aggregated TA match is 0.9662 in 1991 (using a cut-off of 0.67). This is lower than the highest match quality statistic between LMA and Aggregated RC of 0.9881 (also using a cut-off of 0.67). As Table 10 shows, the aggregate TAs that have a particularly bad match with LMAs are North Auckland and South Auckland. Figure 8 shows the various boundaries within the Auckland Region. There are two key LMAs, LMA 7 and LMA 8, and three key TAs, North Shore City, Auckland City, and Manukau City.

**Figure 8: Map of overlap in Auckland Region**




The reason for the poor match between LMA and aggregate TA is obvious from the map: the boundary between LMA 7 and LMA 8 is in the middle of Auckland City TA. Auckland City TA's (2001) population is split between LMA 7 (268,494) and LMA 8 (99,219). Auckland City was therefore allocated to North Auckland Aggregate TA, because the rest of LMA 7 was in Rodney, North Shore, and Waitakere TAs. An alternative approach to avoid this overlap issue is to treat Auckland City TA as 'a city of two halves', and define a separate labour market consisting only of Auckland City TA. The benefit of this is that it will remove the main source of mismatch between LMAs and the aggregate TA

grouping. It is then possible to create an alternative aggregation of TAs, dividing Auckland Region into three smaller regions instead of two[6].

Table 11 compares the match quality statistic between LMA and the three aggregations explored in this paper: aggregate TA, alternative aggregate TA (treating Auckland as its own labour market) and aggregate RC, for a range of cut-off points. The table shows that for all cut-off values, the 'alternative aggregate TA' grouping has the highest total match quality statistic. For a cut-off of 0.90, the value is 0.9695 (0.9716) for 1991 (2001), compared with 0.8542 (0.8445) for the initial 'aggregate TA' grouping and 0.9665 (0.9683) for the Aggregate RC aggregation. The breakdown of the individual match quality statistics for each of 'Alternative Aggregated TA' for the cut-off that gives the highest match statistic (0.67) is contained in Appendix Table 11.

Returning to the earlier example of the Motu research project on labour market adjustment, these results suggest that the best way to achieve our desired regional aggregation is to group TAs in the 'alternative aggregate TA' grouping outlined above. Using this aggregation gives us the best match with labour market areas of all possible aggregations. As the grouping is composed of TAs, it gives a perfect match with the house price data series that is released at TA level. The disadvantage of splitting Auckland is that we will have somewhat less power to identify labour market dynamics, to the extent that there is interdependence between the three Auckland areas.

**Table 11: Comparison of match quality statistics for LMA concordances**

| | 1991 | | | 2001 | | |
|---|---|---|---|---|---|---|
| **Cut-off value** | **Agg TA** | **Alt Agg TA** | **Agg RC** | **Agg TA** | **Alt Agg TA** | **AggRC** |
| 0.5 | 0.9662 | 0.9911 | 0.9881 | 0.9651 | 0.9916 | 0.9883 |
| 0.6 | 0.9662 | 0.9911 | 0.9881 | 0.9651 | 0.9916 | 0.9883 |
| 0.7 | 0.9620 | 0.9869 | 0.9838 | 0.9602 | 0.9868 | 0.9835 |
| 0.8 | 0.8646 | 0.9800 | 0.9769 | 0.8504 | 0.9775 | 0.9742 |
| 0.9 | 0.8542 | 0.9695 | 0.9665 | 0.8445 | 0.9716 | 0.9683 |
| 1 | 0.7200 | 0.8353 | 0.7944 | 0.7151 | 0.8422 | 0.7881 |

[6] North Auckland (Rodney TA, North Shore TA, Waitakere TA); Central (Auckland City TA); and South Auckland (Manukau City TA, Papakura District TA, Franklin District TA).

# 6 Conclusion

This paper has developed a match quality statistic to indicate the quality of match between different regional aggregations. The match quality statistic considers three potential sources of error: error from counting additional population in a region, error from omitting population from a region, and error from not allocating population. This match quality statistic can be used by empirical researchers to quantify the trade-off between specificity and completeness when working with data released at different regional aggregations.

We applied this match quality statistic to several common geographical aggregations, using 1991 and 2001 census data. The match between TAs and regional councils is good (match quality statistic of 0.9946 for 1991, using a cut-off value of 0.67). The main exception is Franklin District, which overlaps Auckland Regional Council and Waikato Regional Council. The quality of match between LMAs and aggregate regional councils is also high. The maximum match quality statistic is 0.9881 (0.9764) for 1991 (2001), achieved using a cut-off of 0.67. The aggregate regional councils that have the lowest match statistic are Northland, Waikato, Manawatu-Wanganui, Southland, and Otago.

One weakness with using aggregated regional council boundaries is that large regional councils, such as Auckland and Wellington, may have several distinct labour market areas. To resolve this, we created an aggregation that divided each of Auckland and Wellington into two regions, by combining TAs. This aggregation was called 'aggregated TAs'. The LMA to aggregated TA match is not as good as the LMA to aggregate RC match, with the maximum match quality statistic 0.9662 (1991). This lower statistic is caused by the overlap occurring in Auckland City TA, whose population is split between two LMAs. An alternative aggregation of TAs is to treat Auckland City TA as 'a city of two halves', and give it its own labour market. This divides Auckland Region into three sub-regions: North, City, and South. The match quality statistic between LMA and Alternative Aggregate TA is 0.9911 (0.9912) 1991 (2001). This aggregation gives the best quality match between labour market areas and TAs.

The match quality statistic developed in this paper allows researchers to make own decisions regarding trade-off between specificity and completeness when working with regionally aggregated data. We have provided the programme coded as a Stata® ado file in the Appendix to this paper.

Although all of the examples in this paper have used population counts as the basis for calculating match quality, the methods are readily applied to measuring the degree of concordance along other dimensions, such as land area, employment, or dwelling counts.

# Appendix A: Construction of Aggregated TA Grouping

### Appendix Table 1: 'Aggregated TA' Regional Aggregation

| Aggregate TA Name | Component TAs | |
|---|---|---|
| Northland | Far North District | Kaipara District |
| | Whangarei District | |
| Auckland North | Rodney District | Waitakere City |
| | North Shore City | Auckland City |
| Auckland South | Manukau City | |
| | Papakura District | Franklin District |
| Waikato | Thames-Coromandel District | Waipa District |
| | Hauraki District | Otorohanga District |
| | Waikato District | South Waikato District |
| | Matamata-Piako District | Waitomo District |
| | Hamilton City | Taupo District |
| Bay of Plenty | Western Bay of Plenty District | Whakatane District |
| | Tauranga District | Kawerau District |
| | Rotorua District | Opotiki District |
| Gisborne & Hawke's Bay | Gisborne District | Napier City |
| | Wairoa District | Central Hawke's Bay District |
| | Hastings District | |
| Taranaki | New Plymouth District | South Taranaki District |
| | Stratford District | |
| Manawatu | Ruapehu District | Palmerston North City |
| | Wanganui District | Tararua District |
| | Rangitikei District | Horowhenua District |
| | Manawatu District | |
| Wellington West | Kapiti Coast District | Wellington City |
| | Porirua City | |
| Wellington East | Upper Hutt City | Carterton District |
| | Lower Hutt City | South Wairarapa District |
| | Masterton District | |
| Marlborough, Nelson, Tasman, West Coast | Tasman District | Buller District |
| | Nelson City | Grey District |
| | Marlborough District | Westland District |
| Canterbury | Kaikoura District | Selwyn District |
| | Hurunui District | Ashburton District |
| | Waimakariri District | Timaru District |
| | Christchurch City | Mackenzie District |
| | Banks Peninsula District | Waimate District |
| Otago | Waitaki District | Dunedin City |
| | Central Otago District | Clutha District |
| | Queenstown-Lakes District | |
| Southland | Southland District | Invercargill City |
| | Gore District | |

# Appendix B: Match Quality Statistics

These tables give the match quality statistic going from each of the levels of regional aggregation to the others, for a range of cut-off values. The results in Section 4 of the paper use a cut-off of value 0.90.

**Appendix Table 2: Concordance Statistics for Area Unit**

| 1991 | AU to | TA | LMA | RC | Agg TA | Agg RC |
|---|---|---|---|---|---|---|
| | 0.5 | 1 | 1 | 1 | 1 | 1 |
| | 0.75 | 1 | 1 | 1 | 1 | 1 |
| cut-off | 0.9 | 1 | 1 | 1 | 1 | 1 |
| | 0.95 | 1 | 1 | 1 | 1 | 1 |
| | 1 | 1 | 1 | 1 | 1 | 1 |
| 2001 | AU to | TA | LMA | RC | Agg TA | Agg RC |
| | 0.5 | 1 | 1 | 1 | 1 | 1 |
| | 0.75 | 1 | 1 | 1 | 1 | 1 |
| cut-off | 0.9 | 1 | 1 | 1 | 1 | 1 |
| | 0.95 | 1 | 1 | 1 | 1 | 1 |
| | 1 | 1 | 1 | 1 | 1 | 1 |

**Appendix Table 3: Concordance Statistics for Territorial Authority**

| 1991 | TA to: | AU | LMA | RC | AggTA | AggRC |
|---|---|---|---|---|---|---|
| | 0.5 | 0.0071 | 0.9006 | 0.9946 | 1 | 0.9946 |
| | 0.75 | 0.0025 | 0.7776 | 0.9858 | 1 | 0.9858 |
| Cut-off | 0.9 | 0.0025 | 0.7388 | 0.9858 | 1 | 0.9858 |
| | 0.95 | 0.0025 | 0.7076 | 0.9627 | 1 | 0.9627 |
| | 1 | 0.0025 | 0.6568 | 0.9379 | 1 | 0.9379 |
| 2001 | TA to: | AU | LMA | RC | AggTA | AggRC |
| | 0.5 | 0.0046 | 0.9060 | 0.9947 | 1 | 0.9947 |
| | 0.75 | 0.0019 | 0.7863 | 0.9847 | 1 | 0.9847 |
| Cut-off | 0.9 | 0.0019 | 0.7330 | 0.9847 | 1 | 0.9847 |
| | 0.95 | 0.0019 | 0.7117 | 0.9634 | 1 | 0.9634 |
| | 1 | 0.0019 | 0.6574 | 0.9414 | 1 | 0.9414 |

**Appendix Table 4: Concordance Statistics for Labour Market Area**

| 1991 | LMA to: | AU | TA | RC | AggTA | AggRC |
|---|---|---|---|---|---|---|
| | 0.5 | 0.0039 | 0.6490 | 0.9786 | 0.9662 | 0.9881 |
| | 0.75 | 0 | 0.4049 | 0.9636 | 0.9620 | 0.9838 |
| cut-off | 0.9 | 0 | 0.2474 | 0.9463 | 0.8542 | 0.9665 |
| | 0.95 | 0 | 0.1870 | 0.9225 | 0.8531 | 0.9427 |
| | 1 | 0 | 0.1316 | 0.7742 | 0.7200 | 0.7944 |

| 2001 | LMA to: | AU | TA | RC | AggTA | AggRC |
|---|---|---|---|---|---|---|
| | 0.5 | 0.0022 | 0.6278 | 0.9785 | 0.9651 | 0.9883 |
| | 0.75 | 0 | 0.3819 | 0.9625 | 0.9602 | 0.9835 |
| cut-off | 0.9 | 0 | 0.2289 | 0.9473 | 0.8445 | 0.9683 |
| | 0.95 | 0 | 0.1750 | 0.9255 | 0.8435 | 0.9464 |
| | 1 | 0 | 0.1216 | 0.7671 | 0.7151 | 0.7881 |

**Appendix Table 5: Concordance Statistics for Regional Council**

| 1991 | RC to: | AU | TA | LMA | AggTA | AggRC |
|---|---|---|---|---|---|---|
| | 0.5 | 0 | 0.2005 | 0.4808 | 0.8573 | 1 |
| | 0.75 | 0 | 0.0444 | 0.1600 | 0.5962 | 1 |
| cut-off | 0.9 | 0 | 0.0444 | 0.0239 | 0.5962 | 1 |
| | 0.95 | 0 | 0.0444 | 0.0239 | 0.5962 | 1 |
| | 1 | 0 | 0.0444 | 0.0239 | 0.2054 | 1 |
| 2001 | RC to: | AU | TA | LMA | AggTA | AggRC |
| | 0.5 | 0 | 0.1910 | 0.4889 | 0.8525 | 1 |
| | 0.75 | 0 | 0.0446 | 0.1564 | 0.5711 | 1 |
| cut-off | 0.9 | 0 | 0.0446 | 0.0229 | 0.5711 | 1 |
| | 0.95 | 0 | 0.0446 | 0.0229 | 0.5711 | 1 |
| | 1 | 0 | 0.0446 | 0.0229 | 0.1906 | 1 |

**Appendix Table 6: Concordance Statistics for Aggregate Territorial Authority**

| 1991 | AggTA to: | AU | TA | LMA | RC | AggRC |
|---|---|---|---|---|---|---|
| | 0.5 | 0 | 0.2952 | 0.5607 | 0.9408 | 0.9946 |
| | 0.75 | 0 | 0.0670 | 0.4856 | 0.9408 | 0.9946 |
| cut-off | 0.9 | 0 | 0 | 0.1565 | 0.8998 | 0.9946 |
| | 0.95 | 0 | 0 | 0.1565 | 0.8998 | 0.9946 |
| | 1 | 0 | 0 | 0.0904 | 0.5081 | 0.6029 |
| 2001 | AggTA to: | AU | TA | LMA | RC | AggRC |
| | 0.5 | 0 | 0.2916 | 0.6449 | 0.9420 | 0.9947 |
| | 0.75 | 0 | 0.0758 | 0.4734 | 0.9420 | 0.9947 |
| cut-off | 0.9 | 0 | 0 | 0.1663 | 0.9038 | 0.9947 |
| | 0.95 | 0 | 0 | 0.1663 | 0.9038 | 0.9947 |
| | 1 | 0 | 0 | 0.1005 | 0.5172 | 0.6080 |

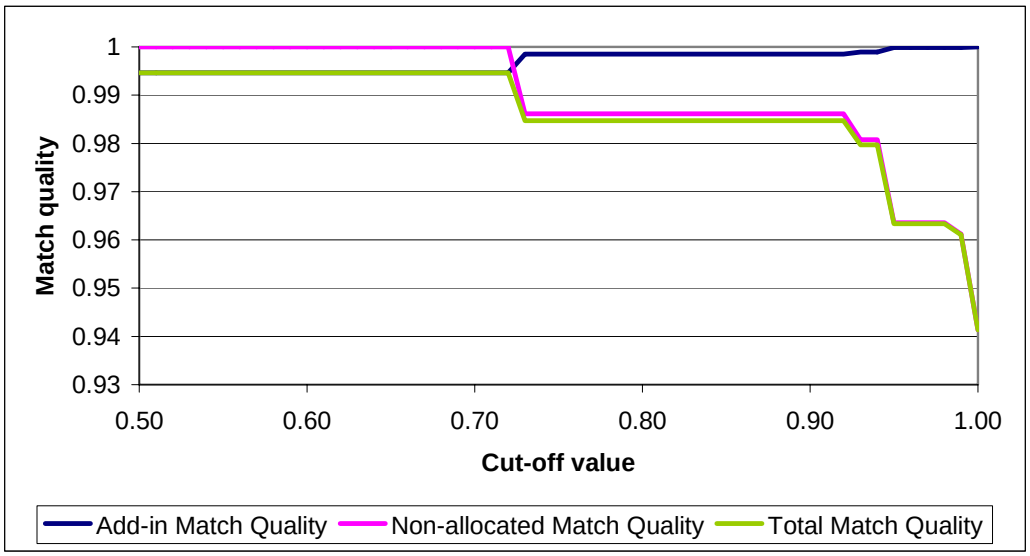
**Appendix Table 7: Concordance Statistics for Aggregate Regional Council**

| 1991 | AggRC to: | AU | TA | LMA | RC | AggTA |
|---|---|---|---|---|---|---|
| | 0.5 | 0 | 0.1561 | 0.4347 | 0.9462 | 0.8573 |
| | 0.75 | 0 | 0 | 0.1277 | 0.9462 | 0.5962 |
| cut-off | 0.9 | 0 | 0 | 0 | 0.9052 | 0.5962 |
| | 0.95 | 0 | 0 | 0 | 0.9052 | 0.5962 |
| | 1 | 0 | 0 | 0 | 0.9052 | 0.1923 |
| 2001 | AggRC to: | AU | TA | LMA | RC | AggTA |
| | 0.5 | 0 | 0.1464 | 0.4647 | 0.9473 | 0.8525 |
| | 0.75 | 0 | 0 | 0.1250 | 0.9473 | 0.5711 |
| cut-off | 0.9 | 0 | 0 | 0 | 0.9091 | 0.5711 |
| | 0.95 | 0 | 0 | 0 | 0.9091 | 0.5711 |
| | 1 | 0 | 0 | 0 | 0.9091 | 0.1789 |

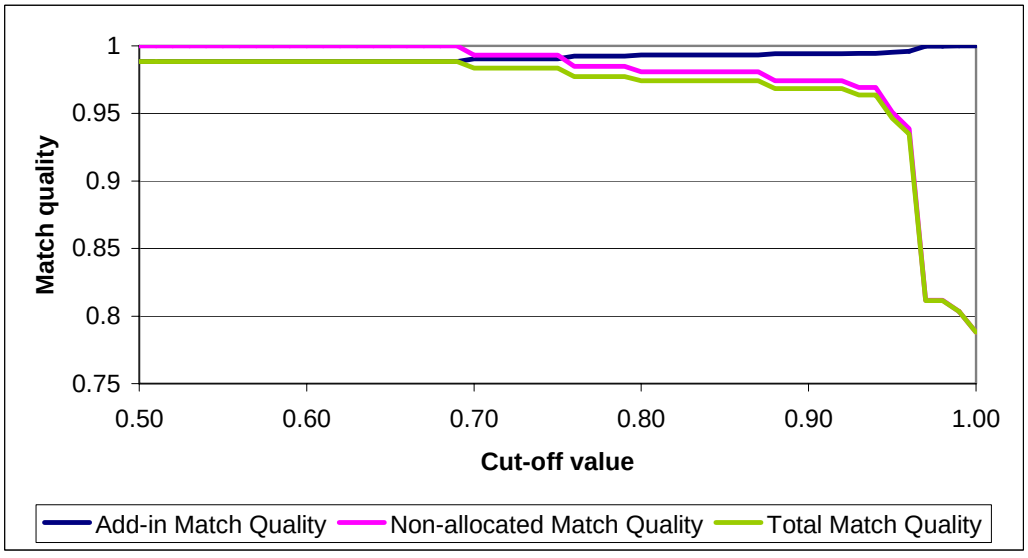
# Appendix C: 2001 Match Quality Graphs

This section contains the 2001 version of the figures in Section 4.

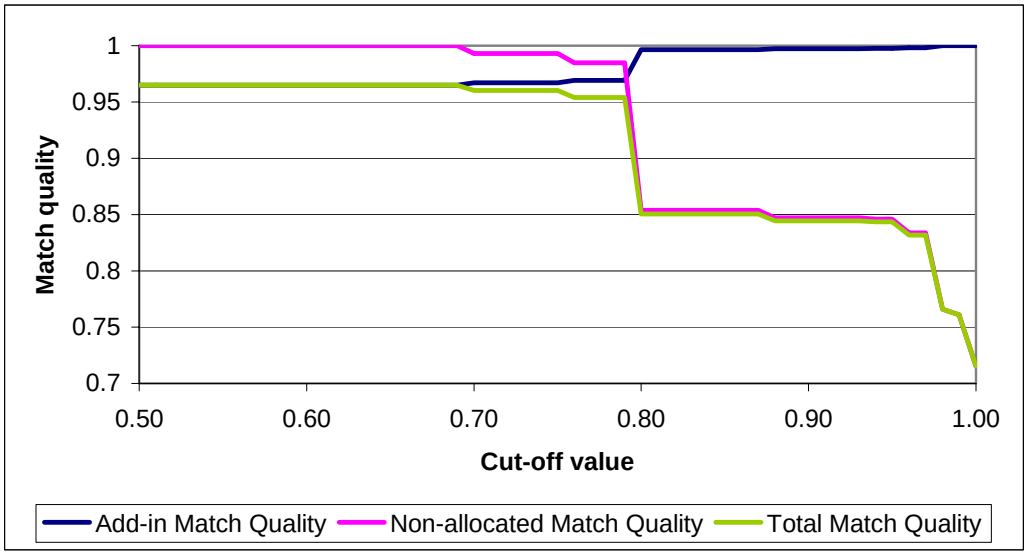
**Appendix Figure 1: 2001 Match quality statistic TA to RC, changing cut-off value**




**Appendix Figure 2: 2001 LMA to AggRC match quality statistic**



**Appendix Figure 3: 2001 LMA to AggTA match quality statistic**



# Appendix D: Details of Population Overlaps

These tables give details of the population breakdown for the overlapping regions for each of the three concordances examined in detail in Section 4: TA to RC, LMA to Aggregated RC, and LMA to Aggregated TA.

**Appendix Table 8: Details of population overlaps between TA and RC**

| TA | RC | 1991 Population | Share of TA population | 2001 Population | Share of TA population |
|---|---|---|---|---|---|
| Franklin | Auckland | 29658 | 0.710 | 37242 | 0.721 |
| Franklin | Waikato | 12111 | 0.290 | 14424 | 0.279 |
| Waitomo | Waikato | 10011 | 0.992 | 9390 | 0.992 |
| Waitomo | Manawatu-Wanganui | 81 | 0.008 | 72 | 0.008 |
| Taupo | Waikato | 27711 | 0.991 | 31248 | 0.991 |
| Taupo | Bay of Plenty | 216 | 0.008 | 183 | 0.006 |
| Taupo | Hawke's Bay | 48 | 0.002 | 87 | 0.003 |
| Taupo | Manawatu-Wanganui | 0 | 0.000 | 0 | 0.000 |
| Rotorua | Waikato | 3534 | 0.057 | 3426 | 0.053 |
| Rotorua | Bay of Plenty | 58023 | 0.943 | 61029 | 0.947 |
| Stratford | Taranaki | 9648 | 0.977 | 8715 | 0.981 |
| Stratford | Manawatu-Wanganui | 231 | 0.023 | 171 | 0.019 |
| Rangitikei | Hawke's Bay | 24 | 0.001 | 30 | 0.002 |
| Rangitikei | Manawatu-Wanganui | 16560 | 0.999 | 15078 | 0.998 |
| Tararua | Manawatu-Wanganui | 19842 | 1.000 | 17850 | 0.999 |
| Tararua | Wellington | 6 | 0.000 | 12 | 0.001 |
| Waitaki | Canterbury | 2031 | 0.093 | 1569 | 0.078 |
| Waitaki | Otago | 19866 | 0.907 | 18513 | 0.922 |

**Appendix Table 9: Details of population overlaps between LMA and Aggregate RC**

| LMA | Agg RC | 1991 Population | Share of LMA population | 2001 Population | Share of LMA population |
|---|---|---|---|---|---|
| 6 | Northland | 6969 | 0.329 | 7734 | 0.301 |
| 6 | Auckland | 14241 | 0.671 | 17997 | 0.699 |
| 8 | Auckland | 376851 | 0.969 | 460338 | 0.970 |
| 8 | Waikato | 12111 | 0.031 | 14424 | 0.030 |
| 10 | Waikato | 11685 | 0.817 | 11448 | 0.790 |
| 10 | Bay of Plenty | 2625 | 0.183 | 3039 | 0.210 |
| 18 | Waikato | 10011 | 0.992 | 9390 | 0.992 |
| 18 | Manawatu-Wanganui | 81 | 0.008 | 72 | 0.008 |
| 19 | Waikato | 26130 | 0.990 | 29964 | 0.991 |
| 19 | Bay of Plenty | 216 | 0.008 | 183 | 0.006 |
| 19 | Manawatu-Wanganui | 0 | 0.000 | 0 | 0.000 |
| 19 | Gisborne and Hawkes | 48 | 0.002 | 87 | 0.003 |
| 22 | Waikato | 3534 | 0.054 | 3426 | 0.050 |
| 22 | Bay of Plenty | 62139 | 0.946 | 64572 | 0.950 |
| 29 | Taranaki | 11910 | 0.981 | 10815 | 0.984 |
| 29 | Manawatu-Wanganui | 231 | 0.019 | 171 | 0.016 |
| 32 | Manawatu-Wanganui | 12144 | 0.998 | 10563 | 0.997 |
| 32 | Gisborne & Hawke's Bay | 24 | 0.002 | 30 | 0.003 |
| 33 | Taranaki | 2064 | 0.044 | 1935 | 0.042 |
| 33 | Manawatu-Wanganui | 45228 | 0.956 | 43803 | 0.958 |
| 38 | Manawatu-Wanganui | 23292 | 0.768 | 23331 | 0.750 |
| 38 | Wellington | 7035 | 0.232 | 7758 | 0.250 |
| 44 | Southland | 0 | 0.000 | 6 | 0.001 |
| 44 | Nelson, West Coast Tasman, Marlborough | 6711 | 1.000 | 7725 | 0.999 |
| 52 | Canterbury | 1647 | 0.083 | 1290 | 0.071 |
| 52 | Otago | 18132 | 0.917 | 16977 | 0.929 |
| 53 | Otago | 17712 | 0.980 | 19140 | 0.981 |
| 53 | Nelson, West Coast Tasman, Marlborough | 354 | 0.020 | 375 | 0.019 |
| 57 | Otago | 3357 | 0.125 | 3120 | 0.124 |
| 57 | Southland | 23523 | 0.875 | 22119 | 0.876 |

**Appendix Table 10: Details of population between LMA and Aggregate TA**

| LMA | Agg TA | 1991 Population | Share of LMA population | 2001 Population | Share of LMA population |
|---|---|---|---|---|---|
| 6 | Northland | 6969 | 32.86% | 7734 | 30.06% |
| 6 | North Auckland | 14241 | 67.14% | 17997 | 69.94% |
| 8 | North Auckland | 84042 | 21.61% | 99219 | 20.90% |
| 8 | South Auckland | 304920 | 78.39% | 375543 | 79.10% |
| 10 | Waikato | 11685 | 81.66% | 11448 | 79.02% |

| | | | | | |
|---|---|---|---|---|---|
| 10 | Bay of Plenty | 2625 | 18.34% | 3039 | 20.98% |
| 33 | Taranaki | 2064 | 4.36% | 1935 | 4.23% |
| 33 | Manawatu | 45228 | 95.64% | 43803 | 95.77% |
| 38 | Manawatu | 23292 | 76.80% | 23331 | 75.05% |
| 38 | Wellington West | 7035 | 23.20% | 7758 | 24.95% |
| 39 | Wellington West | 9 | 0.01% | 30 | 0.02% |
| 39 | Wellington East | 127176 | 99.99% | 127140 | 99.98% |
| 40 | Wellington West | 222879 | 96.86% | 245835 | 97.22% |
| 40 | Wellington East | 7233 | 3.14% | 7029 | 2.78% |
| 41 | Manawatu | 6 | 0.02% | 12 | 0.03% |
| 41 | Wellington East | 35952 | 99.98% | 35883 | 99.97% |
| 44 | Marlborough, Nelson, Tasman, West Coast | 6711 | 100.00% | 7725 | 99.92% |
| 44 | Southland | 0 | 0.00% | 6 | 0.08% |
| 51 | Canterbury | 3660 | 90.50% | 3714 | 93.01% |
| 51 | Otago | 384 | 9.50% | 279 | 6.99% |
| 53 | Marlborough, Nelson, Tasman, West Coast | 354 | 1.96% | 375 | 1.92% |
| 53 | Otago | 17712 | 98.04% | 19140 | 98.08% |
| 57 | Otago | 3357 | 12.49% | 3120 | 12.36% |
| 57 | Southland | 23523 | 87.51% | 22119 | 87.64% |

**Appendix Table 11: Concordance Statistics for Alternative LMA to Alternative Aggregated TA grouping, using a cut-off of 0.67**

| | 2001 | | | | 1991 | | | |
|---|---|---|---|---|---|---|---|---|
| **Alternative Agg TA** | **M1** | **M2** | **M** | **Share of national population** | **M1** | **M2** | **M** | **Share of national population** |
| Northland | 1 | 0.9450 | 0.9450 | 3.76% | 1 | 0.9448 | 0.9448 | 3.75% |
| North Auckland | 0.9798 | 1 | 0.9798 | 10.21% | 0.9820 | 1 | 0.9820 | 11.50% |
| Auckland City | 1 | 1 | 1 | 9.08% | 1 | 1 | 1 | 9.84% |
| South Auckland | 1 | 1 | 1 | 9.04% | 1 | 1 | 1 | 10.05% |
| Waikato | 0.9917 | 1 | 0.9917 | 9.36% | 0.9911 | 1 | 0.9911 | 9.11% |
| Bay of Plenty | 1 | 0.9873 | 0.9873 | 6.15% | 1 | 0.9875 | 0.9875 | 6.49% |
| Gisborne & Hawke's Bay | 1 | 1 | 1 | 5.41% | 1 | 1 | 1 | 5.00% |
| Taranaki | 1 | 0.9808 | 0.9808 | 3.18% | 1 | 0.9812 | 0.9812 | 2.76% |
| Manawatu | 0.9595 | 1 | 0.9594 | 6.66% | 0.9559 | 0.9999 | 0.9559 | 5.89% |
| Wellington West | 0.9685 | 0.9694 | 0.9379 | 6.82% | 0.9723 | 0.9693 | 0.9416 | 6.79% |
| Wellington East | 0.9999 | 0.9575 | 0.9575 | 5.05% | 0.9998 | 0.9587 | 0.9584 | 4.55% |
| Nelson, Tasman, West Coast | 1 | 0.9974 | 0.9974 | 4.07% | 1 | 0.9975 | 0.9975 | 4.09% |
| Canterbury | 0.9991 | 1 | 0.9991 | 12.93% | 0.9994 | 1 | 0.9994 | 12.84% |
| Otago | 0.9980 | 0.9792 | 0.9772 | 5.32% | 0.9980 | 0.9814 | 0.9794 | 4.90% |
| Southland | 0.9664 | 1 | 0.9664 | 2.96% | 0.9657 | 0.9999 | 0.9656 | 2.44% |

# Appendix E: Stata® ADO file

```
* Match quality statistic
* For methodology, refer to "Grimes, Maré, Morten (2006) "Defining Areas", Motu Working Paper
* This ado file is available for use, please reference the above paper
* Builds on earlier work by Jason Timmins
*
* Melanie Morten and David C Maré
* Motu Economic and Public Policy Trust
* www.motu.org.nz
* melanie.morten@motu.org.nz; dave.mare@motu.org.nz
* 25 September 2006
*
*
* Syntax for this command is
*********************************************************************************************
* mq from to pop, c(cutoff) NOPTable NOTable REPlace
*
* where from is the initial regional aggregation
* to is the final regional aggregation
* pop is the weighting variable
*
* OPTIONS:
* cutoff   is the minimum proportion of the `from"s population that must be in the `to' for the match to be allowed
*                       if no cutoff value is entered, the default used is 90 (i.e. 90% of the `from's pop required to be in one `to'
* noptab  suppresses display of a table giving details of the population allocation by `from'
* notab    suppresses display of a table with the match quality statistic by `from'
* replace replaces the dataset with the table of match quality statistics
*
* if neither table option is selected then all statistics are displayed
*
* EXAMPLES
* mq TA RC pop, c(85) notab noptab
*           calculates the quality of match from TA to RC, with a cutoff value of 0.85
*           and does not give tables
*
* mq TA RC pop, c(90)
*           calcuates the quality of match between TA to RC with cutoff value of 0.90
*           and displays both summary tables
*
* RETURNED RESULTS
* The final nationwide match quality statistics are returned by the program in the following macros:
*  (type 'return list' to see them)
* r(MM_`cutoff')
* r(MM_1_`cutoff')
* r(MM_3_`cutoff')
* where `cutoff' is the cutoff value given by the user
*
* Note: the program allocated `to'=0 for unallocated population - if one of your regions is coded 0, please change it
* before running the program
*
*********************************************************************************************
*
program mq, rclass
version 9
#delimit ;
set more off;
*! Match quality program, 25 September 2006;
syntax varlist (min=3 max=3) [, Cutoff(real 90) NOPTable NOTable REPlace];

local from: word 1 of `varlist';
```

```
local to: word 2 of `varlist';
local pop: word 3 of `varlist';
local c=`cutoff'/100;		/*converts cutoff (e.g. 90) into a proportion (e.g. 0.90). cutoff can become variable_suffix */

capture error (`cutoff'<=50 | `cutoff'>100);
if (_rc==1) {;
		display in red "ERROR! cutoff must be between 50 and 100, cutoff=`cutoff'";
		exit _rc;
		};

tempfile recall tab_addin;
preserve;

sort `from' `to' `pop';
quietly {;
		keep `from' `to' `pop';
		collapse (sum) `pop', by(`from' `to');
		egen act_`from'=sum(`pop'), by (`from');
		egen act_`to'=sum(`pop'), by (`to');
		gen alpha=`pop'/act_`from';
		gen alloc_`to'=`to';
		sort `from' alpha;
		replace alloc_`to'=0 if alpha<(`c');
		by `from': replace alloc_`to'=alloc_`to'[_N]; * if alpha<(`c');
		egen count_`to'=sum(`pop'), by (alloc_`to');
		egen omit =sum(`pop') if alloc_`to'~=`to', by(`to'); /* Number omitted from each `to' */
		egen addin=sum(`pop') if alloc_`to'~=`to', by(alloc_`to'); /* Number added in to allocated_`to' */
		save `recall', replace;
			** get a table of addins and totallocated;
			** Issue is that addins are linked to allocated_`to', want them to be linked to `to';
			** These are currently linked to allocated_`to' and we want a table of them against `to';
			table alloc_`to', c(mean addin mean count_`to') replace missing;
			rename alloc_`to' `to';
			save `tab_addin', replace;
		use `recall', clear;
		sort `to';
		drop addin count_`to'; /* because they are about to get merged in against `to' */
		merge `to' using `tab_addin'; /* add in the 'allocated_`to" tallies to the corresponding `to' */
		drop _merge;
		rename table1 addin;
		rename table2 count_`to';
		egen temp1=mean(omit), by(`to');
		egen temp2=mean(addin), by(`to');
		replace omit=temp1;
		replace addin=temp2;
		drop temp1 temp2;
		replace addin=0 if addin==.;
		replace omit=0 if omit==.;
		collapse (mean) act_`to' count_`to' addin omit, by(`to');
		gen M1_add_`cutoff'=1-addin/act_`to'; /*the bit added in for each `to', as a proportion of total population */
		gen M2_omit_`cutoff'=1-omit/act_`to'; /* the bit omitted for each `to', as a proportion of total population */
		gen M12_all_`cutoff'=(M1_add_`cutoff' + M2_omit_`cutoff')-1; /* = 1-(addin+omit)/act_`to' - the region-specific match quality */
		sum M1_add_`cutoff' [aw=act_`to'];
			local MM_1_`cutoff'=r(mean); /*nationwide add-in mismatch */
		sum M2_omit_`cutoff' [aw=act_`to'];
			local MM_`cutoff'=r(mean); /*omissions = national match quality statistic */
		egen nationalpop=sum(act_`to');
		gen unallocated=sum(addin*(`to'==0));
		replace unallocated=0 if unallocated==.;		/*so if no unallocated, statistic has value 1*/
		gen MM3`cutoff'=1-unallocated/nationalpop; /*this is nationwide unallocated match quality */
		sum MM3`cutoff';
			local MM_3_`cutoff'=r(mean);
		gen truepop=act_`to';
```

```
        };


/*now have done all preparations: just need to display results */
if "`noptable'"=="" {;
        di in yellow;
        di in yellow;
        di in yellow "POPULATION ALLOCATION INFORMATION (cutoff = `cutoff')";
        di in yellow "AGGREGATING `from' INTO `to'";
        di in yellow "================================================";
        di in yellow "`to'=0 measures unallocated population (not allocated to any `to')";
        table `to', c(mean act_`to' mean count_`to' mean addin mean omit);
        drop count_`to' addin omit;
        };
else    {;
        di in red;
        di in red "NOTE: Population allocation information option not requested";
        di in red "   (omit the option 'noptable' to produce these)";
        };

if "`notable'"=="" {;                   /*am giving the sub-region table as an option */
        di in yellow;
        di in yellow;
        di in yellow "MATCH QUALITY STATISTICS BY TARGET AGGREGATION (`to'), cutoff=
`cutoff'";
        di in yellow "AGGREGATING `from' INTO `to'";
        di                                      in                                      yellow
"================================================================";
        di in yellow "M1 gives add-in, M2 gives omit, M12 gives overall,";
        di in yellow "truepop gives region's true population";
        table `to' [aw=act_`to'], c(mean M1_add_`cutoff' mean M2_omit_`cutoff' mean M12_all_`cutoff'
sum truepop) ;
        drop act_`to' M1_add_`cutoff' M2_omit_`cutoff' M12_all_`cutoff' truepop;
        };
else    {;
        di in red;
        di in red "NOTE: Sub-regional match quality statistics option not specified";
        di in red "   (omit the option 'notable' to produce these)";
        };

di in yellow;
di in yellow;
di in yellow "NATIONWIDE MATCH QUALITY STATISTICS, cutoff = `cutoff'";
di in yellow "AGGREGATING `from' INTO `to'";
di in yellow "================================================";
di in yellow "Nationwide match quality statistic is "`MM_`cutoff";
di in yellow "Nationwide add-in match quality statistic is "`MM_1_`cutoff";
di in yellow "Nationwide omission match quality statistic is "`MM_3_`cutoff";
return local MM_`cutoff' "`MM_`cutoff'"";
return local MM_1_`cutoff' "`MM_1_`cutoff'"";
return local MM_3_`cutoff' "`MM_3_`cutoff'";;

if "`replace'"=="" {;
        restore;
        };
end;
```

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