

Similar increase in reproductive performance in different continents of female line, male line and parent stock broiler breeders genetically selected in the UK or South America

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Similar increase in reproductive performance in different continents of female line, male line and parent stock broiler breeders genetically selected in the UK or South America

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Abstract. 1. Field data on the reproductive performance of parent stock and grandparent female line and male line broiler breeders were extracted from a commercial database covering the years of hatch from 1989 to 2002. The data were from the UK, Western Europe, Central and South America and Japan. Quadratic regression curves were fitted to the data to estimate the long term phenotypic trends in total egg production, hatching egg production, chick numbers, hatchability and female mortality.

2. Changes in performance over time were similar in the UK, Western Europe and Central and South America and are consistent with the suggestion that genetic selection in separate breeding programmes in the UK (supplying the UK and Western Europe) and Brazil (serving Central and South America) was associated with similar improvements in the performance of commercial parent stock and grandparent flocks. Changes in performance in Japan (supplied from the UK) were different but recent performance was similar to those in the other regions.

36 3. The mean annual improvement over 10 years to 2002 for male line, female line and parent 37 stock respectively were 0.4, 1.7 and 1.7 for total egg number; 0.5, 1.8 and 1.6 for hatching 38 egg number; 0.6, 1.8 and 1.3 for total chick production; 0.25, 0.47 and 0.09 % for 39 hatchability; and -0.69, -0.05 and -0.41 % for female mortality.

40 4. The results are consistent with claims that significant genetic change in pedigree selection 41 (nucleus) flocks by the primary breeding company are reflected in substantial improvements 42 in reproductive performance in commercial flocks. The presence of similar rates of 43 improvement in different geographical regions as a result of genetic selection in two 44 continents representing tropical and temperate regions suggests that genotype-environment 45 interactions for reproduction traits are not important.

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INTRODUCTION

Genetic selection of broiler chickens for increased broiler traits results in a decline in reproductive output in selection experiments because of the negative genetic correlation between growth rate and egg production (Chambers, 1990). Commercial breeders therefore expend some selection effort in maintaining or improving reproduction in female lines, whereas there is much less emphasis on egg production in the male lines with which they are mated to generate commercial broilers.

54 It has sometimes been stated by those organisations that are critical of modern animal breeding programmes that genetic selection for increased broiler productivity has led to lower 55 56 fitness as shown by decreased reproductive performance and higher mortality. Breeding 57 companies, on the other hand, maintain that they select for increased reproduction and better 58 health in their lines and that reproductive performance has increased, particularly in recent 59 years. Estimates of the genetic progress from selection decisions in purebred nucleus flocks 60 can be obtained routinely using modern statistical methods for calculating breeding values. 61 However the environments in which commercial hybrids are kept are very different from those in the pedigree flocks and selection progress in selection environment may not be 62 63 translated into comparable improvements in commercial performance. Part of the objective of this study was to quantify the changes that have occurred over a recent 15 year period in a 64 65 large number of flocks of commercial parent stock, and the main female and male lines 66 (grandparents of commercial broilers) of a major broiler breeding company.

67 The Aviagen breeding company operates a voluntary system of flock recording for
68 customers producing grandparent crosses for commercial flocks of broiler parent stock
69 (broiler breeders). The performance of parent stock flocks can also be entered into the system.
70 The data are used to provide comparative information on the relative performance of different
71 flocks for technical advice and as an aid in identifying management problems that may be

inhibiting optimum reproductive performance. The great-grandparents of commercial broilers (the parents of the female and male lines) are supplied by Aviagen from separate pedigree breeding populations in the UK, Brazil and USA using similar breeding structures and technologies. A second objective was therefore to determine whether there had been similar changes in reproductive performance of flocks of broiler breeders supplied from separate breeding programmes in two climates, one temperate (UK) and one tropical (Brazil). The UK selection programmes supplies customers in the UK, Western Europe and Japan, and Brazil provides chicks for customers in Central and South America (C&S America). Selection objectives and procedures were identical in the two locations. Primary selection objectives in male lines were feed efficiency and muscle yields, whereas in female lines selection emphasised improved reproduction in addition to other traits. Our third objective was therefore to compare the changes in different continents to assess the importance of putative genotype x environment interactions, *i.e.* whether similar changes had occurred in very different commercial conditions in three continents (Europe, C&S America and Asia).

MATERIALS AND METHODS

87 Data source and data edits

Flock data were entered by flock managers and Aviagen technical staff from farm records dating from 1984. Data analysed were hen housed egg production (total egg production/number of hens at housing), hen housed hatching egg numbers (total hatching egg production/number of hens at housing), hen housed chicks (total chick production/number of hens at housing), hatchability of eggs set (total number of eggs hatching/total number of eggs set, %) and female laying house mortality (total number of hen deaths/number of hens at housing). All 5 traits were adjusted to 60 weeks of age by unspecified commercial correction factors.

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Data from the Ross 308 in the UK, Western Europe, C&S America and Japan were selected for statistical analysis. Commercial broilers are produced by mating an (A $\stackrel{>}{\circ}$ x B $\stackrel{\bigcirc}{\circ}$) male with a (C $\stackrel{>}{\circ}$ x D $\stackrel{\bigcirc}{\circ}$) female. Information on female reproductive performance of the grandparent male line B (ML), female line D (FL) and commercial parent stock (PS) that contribute to the Ross 308 commercial broiler were selected for analysis.

Statistical analysis

Quadratic regression curves were fitted using restricted maximum likelihood (REML) methods (Patterson and Thompson, 1971) to represent long term time trends in the observations. This shape of curve was chosen because it allowed for a long term trend to be increasing, decreasing or both. Higher order polynomials or other curves with multiple turning points were thought to be implausible representations of long term trends. REML was required to estimate variance components between and within hatch week and other sources of random variation associated with the different customers supplying the data.

The manner and extent to which individual data points had been aggregated over birds, houses and farms was unknown. All observations were therefore given the same weight in the fitting process. Standard errors were calculated using deviations about the fitted curve as random variation, assuming the part of the variation due to farms, houses and birds to be small compared with that due to deviation about fitted curves. Estimates of regression coefficients of the trend using equal weights will be unbiased providing there is no association between the size of an observation and the number of birds, houses or farms over which it has been aggregated. Variation between customers in the shape of the curves was taken to be random and the standard errors include this variation. Variation between customers in the level of the curves was taken to be a fixed effect so that any gross differences between them (due to management or climate, for example) would not contribute to the trend. Customers with data spanning less than 3 years were omitted in the estimation of long term trends as

short term trends could be qualitatively different from those in the long term (seasonal cycling within a year, for example). Fitted curves and predicted means in multi-customer regions were arrived at by averaging equally over all customers. RESULTS Data were extracted from the database in mid-2004 when it was assumed that all flocks hatched in 2002 would have completed records. This was the case for all regions except Japan. Data for the period from 1984 to 1990 were not extensive and results of the analyses of data from birds hatched over a 10-year period from 1991 to 2001 or 2002 are presented. The numbers of records analysed and the number of customers contributing to each data set are presented in Table 1. Mean flock performance in 2002 for each trait and all 4 regions are Tables 1,2,3 near here presented in Table 2. Response curves for individual PS flock means from birds hatched from 1991 to 2002 in the UK are plotted in Figure 1 and regional curves for PS, FL and ML respectively are plotted in Figures 2, 3 and 4. The data and curves for hen housed hatching egg numbers were similar to those for total hen housed egg production for all three lines and are not presented. It should be noted that the range but not the scale for total and hatching egg numbers in Figures 1 to 4 are not the same and care should be exercised in comparisons between them. Appropriate numerical contrasts between the three lines may be made by reference to Tables 2 and 3. Response curves and individual data points for PS in the UK (Figure 1) illustrate the wide spread of flock means about the fitted curve that was also observed for FL and ML in the UK and PS, FL and ML in the other regions (data not shown). The response curves for PS in the UK, W. Europe, C&S America and Japan are presented in Figure 2. There was an early decline followed by an improving response for total and hatching egg production. Hatchability showed a small decline in the early 1990s followed

by a subsequent increase in three of the four regions and there was a trivial decline from a relatively high mean hatchability in Western Europe. Mortality also improved in recent years in three regions and showed a small increase in the UK from a relatively low starting point

There was a steady increase in egg production, chick numbers and hatchability in the FL (Figure 3) over the study period and a recent decline in female mortality in all regions except the UK and Western Europe where there was a small increase. Japan showed a substantial decrease in hatchability and chick numbers from a high in the early years and a recent increase to similar levels as the other regions.

Responses for ML flocks (Figure 4) were similar for the UK, W. Europe and C&S America and show a recent improvement in egg and chick production, decreased female mortality and little change in hatchability. The responses for Japan were very different and were comparable with those for PS and FL.

Estimates of the change in response for each trait over the 10 years to 2002 by geographical region are presented in Table 3. The mean annual changes for ML, FL and PS respectively were 0.4, 1.7 and 1.7 for total egg number; 0.5, 1.8 and 1.6 for hatching egg number; 0.6, 1.8 and 1.3 for total chick production; 0.25, 0.47 and 0.09 % for hatchability; and -0.69, -0.05 and -0.41 % for female laying house mortality. Part of the differences in the responses over time for ML in Japan (Table 3) is associated with a change in management of the birds introduced by the customer.

^B 165

DISCUSSION

There is little comparable information in the public domain on changes in reproductive performance in broiler breeders with which to compare these results. Schall and Cherian (2007) reported that there was no detectable change in average hatchability of about 80 % from 1985 to 2005 in the USA. In a smaller data set from 38 rearing farms in Norway from 1996 to 1998 average hatchability was also about 80 % (Heier and Jarp, 2001). Hatchability

171 for PS at the end of our study period was higher than these values with regional means 172 ranging from 80 to 85 %; corresponding means were 70 to 80 % for FL and 65 to 75 % for 173 ML. In contrast to PS, the range of hatchabilities for FL and ML are large and suggest that 174 there is considerable scope for management changes to hatchery procedures to improve the 175 hatchability of these lines in some regions.

Genetic stocks in the UK, W. Europe and Japan are sourced from the same pedigree (nucleus) selection flocks whereas those for C&S America are supplied from Brazil. The similarity of changes in reproduction traits of commercial flocks of parents and grandparents in the UK, W. Europe and C&S America does not contradict the suggestion that genetic selection in the UK and Brazil has resulted in similar changes in commercial performance in different geographical regions. We cannot distinguish between genetic changes and improvements in flock management but there has been little technical innovation, such as the introduction of separate sex feeding in the late 1980s, which could have led to improved reproductive performance in the study period. Conversely, changes that have occurred, *e.g.* the move from manual to automatic egg collection may have had a negative impact on egg production. It is assumed that in principle all customers followed the management targets for body weight control and general management procedures recommended by the breeding company but it is impossible to verify the extent to which these were adhered to in individual flocks. Nevertheless by analysing data from a large number of flocks the influence of temporary differences in flock management practices are minimized: the results are virtually population parameters for FL and ML and encompass a substantial proportion of PS flocks in the regions analysed.

Reporting bias is unquantifiable in the data set but biased reporting serves no useful
purpose to the instigator. If there is any form of selective reporting it is likely to be negative
because producers with poor flocks are more likely to record flock performance as a means of

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solving management problems, or as part of the process of obtaining financial recompensefrom the breeding company and chick supplier.

The extent of the recent phenotypic improvement in egg production (Table 3) is comparable to that attained in commercial table-egg laying hens and if genetic selection is responsible, suggests that this primary breeder is placing heavy emphasis on improving egg and chick production. Taken together the results are consistent with the conclusion that genetic selection in pedigree flocks has been successful and has resulted in substantial improvements in reproductive traits in commercial flocks of broiler breeders in very different geographical regions and climates.

Recent improvements in female mortality are impressive in all regions except for the UK where there has been a slight increase in FL and PS (Table 3). Part of this change may be due to improved husbandry or vaccination and some to selection on fitness traits. We chose to examine female mortality only because many flocks did not report male mortality. Furthermore the male data were considered to be unreliable because regular culling of males is conducted during the laying period on an *ad hoc* basis to maintain overall male fitness and to adjust the male:female mating ratio to avoid over-mating and consequential damage to females.

Whereas the reproductive traits analysed in this paper have been treated as female traits, it should be noted that the male has an influence not only on traits such as hatchability and chick numbers, but potentially on egg production and female mortality *via* social and sexual cues (Leonard *et al.*, 1993; Widowski *et al.*, 1998) and the effects of social and mating stress (Millman and Duncan, 2000a and b).

Reproductive efficiency, productivity and health are important considerations in
 assessing the welfare of any group of animals and the evidence of this analysis is that genetic
 selection has led to substantial improvements in these criteria over a recent 10 year period. A

corollary is that feed restriction during the rearing period has not had a negative effect on reproductive fitness during a decade of substantial genetic improvement in broiler growth rate and feed efficiency. In conclusion, there has been substantial improvement over a recent 10 year period in

the reproductive traits of PS and FL, which contribute half the PS genetic material, and mortality has shown an improvement in parent and grandparent flocks of broiler breeders in three of the four regions analysed. The change in total eggs, hatching eggs and chick numbers over the same period in ML have also increased but at about half the rate in PS and FL. The rate of change has been similar in different geographical regions and in areas supplied by primary breeding flocks in the UK and Brazil, and are consistent with claims of significant genetic improvement of reproduction traits in primary breeding populations. The similarity of the phenotypic changes in different continents suggests that significant genotype x environment interactions for reproductive performance has not occurred. There is little or no evidence that reproductive traits have decreased during the study period.

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Figure Legends

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261	Figure 1. Individual flock means and fitted regression curves for parent stock broiler
262	breeders hatched in the UK from 1991 to 2002 for (a) total hen housed egg production, (b)
263	hatchability of eggs set, (c) number of chicks per hen housed and (d) female mortality.
264	
265	Figure 2. Response curves of flock means of parent stock broiler breeders hatched in the UK,
266	Western Europe, Central and South America and Japan from 1991 to 2002 for (a) total hen
267	housed egg production, (b) hatchability of eggs set, (c) number of chicks per hen housed and
268	(d) female mortality.
269	
270	Figure 3. Response curves of flock means of female line grandparent broiler breeder females
271	hatched in the UK, Western Europe, Central and South America and Japan from 1991 to
272	2002 for (a) total hen housed egg production, (b) hatchability of eggs set, (c) number of
273	chicks per hen housed and (d) female mortality.
274	
275	Figure 4. Response curves of flock means of male line grandparent broiler breeder females
276	hatched in the UK, Western Europe, Central and South America and Japan from 1991 to

2002 for (a) total hen housed egg production, (b) hatchability of eggs set, (c) number of

chicks per hen housed (d) and female mortality.

279	Fable 1. Total number of flocks and customers for hen housed egg production, hatchability of eggs set, hen housed chick numbers and female

mortality to 60 weeks of age for broiler grandparent male and female lines and broiler parent stock in the UK, Western Europe, Central and South

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America and Japan

	Total eggs, n/hh ¹		Hatching eggs, n/hh		Chicks, n/hh		Hatchability, %		Female mortality, %	
	Flocks	Customers	Flocks	Customers	Flocks	Customers	Flocks	Customers	Flocks	Customers
UK	302		304	1	279	1	280	1	285	1
W. Europe	362	7	350	8	206	5	210	5	348	7
C&S America	352	8	334	8	294	7	294	7	296	8
Japan ²	106	1	106	1	90	1	90	1	96	1
UK	650	1	650	1	570	1	570	1	610	1
W. Europe	425	8	398	8	235	5	236	5	394	7
C&S America	498	12	482	12	404	10	404	10	436	12
Japan ²	110	1	107	1	92	1	92	1	105	1
UK	1469	17	1570	17	1555	17	1555	17	765	14
W. Europe	495	13	514	15	439	11	442	11	506	15
C&S America	1038	16	1065	17	1036	15	1037	15	851	13
Japan ²	759	19	757	19	283	12	284	12	725	19
	UK W. Europe C&S America Japan ² UK W. Europe C&S America Japan ² UK W. Europe C&S America Japan ²	Flocks UK 302 W. Europe 362 C&S America 352 Japan ² 106 UK 650 W. Europe 425 C&S America 498 Japan ² 110 UK 1469 W. Europe 495 C&S America 1038 Japan ² 759	Flocks Customers UK 302 1 W. Europe 362 7 C&S America 352 8 Japan ² 106 1 UK 650 1 W. Europe 425 8 C&S America 498 12 Japan ² 110 1 UK 1469 17 W. Europe 495 13 C&S America 1038 16 Japan ² 759 19	FlocksCustomersFlocksUK 302 1 304 W. Europe 362 7 350 C&S America 352 8 334 Japan ² 106 1 106 UK 650 1 650 W. Europe 425 8 398 C&S America 498 12 482 Japan ² 110 1 107 UK 1469 17 1570 W. Europe 495 13 514 C&S America 1038 16 1065 Japan ² 759 19 757	FlocksCustomersFlocksCustomersUK 302 1 304 1W. Europe 362 7 350 8C&S America 352 8 334 8Japan ² 106 1 106 1UK 650 1 650 1W. Europe 425 8 398 8C&S America 498 12 482 12 Japan ² 110 1 107 1UK 1469 17 1570 17 W. Europe 495 13 514 15 C&S America 1038 16 1065 17 Japan ² 759 19 757 19	FlocksCustomersFlocksCustomersFlocksUK 302 1 304 1 279 W. Europe 362 7 350 8 206 C&S America 352 8 334 8 294 Japan ² 106 1 106 1 90 UK 650 1 650 1 570 W. Europe 425 8 398 8 235 C&S America 498 12 482 12 404 Japan ² 110 1 107 1 92 UK 1469 17 1570 17 1555 W. Europe 495 13 514 15 439 C&S America 1038 16 1065 17 1036 Japan ² 759 19 757 19 283	FlocksCustomersFlocksCustomersFlocksCustomersUK 302 1 304 1 279 1W. Europe 362 7 350 8 206 5C&S America 352 8 334 8 294 7Japan ² 106 1 106 1 90 1UK 650 1 650 1 570 1W. Europe 425 8 398 8 235 5C&S America 498 12 482 12 404 10 Japan ² 110 1 107 1 92 1UK 1469 17 1570 17 1555 17 W. Europe 495 13 514 15 439 11 C&S America 1038 16 1065 17 1036 15 Japan ² 759 19 757 19 283 12	FlocksCustomersFlocksCustomersFlocksCustomersFlocksUK 302 1 304 1 279 1 280 W. Europe 362 7 350 8 206 5 210 C&S America 352 8 334 8 294 7 294 Japan ² 106 1 106 1 90 1 90 UK 650 1 650 1 570 1 570 W. Europe 425 8 398 8 235 5 236 C&S America 498 12 482 12 404 10 404 Japan ² 110 1 107 1 92 1 92 UK 1469 17 1570 17 1555 17 1555 W. Europe 495 13 514 15 439 11 442 C&S America 1038 16 1065 17 1036 15 1037 Japan ² 759 19 757 19 283 12 284	FlocksCustomersFlocksCustomersFlocksCustomersFlocksCustomersUK 302 1 304 1 279 1 280 1W. Europe 362 7 350 8 206 5 210 5C&S America 352 8 334 8 294 7 294 7Japan ² 10611061 90 1 90 1UK 650 1 650 1 570 1 570 1W. Europe 425 8 398 8 235 5 236 5C&S America 498 12 482 12 404 10 404 10Japan ² 11011071 92 1 92 1UK146917157017155517 1555 17W. Europe 495 13 514 15 439 11 442 11C&S America103816106517103615103715Japan ² 75919 757 19 283 12 284 12	FlocksCustomersFlocksCustomersFlocksCustomersFlocksCustomersFlocksUK 302 1 304 1 279 1 280 1 285 W. Europe 362 7 350 8 206 5 210 5 348 C&S America 352 8 334 8 294 7 294 7 296 Japan ² 10611061 90 1 90 1 96 UK 650 1 650 1 570 1 570 1 610 W. Europe 425 8 398 8 235 5 236 5 394 C&S America 498 12 482 12 404 10 404 10 436 Japan ² 11011071 92 1 92 1 105 UK 1469 17 1570 17 1555 17 765 W. Europe 495 13 514 15 439 11 442 11 506 C&S America 1038 16 1065 17 1036 15 1037 15 851 Ianan ² 759 19 757 19 283 12 284 12 725

³³₃₄283 ¹ hh = hen housed.

² Means for birds hatched to 2001.

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2 285 3	Table 2. Means and standard deviation for hen housed egg production, hatchability of eggs set, hen housed chick numbers and female mortality to 60

weeks of age for broiler grandparent male and female lines and broiler parent stock hatched in 2002 in the UK, Western Europe, Central and South

America and Japan

Genotype	Location	Total eggs,n/hh ¹		Hatching eggs, n/hh		Chicks, n/hh		Hatchability, %		Mortality Mortality	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	
Male line	UK	103	12	92	10	63	8	67.6	1.0	13.2	
	W. Europe	101	7	94	8	67	8	72.6	2.7	13.1	
	C&S America	123	4	108	6	85	3	78.7	3.8	7.2	
	Japan ²	99	9	90	9	68	8	75.8	3.0	9.8	
Female line	UK	159	10	142	9	103	12	72.6	5.0	11.3	
	W. Europe	155	7	146	7	112	9	77.6	2.6	10.8	
	C&S America	156	11	143	12	105	16	73.4	6.3	11.8	
	Japan ²	164	3	151	4	122	7	80.4	4.4	7.4	
Parent stock	UK	168	7	160	7	132	8	82.7	2.4	9.5	
	W. Europe	161	8	153	8	122	8	79.6	2.8	9.5	
	C&S America	176	12	168	12	149	6	84.5	2.2	6.9	
	Japan ²	166	8	153	9	130	9	85.0	3 .1	7.5	

 1 hh = hen housed.

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² Means and SD for birds hatched in 2001.

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2 291 **Table 3.** Total 10 year change to 2002 of hen housed egg production, hatchability of eggs set, hen housed chick numbers and female mortality to 60 weeks of age estimated by fitting a quadratic regression model to flock means for broiler grandparent female and male lines and broiler parent stock 4 292 in the UK, Western Europe, Central and South America and Japan

Genotype	Location	Total eggs,n/hh ¹		Hatching	g eggs, n/hh	Chicks, n/hh		Hatchability, %		Mortality, %	
		Change	SE	Change	SE	Change	SE	Change	SE	Change	SE
Male line	UK	12.4	2.25	11.9	2.23	8.9	1.92	4.1	0.97	-6.7	1.01
	W. Europe	7.3	2.76	7.6	3.10	12.7	2.75	2.4	1.50	-11.3	1.36
	C&S America	10.2	3.18	12.7	3.21	9.8	2.80	1.1	1.41	-2.7	1.99
	Japan ²	-15.3	3.01	-10.7	3.18	-6.5	2.83	2.4	1.56	-6.7	2.32
	Mean	3.7		5.4		6.2		2.5		-6.9	
Female line	UK	16.7	1.64	13.3	1.73	10.8	1.86	-0.3	0.85	1.8	0.60
	W. Europe	21.6	2.07	25.1	2.65	20.8	2.32	6.0	1.19	-3.5	0.90
	C&S America	20.1	2.61	21.1	2.66	21.8	2.94	5.5	1.08	0.4	1.18
	Japan ²	8.3	2.74	13.7	2.73	17.2	2.98	4.7	1.43	-0.6	1.56
	Mean	16.7		18.3		17.7		4.0		-0.5	
Parent stock	UK	17.8	1.1	16.2	1.35	14.7	1.25	0.9	0.38	1.4	1.06
	W. Europe	14.6	4.05	14.6	3.83	10.2	5.52	1.3	1.92	-5.5	1.89
	C&S America ²	18.0	3.84	17.8	3.40	13.3	4.23	-0.6	0.99	-8.1	2.89
	Japan ^{2,3}	15.4	1.43	11.0	1.55	14.1	1.89	2.6	0.61	-2.8	0.61
	Mean ⁴	16.8		16.2		12.7		0.9		-4.1	

35 295 36 296 37 1 hh = hen housed.

² Changes to 2001 only.

³⁹₄₀298 ³ Data for the last 5 years only were available.

41 299 ⁴ Mean excluding Japan.











