Stochastic projections of persons, jobs and residences

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This paper has been written for presentation at the National Conference of the Australian Population Association, Melbourne, 29/11/00-1/12/00. Richard Cumpston is a director of Cumpston Sarjeant Pty Ltd, consulting actuaries, Melbourne.

Summary

Hugh Sarjeant and I are developing regional projection models, intended to provide 50-100 year projections for each of the 2600 postcodes in Australia. Our work was initially prompted by CSIRO's need to answer questions such as "Where should a proposed sewage works, with a 100-year lifetime, be built?". Other government, commercial and personal applications are possible.

The demanding requirements have led us to adopt methods very different to those normally used for regional population projections. Instead of analysing cohorts, we are simulating individuals, randomly generating their probabilities of birth, partnership, home purchase, employment and death. Simulating individuals gives us the flexibility to model social and economic variables at fine geographic scales.

Our models are employment driven, as we simulate the movement of individuals to be within reasonable access of their jobs, taking into account the availability of residential land. We model the development of shopping centres to service regions, taking into account the purchase patterns of individuals. The locations of firms are modelled, taking into account their needs to be near resources, markets, other firms or workers.

The models are money-based, as we try to replicate all the cash flows and assets of individuals. Housing prices are thus important, and automatically generated. An emerging issue in Australia is the extent to which prime agricultural land at the edge of cities will be used for homes, shopping centres and hobby farms.

We estimate behavioural probabilities from mass data, taking into account any available survey data. For example, we have just completed models of purchase patterns for each of 10 retail sectors for 200 statistical areas in Victoria, by modelling the potential purchases of residents in each area from each other area.

For 1 to 1 models of Australia, the computational requirements are demanding. To keep simulation times reasonable, we want to store all the data in computer memory. This will need 5 to 10 gigabytes of memory, which should soon be available in personal computers. To retain flexibility and minimise programming effort, we are using database techniques.

We are helped by the very good data available from the Australian Bureau of Statistics, derived from population censuses, business registrations and surveys. Deriving hypothetical households and firms from these and other sources presents many challenges. For example, suppose that we know the numbers of workers resident in each of 2000 areas, the numbers of persons employed in each area, and the geographic

centroid of each area. We also have survey data on the distribution of distances between employment and residence. How are we to allocate persons to jobs?

The employment-driven nature of the models gives them the capacity to respond to new developments. For example, sheep and cattle farms in western Victoria are currently being sold for use as blue gum plantations. What effects will this have on towns in the area? More generally, will the internet result in greater population dispersion?

1. Introduction

Hugh Sarjeant and I are developing regional projection models, intended to provide 50-100 year projections of persons, jobs and residences for each of the 2600 postcodes in Australia. This is an ambitious project, as we are not aware of any similar models now working anywhere in the world.

Our work was initially prompted in 1997 by Barney Foran, of Australia's Commonwealth Scientific and Industrial Research Organization. CSIRO sometimes needs to answer questions such as "Where should a proposed sewage works, with a 100-year lifetime, be built?". Questions such as these involve a longer time frame, and a more regional focus, than the population projections normally available from the Australian Bureau of Statistics or the state planning authorities.

Our work rests on the belief that employment is the crucial factor in deciding where most people live. We thus have to model jobs as well as persons. This requires larger models, using unfamiliar modelling techniques. If the challenging problems can be solved, the resulting models may have a range of applications. We are fortunate that our work is privately funded, and not subject to specific tasks or deadlines.

Australia is sparsely populated, with 19 million people living mainly on the coasts of 7,730,619 square kilometres of land. Many of the our examples are for Victoria, Australia's most densely populated state, which has 4.8 million people in 227,767 square kilometres. Our sprawling cities and wasteful use of land may be unfamiliar in Europe, but more common in the United States and Canada.

2. Projection methods

2.1 Cohort population projections

Population projections are normally made by cohort methods, where groups of persons of known sex and age are projected forward a year at a time, allowing for births, deaths and migration. The numbers of persons in each group are projected, but not their individual characteristics. The assumptions underlying these projections are sometimes randomly varied, giving "probabilistic" population projections (see Lutz, Sanderson & Scherbov, 1996).

2.2 Our stochastic projections of persons and households

By contrast, we are projecting individual persons and households, and randomly simulating the events happening to each one in each time period. Some of the events we simulate are births, deaths, partnership formation and dissolution, persons entering and leaving households, employment, migration and home purchase. Probability distributions are assumed for each event, and in each simulation period random numbers are drawn to determine which events actually happen. Job seekers are plausibly matched with vacancies, home buyers are matched with dwellings for sale, and persons seeking partners are matched with other persons seeking partners.

2.3 Storage efficiency of individual projections

Orcutt, Greenberger, Korbel & Rivlin (1961, p287) noted that several million cross-classifications are required to represent different types of household, allowing only for age, sex and marital status of the head of household, and the number, age and sex of children. Adding other information, such as income, assets and region, makes the numbers of cross-classifications impractical even for today's computers. For example, 10 variables, each with 10 possible values, give 10 billion cross-classifications to be stored. If these 10 variables were to be stored for each of 20 million people, 200 million values would need to stored. The storage efficiency of individual projections, compared with cohort projections, increases with the number of variables.

2.4 Migration assumptions

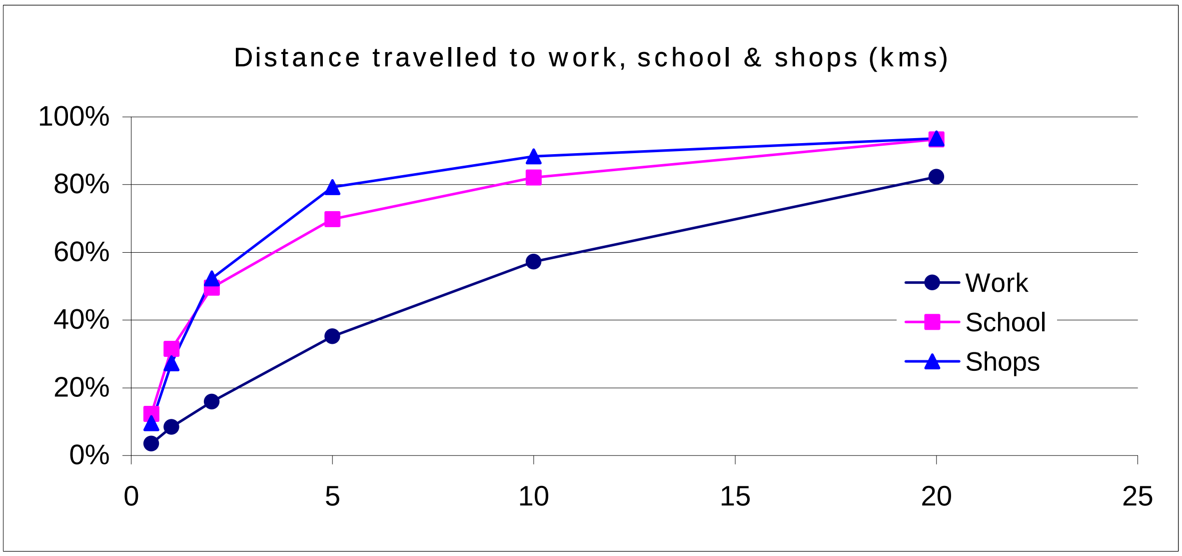
Cohort population projections often assume constant numbers of migrants, or constant migration rates, between regions. For example, the Australian Bureau of Statistics (1998a), in its population projections for each Australian state from 1997 to 2051, assumed constant net numbers of migrants into each state. But the poor results from our attempts to fit multiplicative probability models to migration between Australian states and statistical subdivisions led us to conclude that the models were inadequate reflections of the complex patterns of migration, and had little predictive value (Cumpston & Sarjeant, 1998). Stochastic projections allow us to simulate migration allowing for industry changes and individual circumstances.

3. Employment-driven models

3.1 Distances travelled from home to work, school or shops

Distance from home	Work	School/ college	Shops
Less than 500 ms	3.1%	11.6%	7.9%
500 ms to less than 1 km	4.3%	18.1%	14.6%
1km to less than 2	6.6%	17.1%	20.7%
2 km to less than 5	17.0%	19.1%	22.3%
5 km to less than 10	19.5%	11.7%	7.5%
10 km to less than 20	22.1%	10.6%	4.4%
20 km or more	15.6%	6.2%	5.2%
Not applicable	11.9%	5.7%	17.4%
Total	100.0%	100.0%	100.0%

The above Victorian survey data are from the Australian Bureau of Statistics (1995).



The median distance from home to work was about 8 kms, showing that most workers like to live close to their work (and even closer to schools and shops). Because of this close link between employment and residence, the geographic dispersion of different industries is very relevant to regional population projections. Note that 84% of persons used a car as their main method of travel to work, and only 8% used public transport.

3.2 Employment locations and transport costs (Victoria 1998)

Industry group	Average distance of workers from capital (kms)	Effect of distance from capital	Distance of peak from capital (kms)	Percent workers	Transport costs as % of production
Agriculture, forestry, fishing	179	Rising		4.0%	3.8%
Mining	81	Peaked	171	0.3%	1.9%
Manufacturing	49	Peaked	30	16.8%	3.2%
Electricity, gas, water supply	91	Peaked	135	0.7%	2.5%
Construction	59	Peaked	41	6.1%	2.8%
Wholesale trade	52	Peaked	25	6.3%	4.2%
Retail trade	60	Peaked	29	14.3%	1.0%
Accommodation, cafes, restaurants	64	Peaked	3	4.0%	1.7%
Transport, storage	51	Peaked	29	4.0%	4.0%
Communication services	44	Peaked	12	2.3%	3.1%
Finance, insurance	39	Peaked	4	4.2%	0.7%
Property, business services	38	Falling		10.2%	1.1%
Government administration, defence	63	Peaked	27	3.9%	3.0%
Education	58	Peaked	5	7.2%	0.5%
Health, community services	59	Peaked	4	9.6%	1.4%
Cultural, recreational services	43	Falling		2.4%	2.4%
Personal, other services	54	Falling		3.6%	2.3%
Total	58			100.0%	2.4%

Most of the above table is derived from the numbers of workers employed in each of the 17 industry groups in Victoria, as recorded in the Business Register of the Australian Bureau of Statistics. The numbers analysed are for 195 statistical local areas, varying in size from 680 to 110,000 persons. The average distance of workers from the capital were estimated as 58 kms, using great circle distances from the centroid of each statistical local area. For comparison, the average distance from the capital of persons living in Victoria is about 60 kms, and the distance of the most remote statistical local area from the capital is 471 kms (Mildura).

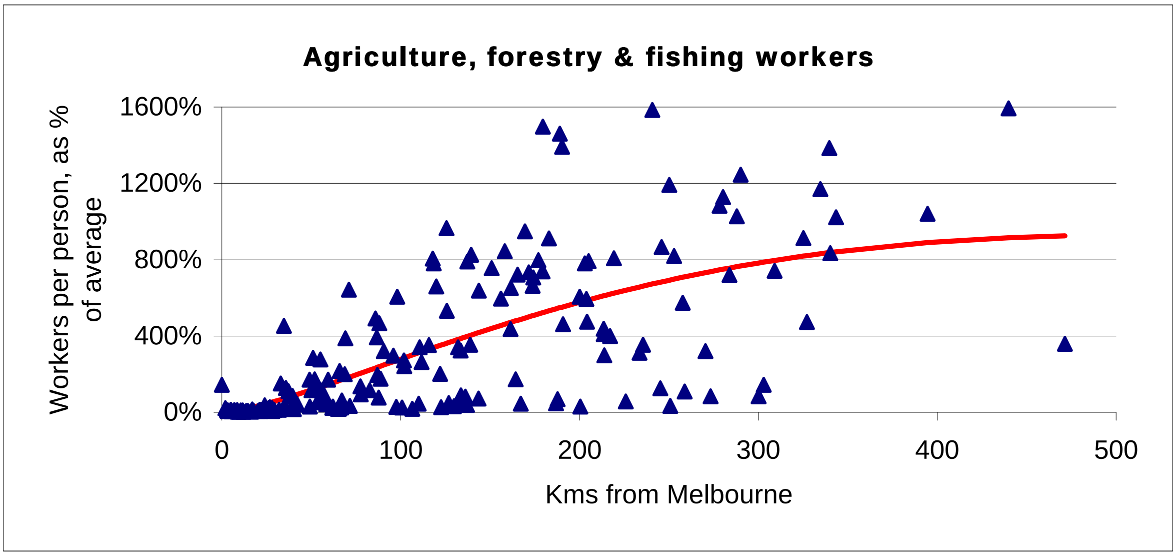
3.3 Transport costs

The last column of the above table gives transport costs as a percentage of production value, from Australian Bureau of Statistics (1997). Wholesale trade has the highest transport costs for any industry group, but these are only 4.2% of production. For all but a few specialised industries (such as brick manufacture), transport costs may play very little role in the choice of location.

3.4 Location patterns for each industry

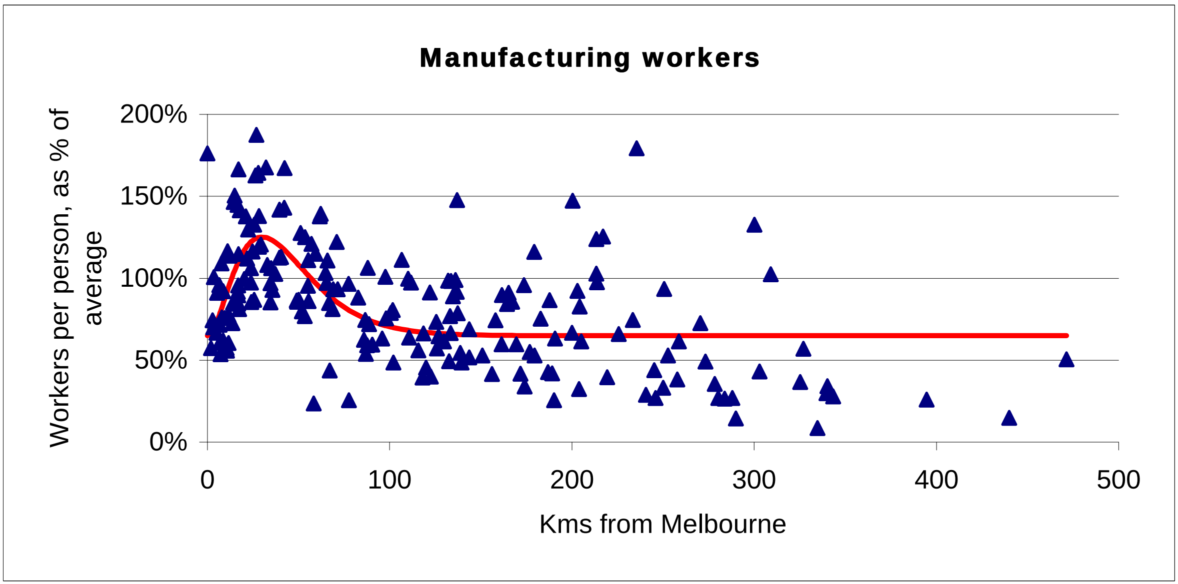
For each of the 17 industry groups, we calculated the numbers of workers per resident in each of the 195 areas, and divided by the same ratio for Victoria as a whole. We fitted simple mathematical distributions to the resulting ratios for each industry, to get some idea of the underlying pattern of dispersion. In general, we found that a gamma distribution plus a constant gave an intuitively acceptable fit. These industries are shown above as "peaked", together with the distance from the capital where the peak occurred. For agriculture, forestry and fishing, we found employment ratios increasing with distance from the capital. For three industries (property and business services, cultural and recreational services and personal and other services), we found that a negative exponential plus a constant gave a more plausible fit.

3.5 Primary industries



Employment ratios for each of the 195 areas are shown above, together with the fitted curve. Agriculture is clearly a regional industry, occurring where soil and water supplies are suitable. Different types of agriculture require more labour, helping explain some of the wide variability in the above graph. Some statistical local areas are essentially rural towns, and others are the agricultural areas surrounding those towns (for example the two rightmost points on the graph are Mildura A and Mildura B). Some primary production appears to occur in the central business district of Melbourne, as a result of the location of head offices of agricultural firms there. In fitting models, the central business district was omitted, to avoid distortions from this "head office" effect. The fitted curve is a gamma function, but the wide dispersions make its validity very dubious.

3.6 Manufacturing



The fitted curve (a gamma function plus a constant) peaks at 30 kms from the centre of the city. There is high dispersion, but the highest concentration of manufacturing workers is only 187%, compared with 1593% for agriculture, forestry and fishing. Again, there is an anomalously high value at the central business district. The high levels of manufacture 20 to 40 kms from Melbourne may reflect relatively cheap land, labour availability, and convenient access to Melbourne's consumers and transport facilities. The availability of education, entertainment and medical facilities for workers and their families may also be relevant.

Marshall (1920) suggested reasons for the concentration of similar industries in an area:

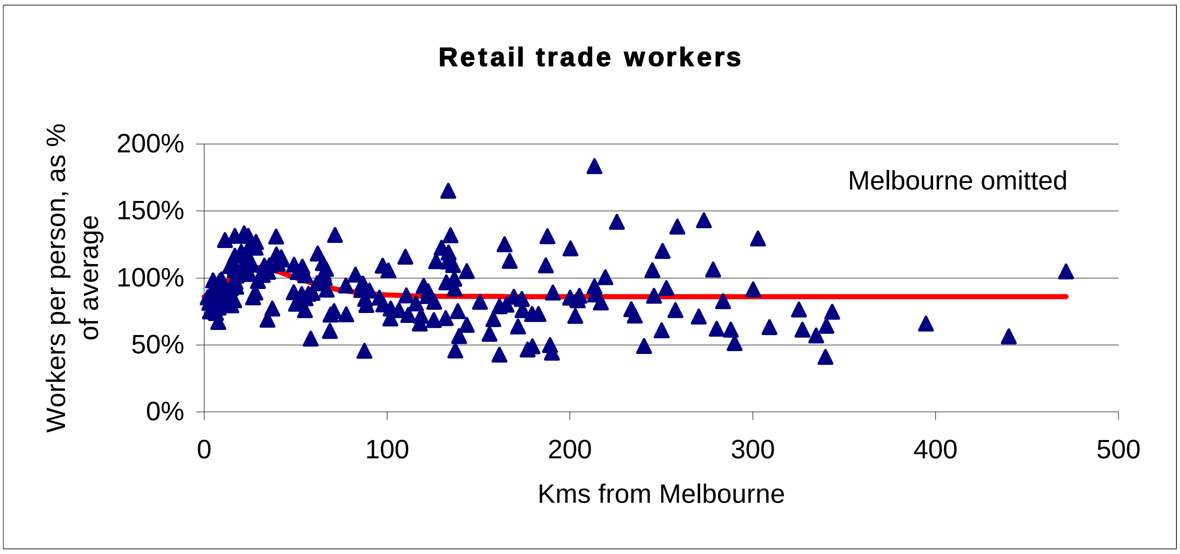
> "Employers are apt to resort to any place where they are likely to find a good choice of workers with the special skill that they require…"
>
> "...the economic use of expensive machinery can sometime be attained in a very high degree in a district in which there is a large aggregate production of the same kind"
>
> "Good work is rightly appreciated, inventions and improvement in machinery, in processes and the general organization of the business have their merits promptly discussed.."

History also places an important role. Large manufacturing plants tend to be built where land is available, at the outskirts of the capital. As the capital grows, these plants may lie well within the current sprawl, rather than at its edge.

3.7 Wholesale trade

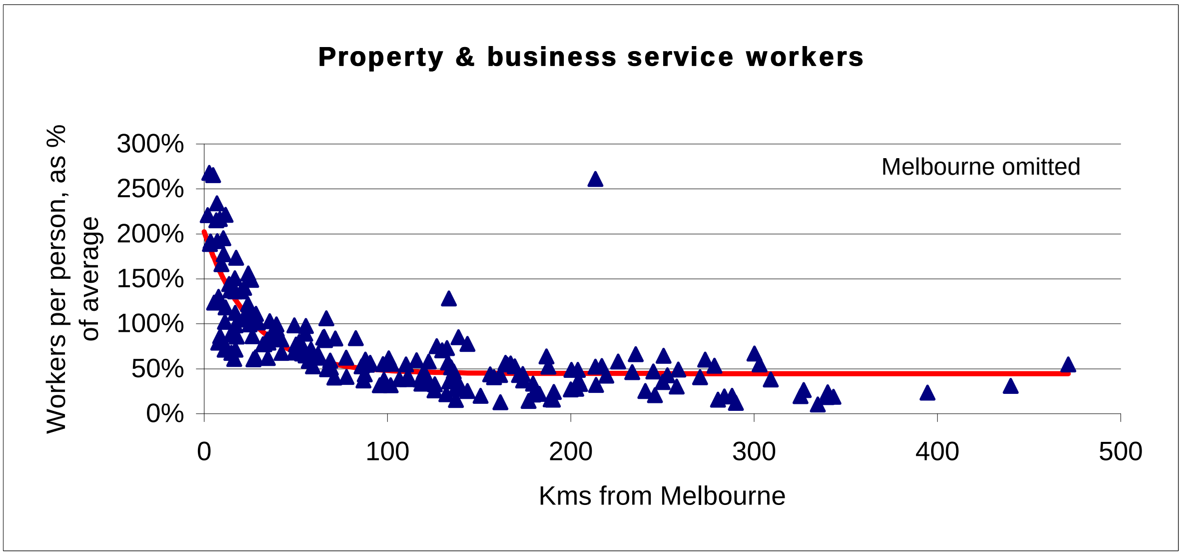
Wholesale trade shows a very similar pattern to manufacturing, with the fitted curve having a peak at 25 kms. Wholesale trade may be concentrated close to Melbourne, to service manufacturers, builders and the retail trade. Proximity to sea, road and rail transport may also be important.

3.8 Retail trade



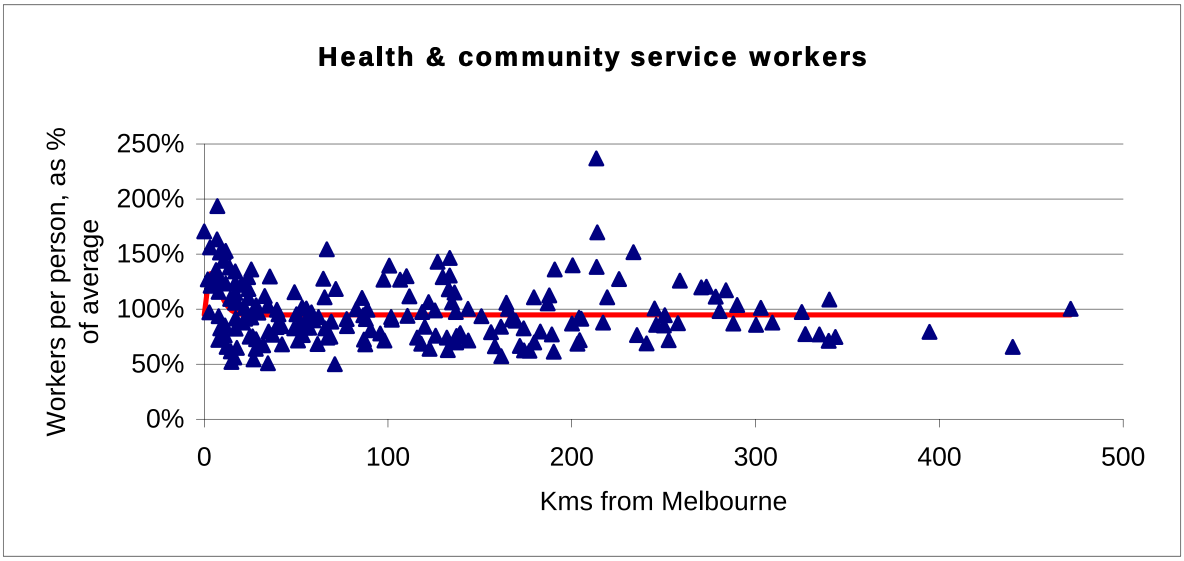
Retail trade shows a much flatter pattern than wholesale, with a small peak at 29 kms. The average distance of retail workers from the centre of Melbourne is 60 kms, identical with the average distance of Victorian residents from Melbourne.

3.9 Property and business services



Property and business service workers show a very different pattern, declining sharply from the centre of the city. The average distance of workers from the centre is 38 kms, less than any other industry group. The fitted curve is a negative exponential, with a constant term.

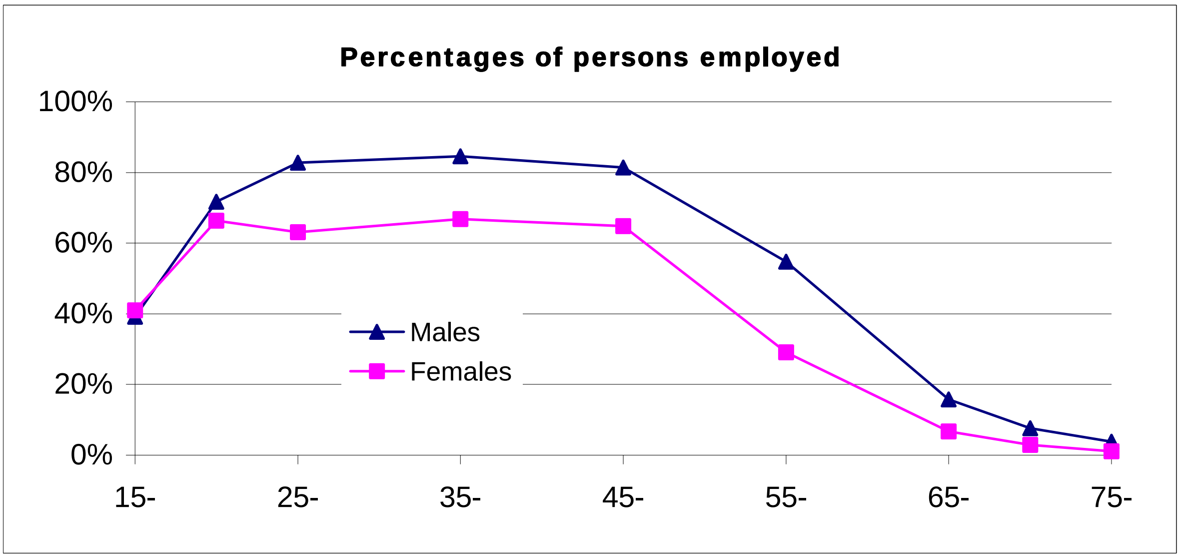
3.10 Health and community services



Health and community services are almost evenly spread throughout the population of Victoria, with an average distance of 59 kms from the centre of Melbourne. The fitted distribution is a large constant, plus a small gamma distribution, peaking at 4 kms from the centre. This small peak may reflect specialised medical facilities, and the major teaching hospitals, close to Melbourne.

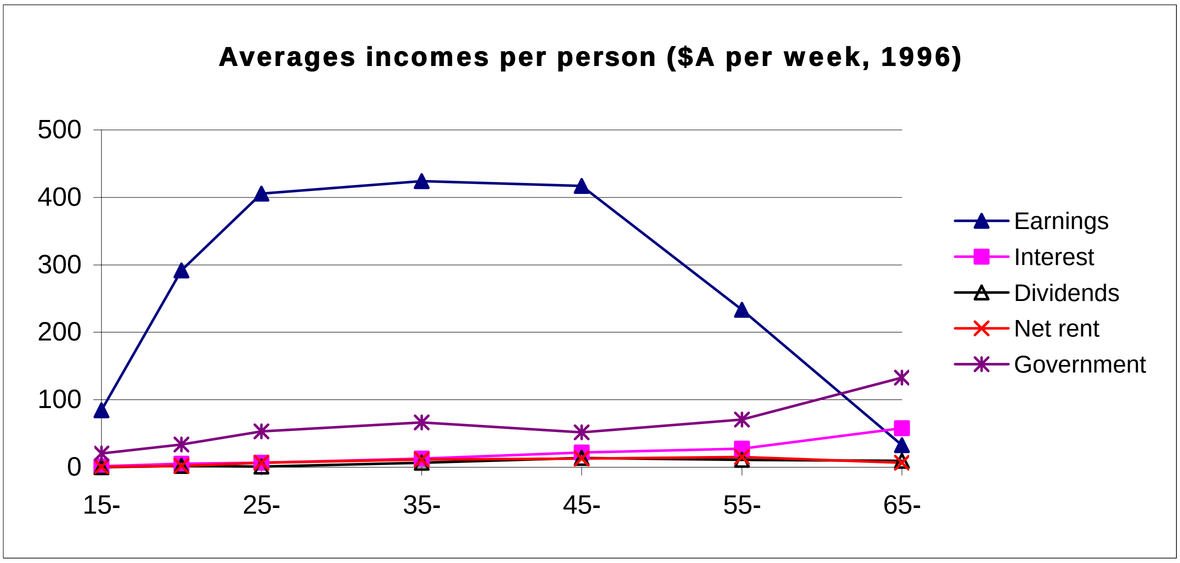
4. Cash flows and assets of individuals

4.1 Percentages of persons employed



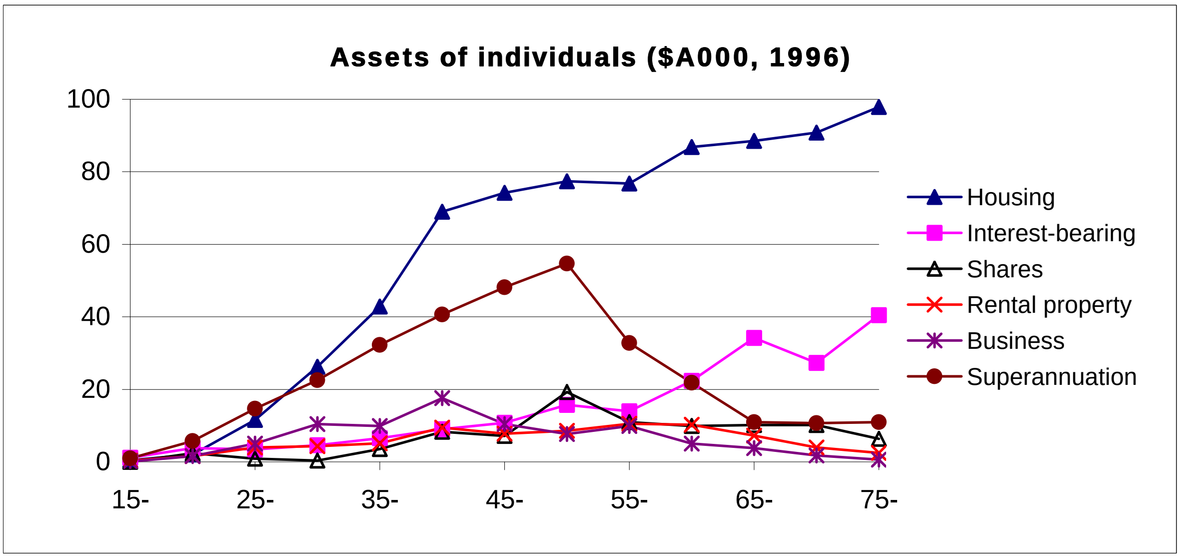
The above data, from the 1996 Australian census, show that most males and females between 20 and 50 are employed, with females having generally lower employment percentages than males.

4.2 Averages incomes by source and age



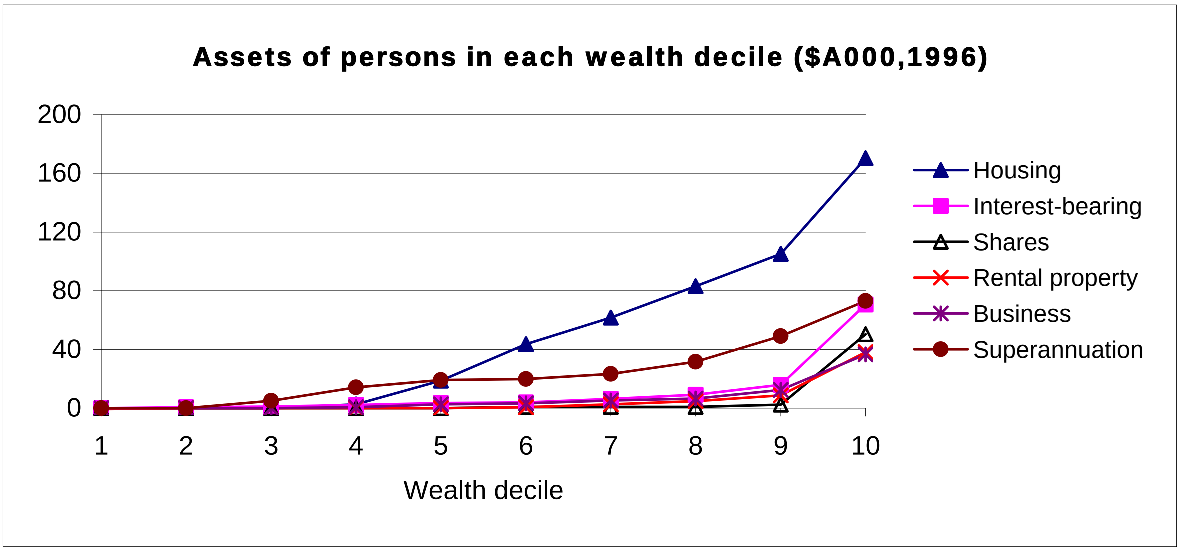
The above estimates of incomes from different sources were obtained from a range of sources, and then adjusted to balance with total incomes reported at the 1996 Australian census. They show the importance of earnings at working ages, and of government pensions and interest for older persons.

4.3 Average assets of individuals, by age



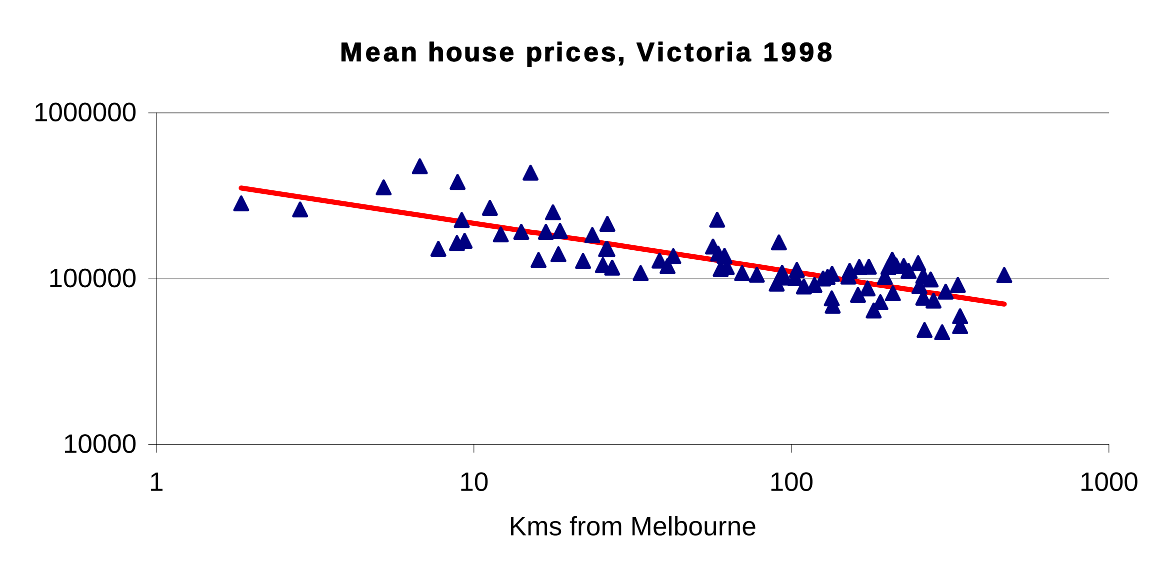
The above estimates were obtained from estimates of wealth per income unit in 1993 (Baekgaard 1998), dividing by the numbers of persons per income unit, and making approximate adjustments from changes from 1993 to 1996. The dominance of housing as the preferred form of investment is clear. Superannuation is becoming more important, with Australian employers now required to make contributions of 8% of wages. Older persons have less superannuation, but more interest-bearing assets.

4.4 Assets of persons in each wealth decile



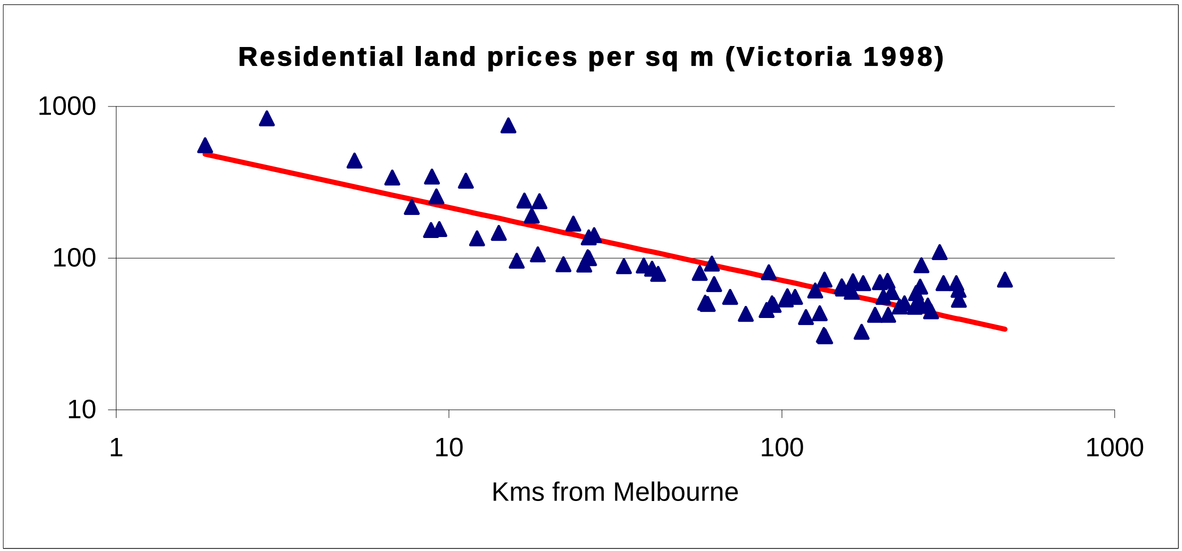
The above estimates are from the same source as those in the previous table. They show the very uneven distribution of wealth in Australia, with those in the bottom 40% of wealth having no net assets, other than superannuation.

4.5 House prices



The above house prices are from sale records maintained by the Valuer General Victoria (Department of Natural Resources & Environment 1999). They are for the 78 local government areas, ranging in population from 3,500 to 184,000 persons. Mean house prices ranged between $47,500 and $477,000, a range of 10 to 1.

4.6 Residential land prices per square km

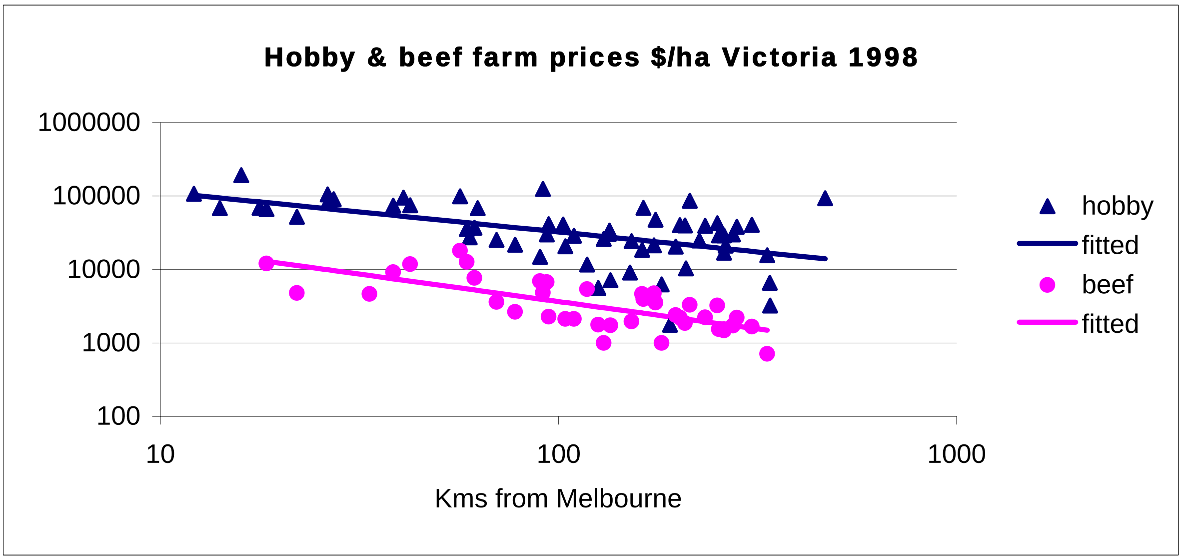


The above residential land prices, for blocks up to 2000 sq ms, are from the same source as the house prices. They ranged from $31 to $836 a sq m, a range of 27 to 1. The fitted line has the formula

$$\ln(\text{price}) = 6.48 - 0.48 * \ln(\text{kms from capital})$$

Effectively, land at twice the distance from the capital is worth 28% less. The reasonable fit to this simple formula, over such a wide price variation, suggests that simple mechanisms are at work. The wider range of jobs in the capital, and the better education, entertainment and medical facilities there, all make distance from the capital a crucial determinant of residential land prices.

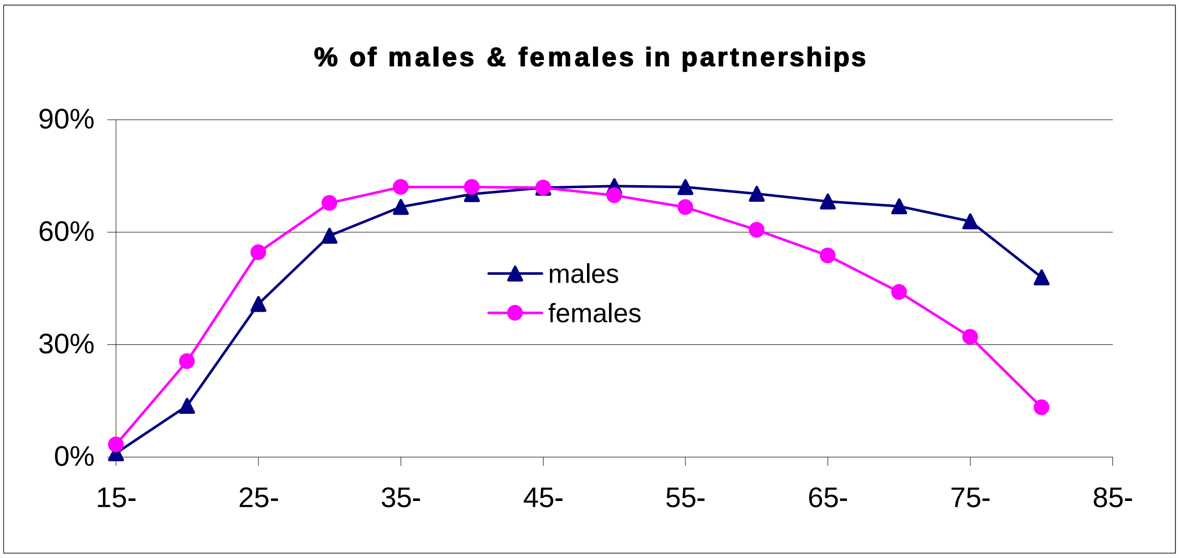
4.7 Hobby and beef farm prices



The same source provides details of sales of different types of farm land. "Hobby" farms are generally of a few hectares, usually too small to allow any sort of economically viable farming. As the graph shows, their mean price per hectare is usually much higher than that of beef farms (this may partly reflect the inclusion of a dwelling in the price). In 1998 the total area of hobby farms sold in Victoria was recorded as 2689 hectares. Assuming the 7.2% sale rate applying to Victorian private buildings in 1998 suggests that the total area of hobby farms may have been about 37,000 hectares. This is small in relation to the 12.8m ha of agricultural land in Victoria, so that the loss of production as a result of hobby farms is still small. Distance from the capital has a large effect on the value of land, both for hobby farms and beef farms.

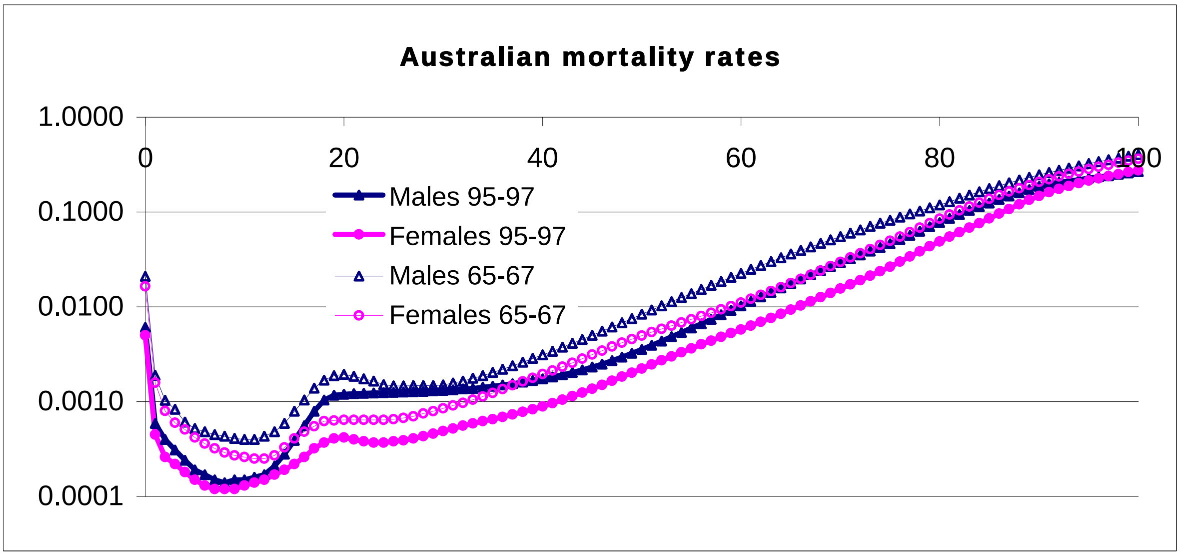
5. Behavioural probabilities

5.1 Probabilities of being in partnership



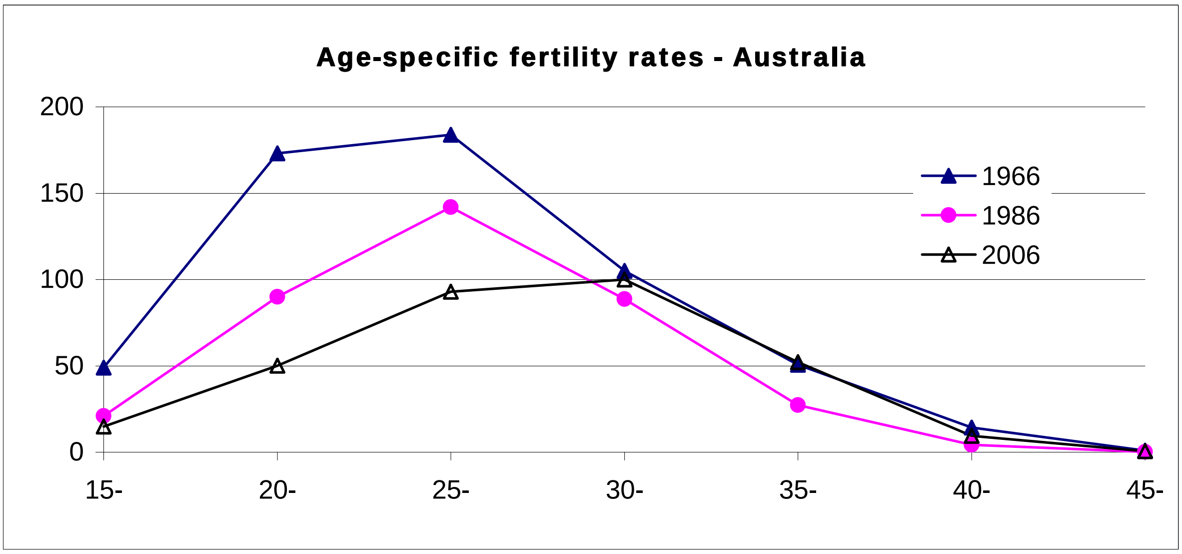
The above percentages in partnerships, from 1996 census data (Australian Bureau of Statistics 1998b), cover both persons in registered marriages and in de facto relationships. Females tend to form partnerships at younger ages than males, but the higher mortality rates of males result in many males dying before their partners, leaving a low proportion of older females still in partnership.

5.2 Probabilities of death



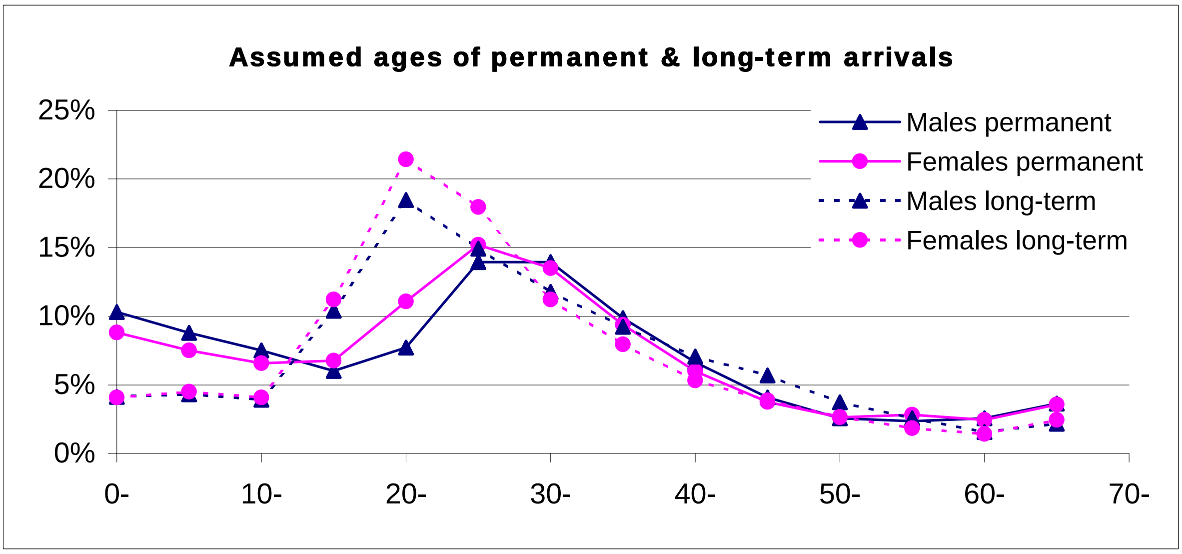
There were substantial improvements in mortality rates at all ages from 1965-67 to 1995-97, particularly for males. The values are from Australian Life Tables published by the Australian Government Actuary. Allowances for future mortality improvements need to be made in population projections.

5.3 Age-specific fertility rates



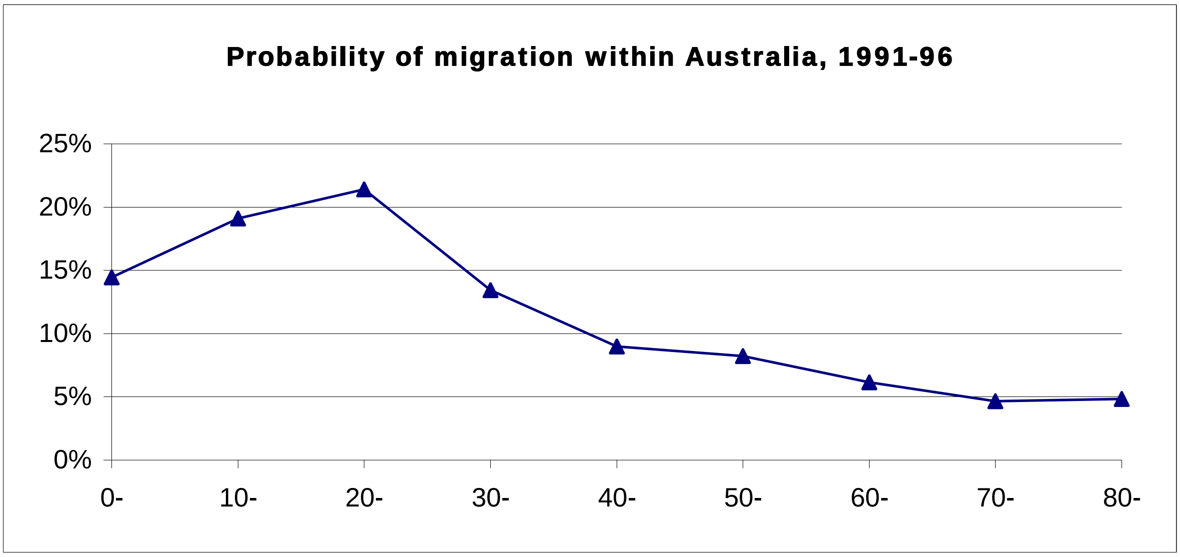
The projected fertility rates for 2006 are "low" assumptions made by the Australian Bureau of Statistics (1998a, p25). They correspond to a total fertility rate of 1.60, still high by comparison with many European countries. Australian total fertility rates have dropped from 2.89 in 1986 to about 1.75 at present.

5.4 Long-term migration to Australia



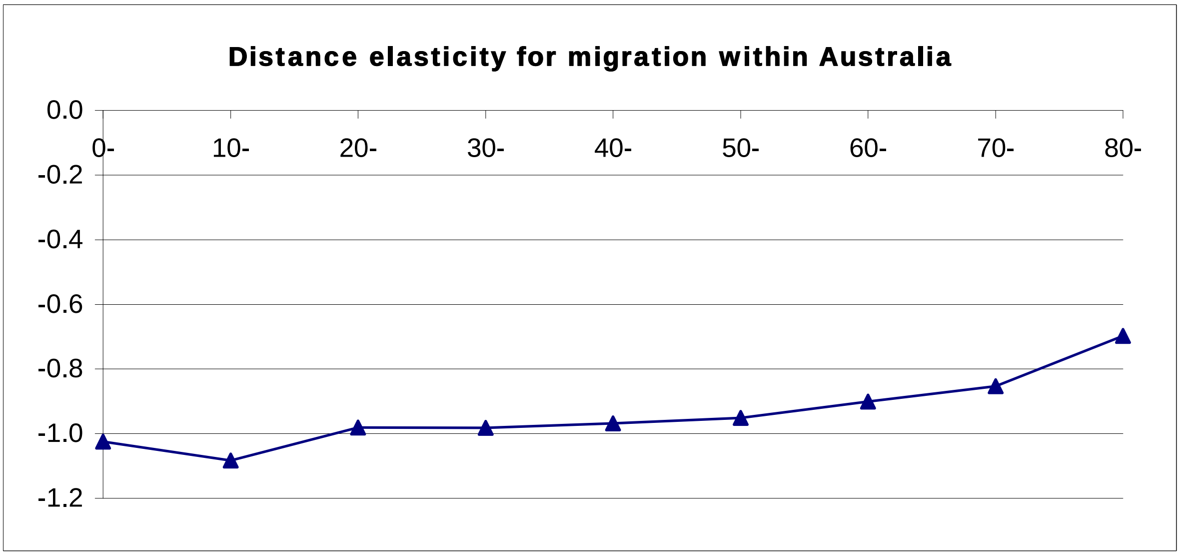
The above assumed age patterns for permanent and long-term arrivals to Australia are from the Australian Bureau of Statistics (1998a, p35). Long-term arrivals are a little younger, and bring fewer children with them. The substantial numbers of permanent and long-term departures from Australia have similar age patterns to the arrivals.

5.5 Probabilities of migration within Australia



The above probabilities are from Cumpston & Sarjeant (1998, page 7). They represent the numbers of persons found to have changed their statistical division of residence between 1991 and 1996, as a percentage of the numbers in 1991. Probabilities of migration were about 22% for those aged 20-29 at the start of the 5 years, and reduced to about 5% for older persons.

5.6 Distance-tolerance when migrating within Australia



We fitted models of the following form separately for each age group:

ln(probability of migration from one SD to another)

= a + b1 ln(source size) + b2 ln(destination size) + c ln(kms)
+ d1 ln(source unemployment) + d2 ln(destination unemployment)
+ e (latitude change) + f (longitude change) + g (1 if ocean destination, 0)
+ h1 ln(source income) + h2 ln(destination income) + i ln(source sex ratio)

The above graph plots the coefficients found for the distance term for each age group. At most ages, a doubling in distance roughly halves the probability of migration. Older persons are however less sensitive to distance. Although they seldom migrate, they may move long distances when they do.

A broadly similar study by Flood, Maher, Newton & Roy (1991) noted that the regression coefficients would have changed a good deal if certain of the variables had been removed, as a result of correlations between the independent variables. The very large differences between their parameter estimates and ours suggest that the choices of explanatory variable, and the fitting procedure, are of great importance.

5.7 Probability of purchase models

Using data on the numbers of persons employed in each of 10 retail industries in the 195 Victorian statistical local areas, we fitted models of the form

probability of purchase in location j by person resident in location i

= Ai exp(-a Dij) * Sj^b * Tj^c

where Ai is the adjustment factor to give probabilities of purchase for persons at location i summing to 1
Dij is the distance from location i to location j
Sj is the total sales of the particular goods at location j
Tj is the total sales of all retail goods at location j
and a, b and c are constants to be fitted for each type of goods.

To ensure that the fitted models were intuitively acceptable, we required the parameters a, b and c to be non-negative. Sales were assumed to be proportional to the numbers of workers in each of the retail industries. The purchases of each good made by persons in an SLA were assumed to be proportional to their median income. Best-fit values of the parameters a, b and c were obtained by minimising the sum of the squares of the differences between actual and expected sale shares.

The following best-fit solutions were obtained for the 10 retail industries:

Industry	Distance parameter a	Own goods parameter b	All goods parameter c	Error sum of squares
Supermarket & grocery stores	0.163	0.924	0.000	0.00088
Speciality food stores	0.131	0.968	0.000	0.00026
Department stores	0.112	0.890	0.000	0.00126
Clothing & softgoods	0.094	0.936	0.084	0.00023
Furniture	0.117	0.969	0.013	0.00025
Recreational	0.125	0.980	0.000	0.00020
Other personal	0.140	0.960	0.029	0.00021
Household repair	0.135	0.947	0.000	0.00095
Motor sales	0.131	0.935	0.030	0.00053
Motor service	0.141	1.002	0.000	0.00036

The fitting process allowed the model for each industry to choose any power functions for the effects of "own good" sales and "all good" sales. For each of the 10 retail industries, the fitted models placed virtually all the weight on "own good" sales. This suggests that specific-purpose shopping is more prevalent than destination shopping. Distance is also important, particularly for supermarket and grocery purchases. Retail industries are highly segmented, however, and generalisations about broad groups may be misleading.

6. Past, present and future

6.1 The view in 1961

Our models are similar to those proposed by Orcutt (1957) and implemented for 4,580 households by Orcutt, Greenberger, Korbel & Rivlin (1961). They commented (p6):

> "Our socio-economic system is a complicated structure containing millions of interacting units, such as individuals, households and firms. It is these units which actually make decisions about spending and saving, investing and producing, marrying and having children. It seems reasonable to expect that our predictions would be more successful if they were based on knowledge about these elemental decision-making units - how they behave, how they respond to changes in their circumstances, and how their interact."

Citing actuarial use of mortality data to estimate probabilities of death for individuals of given sex and age, they suggested (p17) that:

> "An actuarial approach also seems appropriate to predicting many types of economic behaviour…. It may be feasible … to estimate probabilities of house purchase for groups of households with certain observable characteristics"

They noted (p399) that

> "The required computations will be enormous, but two different types of development will serve to keep computing requirements completely manageable. In the first category of developments we must list developments in computing technology. This technology is proceeding at an incredible rate and promises to continue doing so for several years…"
>
> "The second category of developments that will keep computing requirements manageable has to do with model formulation and programming."

6.2 The view in 2000

These early ambitions have only been partly realised. Microsimulation models have been extensively used in government policy making, for example in determining taxation scales, student assistance schemes and social security benefits (see Orcutt, Merz & Quinke H 1986). Although Eliasson (1977) modelled some actual Swedish firms, little use seems to have been made of microsimulations of firms or of regions. An Australian dynamic model currently under development (King, Baekgaard & Robinson 1999) is based on a 1 in 100 sample of Australian census returns, subdivided by state. ILUTE, the Canadian integrated land use, transportation, and environment microsimulation modelling system, is developing simulations of residential housing markets (Miller & Salvini 2000).

6.3 Computer needs

The computational requirements depend on the number of individual people and firms needed for reasonably reliable estimates. For government policy decisions affecting the whole of Australia, a 1 in 100 model is likely to be ample. For projections of the 2600 postcodes, however, 1 in 1 models may be needed. To keep simulation times reasonable for such models, we want to store all the data in computer memory. This will need 5 to 10 gigabytes of memory (for a parsimonious model), which should soon be available in personal computers. It is less clear that computational times will be reasonable, particularly if adequate simulations are made of the housing and employment markets. Our approach is to develop prototype models, and if necessary look for computational approximations.

6.4 Programming techniques

Klosgen (1983) described the hardware and software used in some of the major models. He commented that the limited success of MASH, the first general purpose microsimulation software system, was due mainly to orientation to a special hardware which was soon rendered ineffective by technological progress. Muller (1983) noted the desirability of using data base management systems to avoid programming restrictions and maintain data integrity. To retain flexibility and minimise programming effort, we are using database techniques. For the time being, we are using Access, Excel and Visual Basic, as these are very widely used tools, with growing capabilities, that we use for most of our other work. We understand that at least one model has suffered problems with poor program documentation, and we are trying to document all our models and parameter estimation processes fully before programming. We expect that all our systems will have to be rewritten as we learn from experience and widen the data.

7. Data sources and synthesis

We are helped by the very good small-area data available from the Australian Bureau of Statistics, derived from population censuses, birth and death notifications, business registrations and surveys. These data are available for statistical local areas, and the Bureau provides facilities to approximately estimate postcode values. Taxation, social security and health data are available on a postcode basis. House prices are available from state sources or commercial web sites. Additional tabulations can be bought from most of these sources.

Paass (1983) described a variety of techniques to link data samples. ILUTE is using one such method, described by Beckman, Baggerley & McKay (1996), to create weighted samples of households conforming with census small-area marginal totals. Australian data samples available for research use have severely limited geographic identification, are at best 1 in 100, and are costly. They are derived from census or survey data, and may poorly represent some sectors (such as the affluent). To provide the capability to create 1 in 1 models, and to fully use the wealth of data available to us, we have chosen to create hypothetical persons and households by sequential synthesis, using small-area totals and broad statistical distributions.

We start with the estimated resident population, by sex and 5-year age groups, in a small area. Random selection is used to allocate an exact age to each person. National probabilities of partnership at each age are used to randomly determine whether each person is in a partnership, adjusting the results to give the known numbers of persons in partnerships. Males and females selected as partnered are then randomly paired off with each other, using the national distribution of age differences between partners. Similar statistical processes are used to allocate children to couples and sole parents, and to create group households. Incomes and assets are allocated sequentially, again using known totals for the small area, and national distributions.

This sequential process presents many challenges. For example, suppose that we know the numbers of workers resident in each small area, the numbers of persons employed in each area, and the geographic centroid of each area. We also have survey data on the distribution of distances between employment and residence. How are we to allocate persons to jobs? It is easy to allocate most of the employed to available jobs, using the distance distribution, but problems develop at the end of the process, when the remaining jobs may be long distances from some unallocated workers. A potential answer to such mismatching problems may be to let the projection processes simulate the movement of households to correct initial misallocations. Tests are needed on the validity of the synthesised data for particular applications.

8. Potential applications

The employment-driven nature of the models gives them the capacity to respond to new developments, and to project the slow outcomes of past changes such as rural mechanisation. Assumptions about future industrial patterns are needed, and will inevitably be speculative. The use of microsimulations for regional projections is still new, and their reliability will be suspect for many years.

At this stage, we have no idea where our models are likely to be of practical value. Will they help governments develop policies to cope with the regional impacts of economic changes? Will they help commercial interests plan housing developments, shopping centres and service networks? Or will they be of most value to individuals, trying to make long-term decisions about education, employment and housing?

We are encouraged by the wealth of data available to us, the strong patterns evident from the data, and the growing capacity of computers to make the intensive calculations.

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