Policy Influences on Genetic Diversity in Australian Wheat Production

David Godden and John P. Brennan†

Department of Agricultural Economics, University of Sydney, and Wagga Wagga Agricultural Institute, Wagga Wagga NSW, respectively.

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1. Introduction

The research reported in this paper has its origins in a wider project (e.g. Brennan *et al.* 1999a) examining economic dimensions of genetic diversity in the wheatgrowing industries of Australia and China. Part of this study involved the econometric estimation of the supply of and demand for genetic diversity in the Australian wheat industry. Especially since 1945, government policy has had a major impact on the marketing of Australian wheat, and also on the research and development process. Government policy is therefore a possible shifter of the supply and demand curves, and some "policy" variable would be required to test the significance of this hypothesis. Construction of such a policy variable required the preliminary analysis of the likely forms of government policy that might eventually affect the supply and demand for genetic diversity.

Genetic diversity in the Australian wheatgrowing industry is interesting for three principal reasons. Firstly, individual farmers face an array of risks and uncertainties including price and production risk. Wheat varieties, because of their different genetic makeups, respond differentially to climatic and other environmental (e.g. pest and disease) conditions. Choice of wheat variety offers some opportunities to manage risk and uncertainty in wheat production. For example, some wheat varieties are optimally sown "early" in a season, whereas others may be sown "late". The availability of different varietal types allows farmers to exploit different climatic conditions as they emerge. This factor might be denoted "routine" risk and uncertainty.

Secondly, plant breeding is an economic activity in the sense that breeders are continually searching for improved cultivars within the constraints of available financial resources, and within the constraints of what is genetically possible within existing knowledge. Thus breeders are continually making tradeoffs between an array of plant breeding objectives. The choices that they make – e.g. between "more genetically diverse" varieties, and higher yield or quality – govern the array of varieties that farmers have available to manage their production systems.

Thirdly, there is also an issue of the "ecological" sustainability of the wheat production industry. The possibility of major breakdowns of, for example, disease resistance in a crop kind was recognised following 1970 Southern Corn Leaf Blight in the USA. If the response of each genotype to environmental conditions were perfectly known, then there would be no uncertainty about the sustainability of crop production. Without perfect knowledge, however, there will always be some residual uncertainty about the production stability of the existing range of varieties and nearly-available varieties.

The policy environment affects the economic and social conditions in which farmers and plant breeders make decisions about the development and use of varieties. As the policy environment changes, it is possible that these changes affect the kinds of decisions that breeders and farmers make about wheat varieties and, in particular, the genetic diversity of the set of available varieties.

The possible impact of policy changes on decisions about the development and use of wheat varieties and associated genetic diversity is explored in this paper.

The post-war Australian wheat industry examined in the wider project was extensively regulated. An evaluation of genetic diversity and production variability in this period requires an indication of what Australian wheat production might have been like without such extensive regulation.

Hence the paper commences with a survey of the development of the Australian wheat industry to circa 1950 (section 2). This survey includes (i) the development of the Australian wheat industry at the colony and state level to the mid-twentieth century; (ii) the development of intervention in the industry which was crowned with the first of the peacetime wheat marketing acts in the late 1940s; and (iii) the pattern of production from the mid-twentieth century.

Section 3 broadly outlines the development of the Australian wheat industry 1950-2000. The paper then surveys the development of the Australian agricultural policy environment in the second half of the twentieth century (section 4). This survey is used to explore possible impacts of policy change on the development and use of genetic diversity in the Australian wheat industry.

Finally, in section 5, there is a detailed analysis of the possible effects of specifically wheat industry policy on genetic diversity in the Australian wheat industry 1950-2000.

Information about the wheat industry is based on secondary sources such as Dunsdorfs (1956), Rural Reconstruction Commission (1946), and Whitwell and Sydenham (1991) as the intention was not to again account for the development of the industry, but to examine genetic diversity – and its interaction with the policy environment – in the context of the development of the industry.

2. Background

2.1 Nineteenth century

The development of the Australian wheat industry occurred in several phases.

In the first half of the nineteenth century, the first two colonies of New South Wales and Tasmania (Van Diemen's Land until 1856) struggled to become self-sufficient, including in wheat production. Wheat area in both colonies increased slowly to the mid-1840s after which Tasmania's plateaued (Figure 1a).

After the rapid take-off in wheat growing in the mainland colonies from the mid-nineteenth century, Tasmania became an insignificant wheat producing state despite its geographical suitability for wheat production (cf. Figures 1h and 2c).

In the 1840s, wheat growing accelerated rapidly in South Australia until 1880 after which the area grown plateaued (Figures 1a,b).

Growth in wheat area accelerated rapidly in Victoria from 1855; the growth rate in area increased rapidly again from about 1875 and continued at a rapid rate until the First World War (Figures 1a,b).

After slow growth throughout the nineteenth century, wheat growing increased rapidly in NSW from the early 1890s (Figure 1b); this development had previously been inhibited by the separation of good wheatgrowing areas from the population centre of Sydney by the Great Dividing Range, and was overcome by railway expansion.

Figure 1: Australian Wheat Statistics to Mid-Twentieth Century

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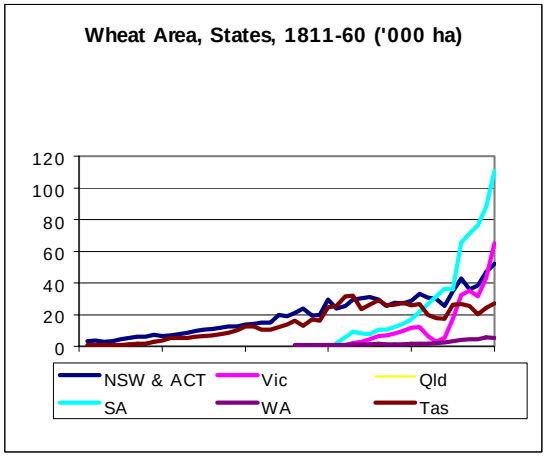

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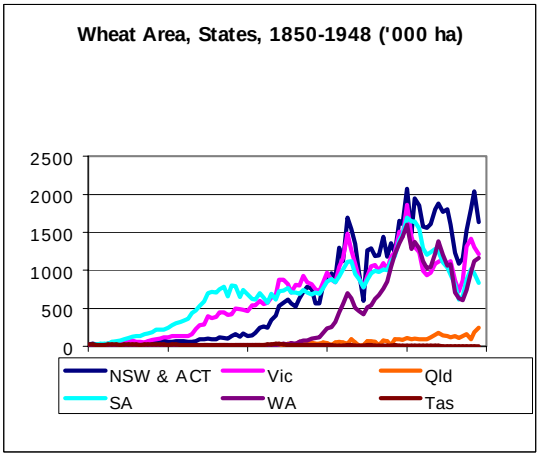

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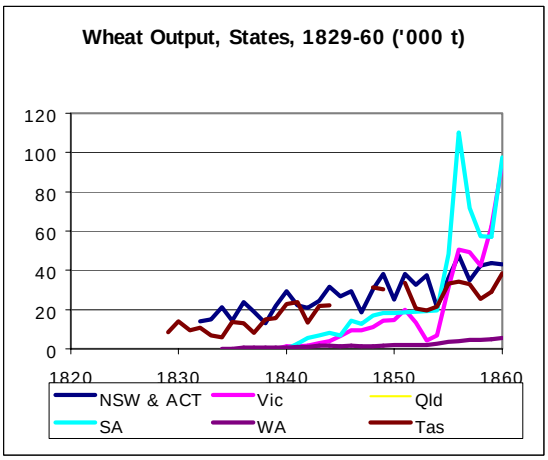

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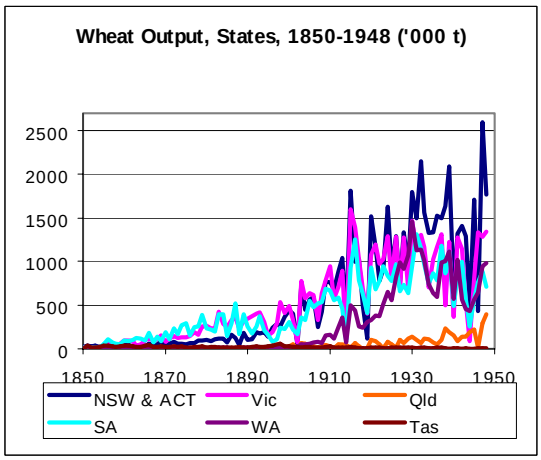

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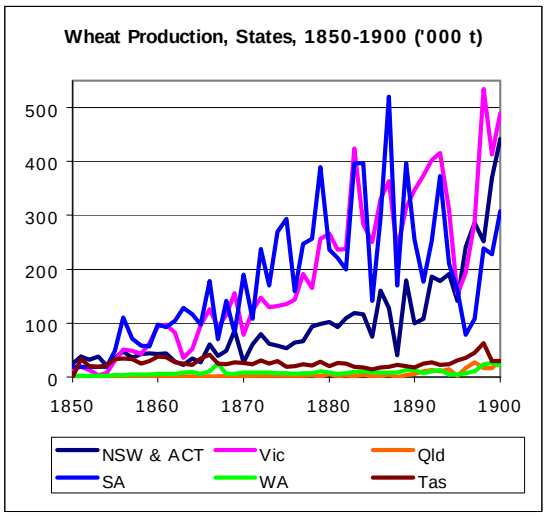

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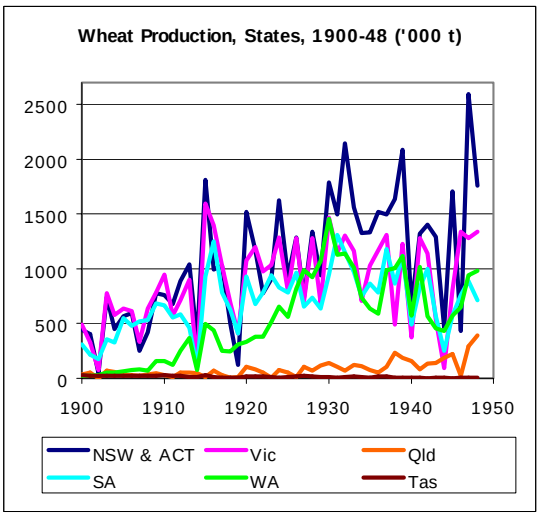

Figure 1: Australian Wheat Statistics to Mid-Twentieth Century (continued)

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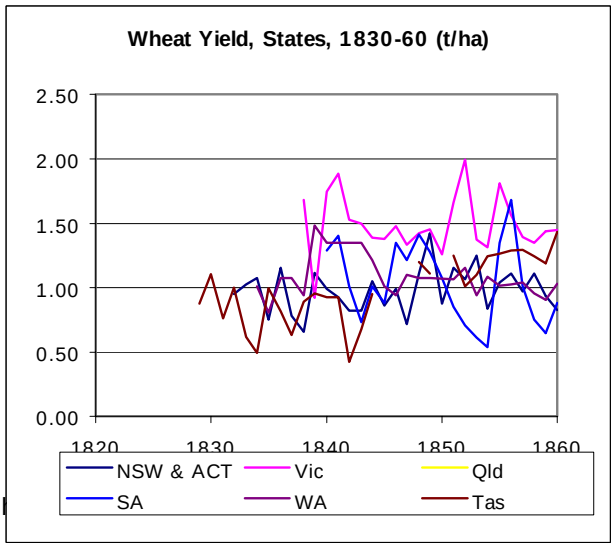

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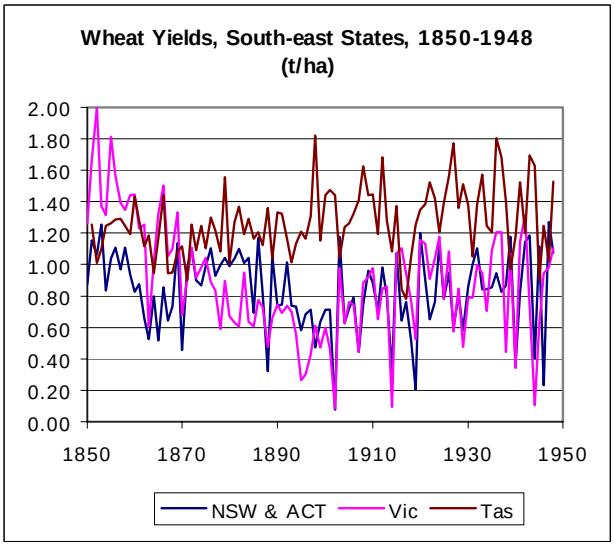

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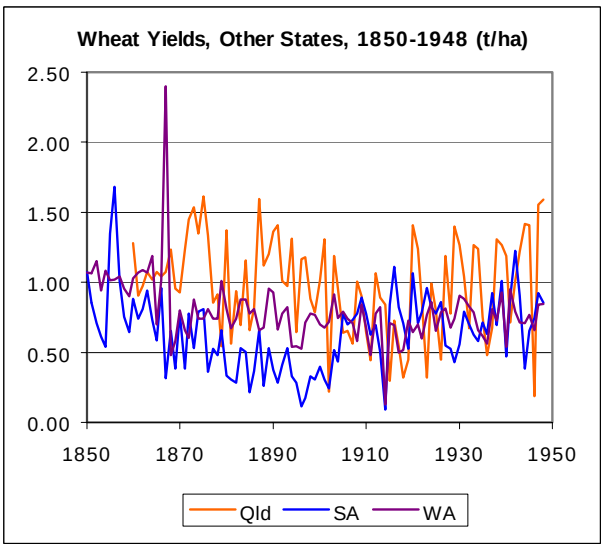


Source: Dunsdorfs (1956)

As most – although not all – Australian soils were nutrient (especially phosphate) deficient or easily nutrient depleted, secular declines in wheat yields occurred from 1850, and were especially severe in Victoria and South Australia (Figures 1h,i and Table 1).

Average State yields should, however, be interpreted cautiously since they are influenced not simply by soil fertility, but also changes in cropping practices, short- and longer-run climatic cycles (cf. Godden 1999), and especially changes in the Ricardian extensive margin (e.g. Dunsdorfs 1956, pp.136-7). Brennan and Spohr (1985) showed that changes in State average yields can be misleading because of location shifts.

Table 1: State Mean Yields, Yield Trends and Relative Yield Variability, 1850-1997

	NSW	Victoria	Queensland	South Australia	Western Australia	Tasmania
Av 1850-1900+						
Mean yield (t/ha)	0.87	0.96	1.08	0.59	0.87	0.86
Trend yield (t/ha/yr)	-0.005**	-0.023**	-0.003^	-0.015**	-0.009**	0.002?
SER/mean	0.233	0.210	0.258	0.366	0.292	0.190
Av 1901-48						
Mean yield (t/ha)	0.80	0.82	0.90	0.71	0.72	1.34
Trend yield (t/ha/yr)	0.005~	0.005~	0.010**	0.005**	0.002~	0.001^
SER/mean	0.344	0.362	0.395	0.306	0.196	0.180
Av 1948-97						
Mean yield (t/ha)	1.42	1.60	1.36	1.22	1.13	2.09
Trend yield (t/ha/yr)	0.018**	0.016**	0.005?	0.004?	0.015**	0.037**
SER/mean	0.311	0.245	0.299	0.309	0.190	0.310

+ fewer data points for Queensland (1860-1900) and Tasmania (1851-1900)

** statistically significant

^ statistically insignificant

? low significance

~ borderline significance

Source: computed from data in Dunsdorfs (1956)

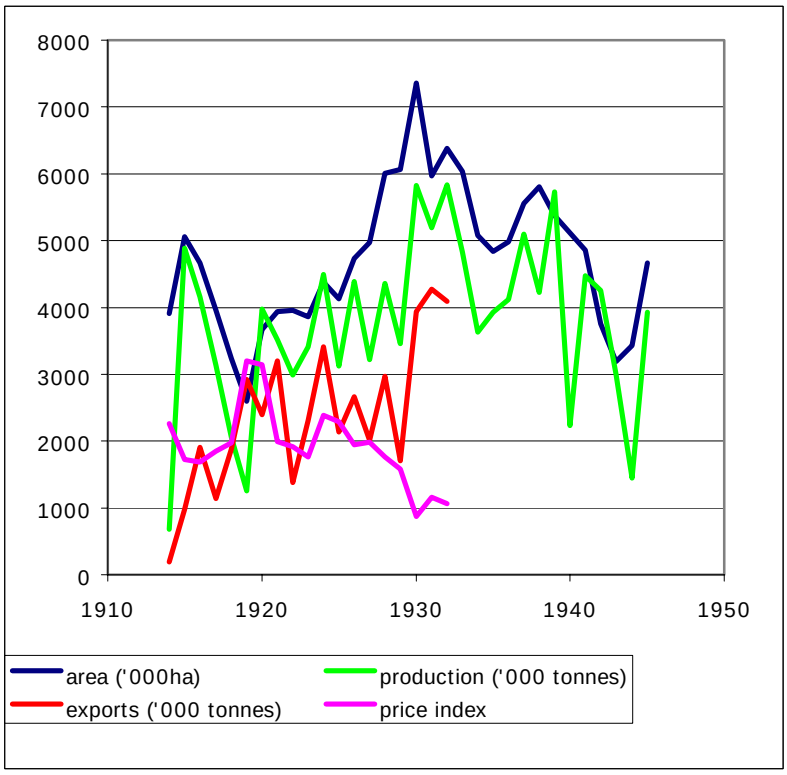
2.2 Early twentieth century

By the early twentieth century, the pattern of wheatgrowing in Australia had been largely established. This pattern involved:

- extensive areas of production in the principal wheatgrowing states – about 500,000 hectares in each of NSW, Victoria and South Australia; wheatgrowing expanded rapidly in Western Australia from 1910. Expansion of wheat production in Queensland occurred from the late 1930s (Whitwell and Sydenham 1991).
- wheatgrowing was a low-input system, dependent on a rainfall pattern which was erratic in annual amount (cf. Godden 1999) and also in seasonal timing and intensity, and interacted with pests and diseases (especially rusts); this variability was reflected in highly erratic wheat yields (Figures 1g,h,i). The variability of yield – estimated as the standard error about the estimated trend line relative to mean yield – is shown in Table 1.
- there had been considerable experimentation and innovation with labour-saving machinery for all aspects of wheat production;[1] and there was subsequently successful experimentation with varietal improvement (see below).
- wheatgrowing had largely evolved into one (key) enterprise in a mixed-farming system, except in Western Australia (Whitwell and Sydenham 1991, p.32). Unincorporated business structures (sole proprietorship, partnership or family) predominated, and the absence of limited liability increased the financial vulnerability of farms by limiting borrowing options (Whitwell and Sydenham 1991, p.33).
- wheatgrowing was increasingly oriented to production for export, initially inter-colonial trade (e.g. South Australia to NSW) and subsequently outside Australia (and especially the United Kingdom); wheat exports expanded rapidly after 1900 (cf. Figure 3).

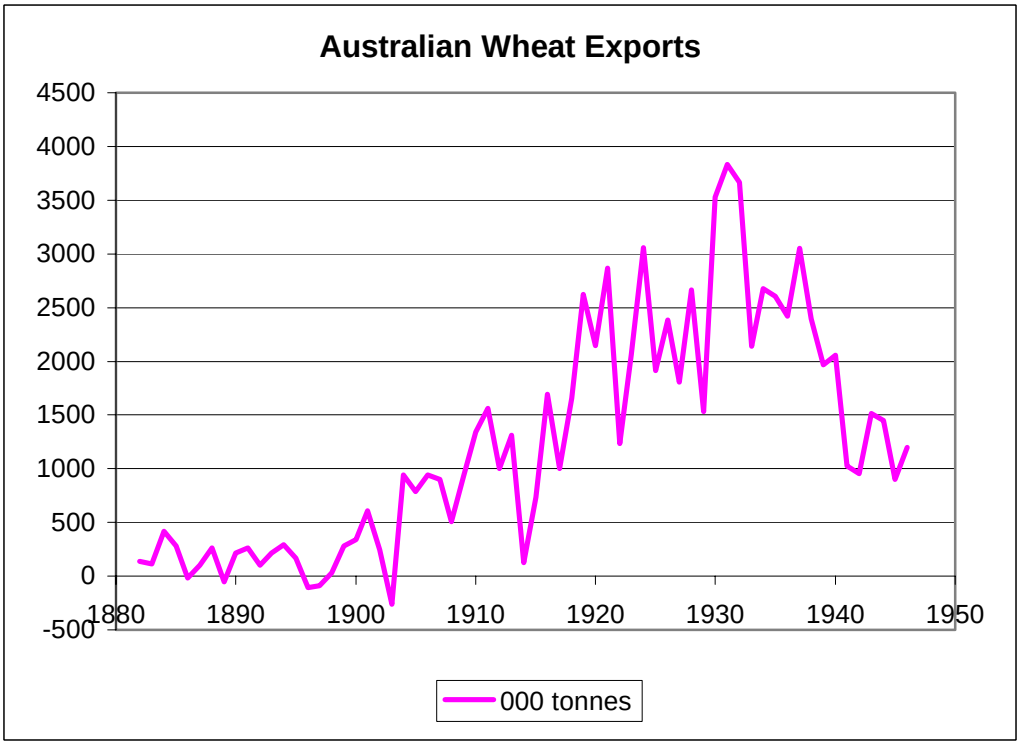
[1] Especially in South Australia

Figure 3: Development of Wheat Exports, Australia, 1910-45



Source: Rural Reconstruction Commission (1946)

(Net) Exports of Wheat (Dunsdorfs 1956, p.476)



The First World War affected the Australian wheat industry in three principal ways. Firstly, military enlistment from war's outbreak in 1914, which was especially high in country areas, rapidly reduced the farm workforce and led to a substantial reduction in area grown and thus output in the early war years (Figures 1b,d). Secondly, to control wheat marketing, the first Australian Wheat Board was established which, by war's end, provided wheatgrowers "with the highest prices – and possibly the greatest sense of security – they had enjoyed for 30 years" (Whitwell and Sydenham 1991, p.42).

This marketing experiment was followed by the temporary emergence of "co-operative state-wide pools" in early 1920s (Whitwell and Sydenham 1991, pp.36-37) with more permanent pools only in Queensland (statutory) and Western Australia (voluntary) (Whitwell and Sydenham 1991, pp.42,45-6 respectively). Thirdly, following cessation of hostilities and development of extensive (and generally disastrous) "soldier settlement" schemes, wheat area grew rapidly in the 1920s. Wheat area increased four-fold in Western Australia and 3.5 fold in NSW from the disastrously small area of 1919 to 1930; and area similarly doubled in Victoria and South Australia (Figure 1b).[2]

During the first half of the twentieth century, the declines in average state wheat yields that characterised the nineteenth century were arrested (Figures 1h,i and Table 1). However, except in Queensland and South Australia, there was no statistically significant yield trend in the period 1901-48. In Queensland, average state yield increased approximately 10kg/ha/year, and in South Australia the corresponding estimate was 5 kg/ha/year. Variability – estimated as the ratio of the standard error of a regression of yield against time, relative to mean yield – was low (approximately 0.2) in Western Australia and Tasmania (Table 1). The corresponding variability estimates for the other states were much higher, ranging 0.3-0.4.

2.3 Progress in wheat breeding

The principal uses of wheat were for breadmaking and for livestock feed (hay and grain for both farm animals and other draught animals). Since the principal costs of growing (e.g. sowing, harvesting) were independent of end-use, the farmer's optimal strategy was to aim for the highest valued use, since this would provide the greatest gross margin to allow transportation to market.[3] Additionally, since crops damaged by weather or disease were still suitable for animal use, there was likely to be sufficient material available for other local uses. Where there was no yield penalty for growing bread wheats, it was optimal to aim for bread wheats. Where there was a bread variety penalty, then the farmer needed to consider the yield/price tradeoff, and determine which provided the higher gross revenue (and thus gross margin).

Development of commercial wheat growing in Australia provided considerable challenges in the new colonies. Principal among these challenges were to develop early maturing varieties to enable wheatgrowing to spread to drier areas, to breed for disease resistance (e.g. rust), to obtain higher yields, and to improve quality defined in terms of suitability for breadmaking. Dunsdorfs (1956, p.193-95) also argued that an important aspect of this early wheat breeding effort was in reducing harvesting costs. For example, Dunsdorfs argued that because of its shorter straw, Farrer's variety Federation stood upright and was better suited to mechanical stripping; further, it held grain after ripening thus extending the harvest period. Extensive introductions and selections were made in the nineteenth century (Dunsdorfs 1956, pp.189-90; Macindoe and Walkden Brown 1968, pp.1-2, and see also the latter's variety listing pp.51ff). Systematic breeding efforts began in the 1880s. While Macindoe and Walkden Brown gave precedence to Farrer in the development of Australian wheat breeding, Dunsdorfs (1968, pp.190-91) argued that there were other breeders of "no less historical significance in blazing the new trail for Australian wheat breeding".

There is at least the appearance of significant latent genetic diversity in the Australian wheat crop around 1900. This apparent diversity was probably over-stated because of the lack of a systematic documentation of the introduction and origins of wheat varieties brought into Australia, and absence of a systematic description of existing wheat varieties (cf. the large numbers of synonyms recognised in Macindoe and Walkden Brown's (1968) listing of Australian wheat varieties). The latent diversity was not translated into effective diversity since few varieties were suitable for Australian growing conditions and, of those that were, many quickly succumbed to disease.

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[2] The low area in 1919 was probably the result of the Spanish influenza pandemic.

[3] Dunsdorfs (1956, p.167) reported that, around 1880, half the price obtained in England for South Australian wheat was taken up by the cost of wheat transport and other charges.

A very rough concept of genetic diversity in Australian wheats may be gained from Macindoe and Walkden Brown's (1968) listing of named varieties. Discounting synonym names, there were about 130 varieties listed as definite or possible introductions, or where the provenance of the variety was unknown. Most of the dated introductions occurred before 1900. These varieties, and others introduced specifically as parents in breeding, formed the basis of the genetic diversity of subsequent varieties. For introduced varieties, direct genetic observation would be required to investigate their genetic diversity. From about 1900, it would be possible to evaluate the relationships among bred varieties using the coefficient of parentage.

In Macindoe and Walkden Brown's (1968) listing of varieties, 235 varieties were attributed to Farrer as ones he bred, selected or introduced. Pye was attributed with breeding 85 varieties. Macindoe and Walkden Brown attributed 160 varieties to "farmers" of which 1 was introduced by a farmer, 106 were selected by farmers, 53 were bred by farmers, and the status of 3 was unclear. The main period of direct farmer involvement with new varieties was 1880-1940: farmers bred or selected 40 new varieties 1880-1900; 51 new varieties 1900-20; and 47 new varieties 1920-40. Six varieties were attributed to other periods and 16 could not be dated.

The creation of State departments of agriculture at about the time that plant improvement was becoming important was of major significance to Australian wheat breeding. While farmers had made important contributions to selecting, and in some cases breeding, new wheat varieties and would continue to do so for some decades, the application of rapidly advancing sciences relating to plant breeding were beyond the capacity of farmers to integrate into activities which, for them, could only be part-time. The nascent government research stations provided opportunities to exploit economies of size and scope in research, of which plant breeding formed a vital part for a country with a relatively new European agriculture based largely on introduced species. Table 2 summarises the contribution of individual breeders employed in government and university institutions (and institutions where an individual breeder was not identified). While institutionalisation of research provided important economies in the plant breeding process, the divorce of breeding objectives from the activities of farmers provided the opportunity for differences to emerge between the objectives of farmers, grain buyers and wheat breeders.

Table 2: Wheat Breeding in Institutions, 1885-1967

Individual Breeder and/or Institution	Number of varieties	Earliest variety	Latest variety
Bateman (Chapman, WA)	1	1943	1943
Breakwell (Roseworthy Agricultural College, SA)	5	1930	1956
Farrer (private & Wagga)	213	1885	1930
Gordon (Werribee, Vic)	15	1914	1946
Hockley (Waite Agricultural Research Institute, SA)	6	1930	1949
Hurst (Wagga, NSW)	8	1913	1928
Hutton (Roseworthy Agricultural College, SA)	1	1930	1930
Kitamura (Temora, NSW)	3	1948	1960
Krause (Roseworthy Agricultural College, SA)	1	1966	1966
Langfield (Merredin, WA)	2	1950	1963
Limbourn (Merredin, WA)	3	1929	1942
Macindoe (New England, NSW)	10	1936	1957
Matheson (Glen Innes, NSW)	4	1956	1963

McTaggart (Longerenong Agricultural College, Vic)	6	1923	1924
Phipps (Waite Agricultural Research Institute, SA)	6	1930	1944
Pridham (Cowra, NSW)	17	1907	1956
Pugsley (Adelaide & Wagga, NSW)	9	1944	1966
Pye (Dookie Agricultural College, Vic)	77	1893	1949
Quodling (Roma, Qld)	4	1900	1922
Raw (Werribee & Dookie Agricultural College, Vic)	8	1939	1965
Richardson (Longerenong Agricultural College, Vic)	2	1917	1917
Rosser (Hermitage, Qld)	2	1959	1960
Scott (Roseworthy Agricultural College, SA)	7	1916	1924
Single (New England, NSW)	3	1936	1959
Soutter (Roma, Qld)	22	1917	1959
Spafford (Roseworthy Agricultural College, SA)	7	1912	1917
Tulloh (Longerenong Agricultural College, Vic)	2	1924	1924
Vickers (Merredin, WA)	1	1958	1958
Waterhouse (Sydney University)	5	1927	1945
Watson (Sydney University)	3	1960	1964
Dookie Agricultural College (Vic)	10	1920	1930
NSW Department of Agriculture	82	1913	1938
Qld Department of Agriculture	14	1895	1939
Roseworthy Agricultural College (SA)	59	1906	1933
University of Sydney	7	1946	1967
Vic Department of Agriculture	5	1918	1939
WA Department of Agriculture	13	1913	1948
Waite Agricultural Research Institute (SA)	6	1948	1951

Source: Macindoe and Walkden Brown (1968)

Note: The varieties attributed to institutions are those varieties where an individual breeder was not identified. There may be some double-counting of varieties where more than one breeder cooperated in the development of a variety, for example where one breeder made a cross and another breeder undertook selection and/or fixing of the variety. Locations without an institutional type are state government experiment farms/stations.

2.4 Evolution of regulatory intervention

The rapid growth in wheat production in the 1920s led to increasing tensions between growers and "parasitical" merchants (Whitwell and Sydenham 1991, p.38). The Great Depression, and the catastrophic attempt by the Commonwealth Government to use wheat industry policy as a tool of macroeconomic management – the highly successful but disastrous "grow more wheat" campaign of 1930-31 (Whitwell and Sydenham 1991, pp.35-6, 50-3) – resulted in rapid reductions in wheat area in Victoria, South Australia and Western Australia in the early 1930s and in NSW from the mid-1930s. Despite these difficulties, wheatgrowers in the principal wheatgrowing states continued to reject state intervention as a policy response to income difficulties and perceived market imperfections (e.g. Whitwell and Sydenham 1991, pp.43-5).

A proposal to introduce a home consumption price support scheme for wheat similar to those in dairying and dried fruits foundered in the mid-1930s when the latter was declared unconstitutional (Whitwell and Sydenham 1991, pp.54-5). The Commonwealth's Wheat Industry Assistance Act of 1938, together with complementary state legislation, provided for a flour tax which was used to create a home consumption price for flour, an export tax on wheat when export prices exceeded domestic prices and a stabilisation fund to hold and disburse these taxes (Whitwell and Sydenham 1991, pp.55-6).

With the outbreak of World War Two, the Commonwealth Government immediately established another Australian Wheat Board under national security regulations. The Board was responsible for marketing, storage and shipping arrangements, compulsory pooling, and introduced an advance payment on deliveries (Whitwell and Sydenham 1991, p.59). In late 1940, stabilisation arrangements were implemented, starting with the 1941-42 harvest, whose key features were a guaranteed price f.o.b. less charges for a specified maximum crop, a stabilisation fund based on wheat production taxes, and a growing licence with basic acreage. In 1942, stabilisation arrangements were modified via a quota scheme with a differential first advance, coupled with a stockfeed wheat subsidy (Whitwell and Sydenham 1991, p.61). "By 1945 it was taken for granted by government and opposition parties alike and by the states and grower organisations that there would and should be a postwar wheat stabilisation scheme" (Whitwell and Sydenham 1991, p.62). In a 1946 referendum, the Commonwealth failed to gain powers to enable it to enact national commodity stabilisation schemes (Whitwell and Sydenham 1991, p.63).

Finally, in 1948, national wheat marketing arrangements involving the essential aspects of the arrangements of WW2 were enacted under peacetime powers. Two major concessions by the Commonwealth Government, which had significant impacts for the following two decades, were the abandonment of demands for production controls and acceptance of cost of production as the basis for farm-gate pricing (Whitwell and Sydenham 1991, pp.62-3).

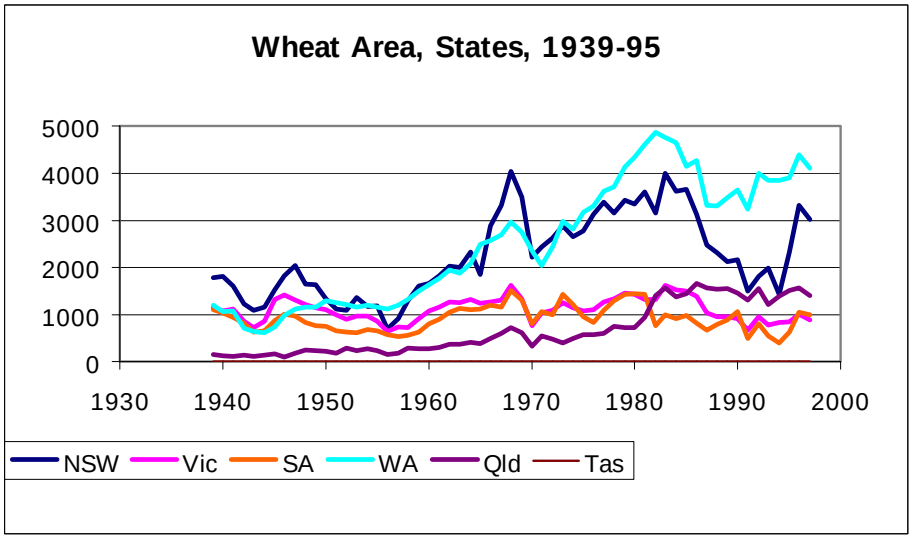
3. Production in second half of twentieth century

The development of the Australian wheat industry in the second half of the twentieth century is illustrated in Figure 2. In the early 1950s, wheat area was either static (Western Australia and Queensland) or declining (Victoria and South Australia, and especially NSW where wheat area fell 65 per cent from 1947 to 1956) (Figure 2a). From the mid-1950s, by contrast, wheat area grew rapidly in NSW (nearly sixfold) and Queensland (fivefold increase) from 1956-68, with area more than doubling in the Victoria, South Australia and Western Australia.

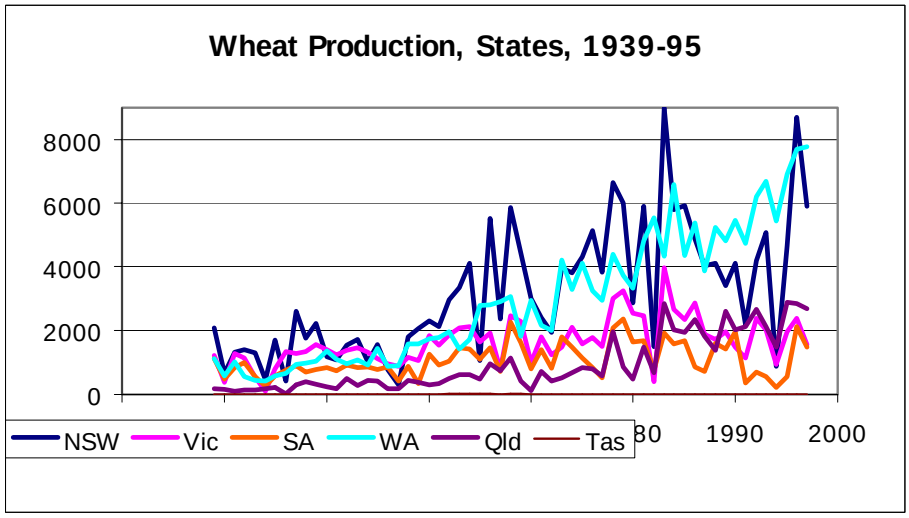
The imposition of quotas temporarily reduced wheat area from 1969, but rapid growth recommenced from the early 1970s until the early 1980s. Area doubled in WA and Queensland, and increased 50-80 per cent in the other states. Under the combined pressure of falling international prices, especially resulting from fierce international competition from highly-protected wheat industries in developed countries, high wool prices until the late 1980s, and severe drought in eastern Australia in the first half of the 1990s, wheat areas tumbled in NSW, Victoria and SA in the period 1980-91 (falling 55-65 per cent), fell 25 per cent in Western Australia, but increased nearly 80 per cent in Queensland. Following the end of the severe drought in the northern part of the eastern wheat belt in the 1990s, and the lift in relative wheat price, wheat area grew rapidly in NSW.

Figure 2: Wheat Area, Production and Yield, Australian States, 1939-95

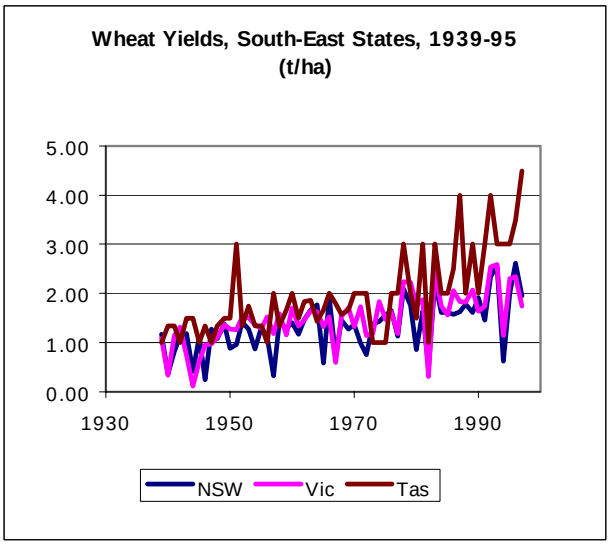
Area ('000 ha)

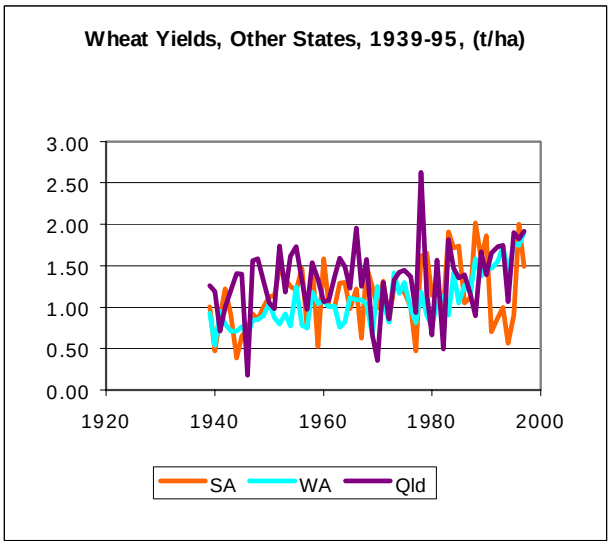


Production (kt)



Yields (t/ha)





Source: Whitwell and Sydenham 1991, and subsequently ABARE 1998

As shown in Table 1, average wheat yields in eastern states (NSW, Queensland) and Western Australia, increased approximately 15-18 kg/ha/year over the period 1950-97 (cf. Figures 2c,d). In Tasmania, average state yields trended at 37 kg/ha/year over the same period. In South Australia and Victoria, there was little evidence of trend (estimated trend was low and of low statistical significance). The variability of wheat yields relative to state mean yield was similar to the 1901-48 period for NSW, South Australia and Western Australia, and declined substantially in Victoria and Queensland (Table 1).

The combination of area changes and average yield changes created different patterns of state level output. In Western Australia, state wheat output increased consistently over the period with relatively little inter-year variability (Figure 2b). By contrast, in the second major wheat producing state, New South Wales, wheat output increased commensurately with that of WA to the early 1980s, tumbled 75 per cent to the early 1990s, and recovered spectacularly in the mid-1990s; the variability about the trend was large compared to WA. The smaller wheat producing states (Victoria, SA and Queensland) increased wheat output to the early 1980s and, like in NSW, wheat output fell substantially to the mid-1990s, especially in SA.

3.1 Variability in Australian agriculture

3.1.1 Sources of variability

As shown in the Green Paper (Harris *et al.* 1974, chapter 4), Australian agriculture experiences substantial output and price variability. As suggested by the Green Paper's analysis, the major components of income variability can be decomposed into output and price variability. These components may also be further subdivided.

The elements of price variability include:

- domestic prices and export prices, and (changes to) the share weights on these two; and
- classes of wheat and their relative price variabilities, and (changes to) the share weights of these classes;

The elements of output variability include area and yield variability:

- the principal determinant of area variability is the relative profitability of wheat relative to key alternative enterprises (wool, beef, sheepmeats), and thus a key component of area variability is relative price variability;
- the principal determinant of yield variability is weather operating directly through the level, seasonal distribution and intensity of rainfall, and indirectly through the influence of rainfall on pest and disease incidence and damage, production-related attributes such as sowing time, flowering time (particularly relative to the last frost), and harvest;
- yield variability may also be influenced by area variability as, for example, increased wheat area prompts expansion into relatively less-favoured areas, induces farmers to extend wheat sequences (increasing pest and disease problems), or brings area out of other crops, pasture or fallow more quickly;
- yield variability may also be affected by output (or input) price variability if the optimal application rate of key inputs (chemicals and fertilisers) is responsive to relative output:input prices, and farmers respond to changes in optimal application rates rather than being guided by past practice; and
- yield variability may also be affected by technology although generally adoption of new technology is slow; however, emergence of diseases could, if farmers were unable to respond quickly enough, be observed as one-off yield decreases that would observed statistically as increased variability.

Because Australian wheat production is spread over a large and climatically-diverse geographical area, seasonal conditions are not uniform across wheat production areas. This diversity is increasingly important since the major expansion of wheatgrowing in Western Australia with its relatively less variable climate. Thus observed variability at the national level is likely to be lower than at the farm level (cf. Harris *et al.* 1974, para. 4.7).

3.1.2 Estimates

At the national level, output variability was substantially greater for broadacre cropping (including wheat) than for all other industries except cotton. This variability was greater 1960-61 to 1972-73 (0.3-

0.5 for broadacre cropping) than over the longer period 1949-50 to 1972-73 (0.3-0.4) (Harris *et al.* 1974, Figures 4.1-4.2). Price variability was low in wheat (0.05) compared to other broadacre cropping (0.1-0.25); surprisingly, the variability of average export prices was also low (Harris *et al.* 1974, Appendix Tables A4.1-A4.2).

Since the analysis was conducted over the period of the wheat price stabilisation scheme it is not surprising that prices were more stable for wheat than other broadacre cropping. The price variability of other broadacre cropping industries was similar to or greater than most other industries with the exception of wool and potatoes (Harris *et al.* 1974, Figures 4.1-4.2).

Corresponding to the Green Paper analysis, variability in the post-WW2 period for the wheat industry at an aggregate level is reported in Table 3. Because of the operation of a highly regulated wheat market through national wheat marketing arrangements, with an objective of "stabilisation", for most of the post-WW2 period, observed variability should be treated cautiously.

For most states in most of the sub-periods reported, relative area and yield variability exceed 0.2, and exceed 0.3 in NSW and Queensland. Western Australia consistently exhibits the lowest relative variability of area and yield (below 0.2). The relative variability of state wheat area tends to be lowest in the period of rapidly increasing yields; conversely, the relative variability of wheat yield tends to be highest in the period of rapidly increasing yields.

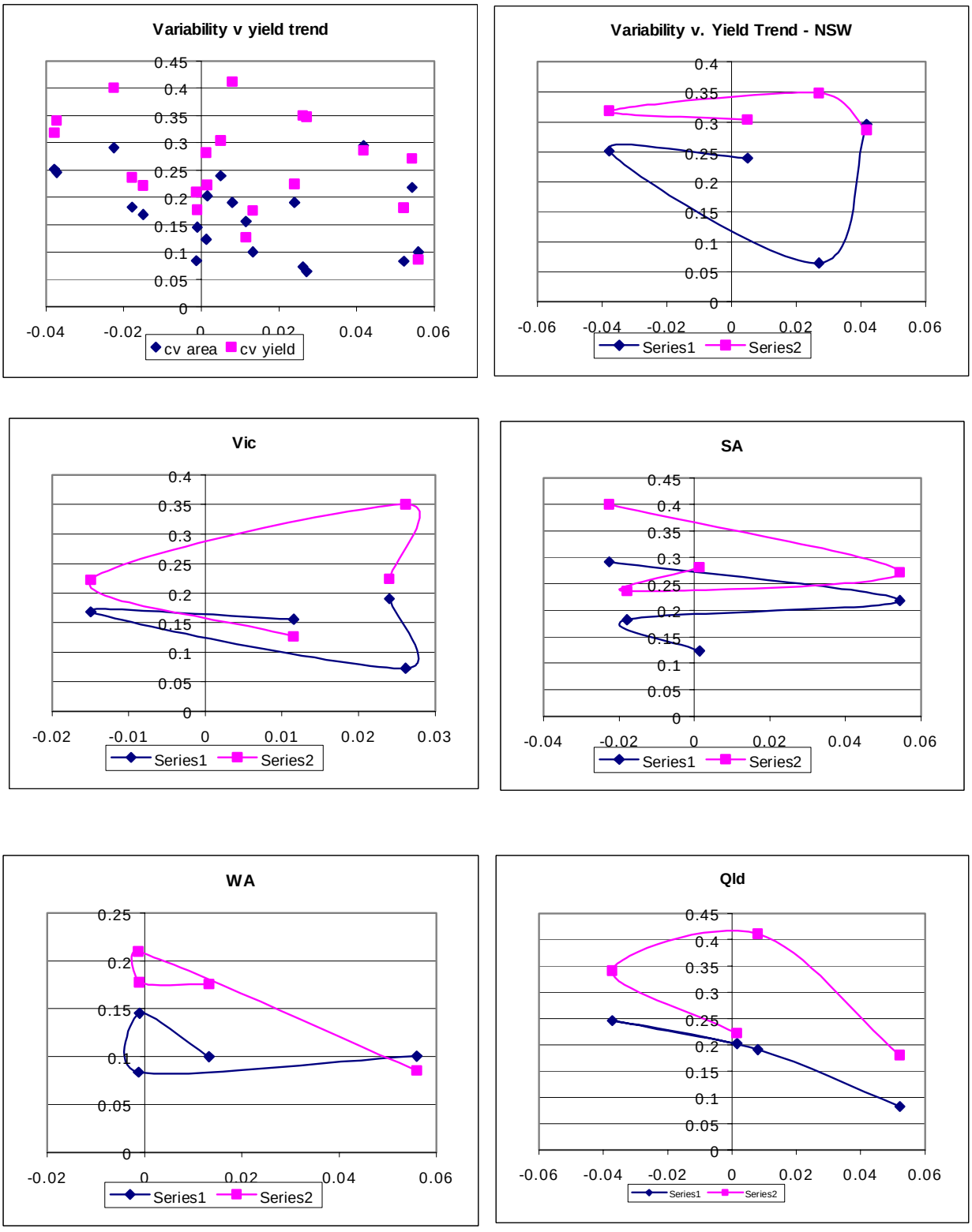
Thus there appears to be a negative correlation between the relative variability of both area and the rate of yield increase at the state and national level (Figure 4). However, since the higher rates of yield increase occur in the latter part of the period, this apparent negative correlation may be an artefact of some other relationship. These higher rates of yield increase are associated with the adoption of semi-dwarf, high-yielding wheat varieties which generally require higher levels of inputs (e.g. fertilisers and chemical weed control); use of these inputs may also reduce variability. Additionally, these periods are also associated with rapid increases in machinery size which may also affect variability, although the a priori effect is ambiguous.

Table 3: Sources of Relative Variability in Australian Wheat Industry

Wheat area						
	NSW	**Vic**	**SA**	**WA**	**Qld**	**Australia**
1949-60	0.240	0.156	0.123	0.100	0.202	0.148
1960-72	0.251	0.169	0.182	0.145	0.246	0.183
1972-85	0.064	0.072	0.218	0.084	0.191	0.056
1985-97	0.295	0.190	0.291	0.100	0.083	0.148
Wheat yield						
	NSW	**Vic**	**SA**	**WA**	**Qld**	**Australia**
1949-60	0.304	0.127	0.281	0.175	0.222	0.160
1960-72	0.319	0.222	0.236	0.178	0.341	0.166
1972-85	0.348	0.350	0.272	0.209	0.411	0.239
1985-97	0.286	0.224	0.400	0.085	0.180	0.144
	Unit values		Export volume		Export prices	
					Current prices	**Constant prices**
1949-60	0.068		0.404		0.114	0.146
1960-72	0.045		0.233		0.085	0.075
1972-85	0.126		0.206		0.159	0.212
1985-98	0.167		0.296		0.166	0.174

Variability estimated as standard error of regression residuals relative to mean of series
Sources: Harris (1974), and computed from ABARE data

Figure 4: Variablity vs. Yield, Australian States



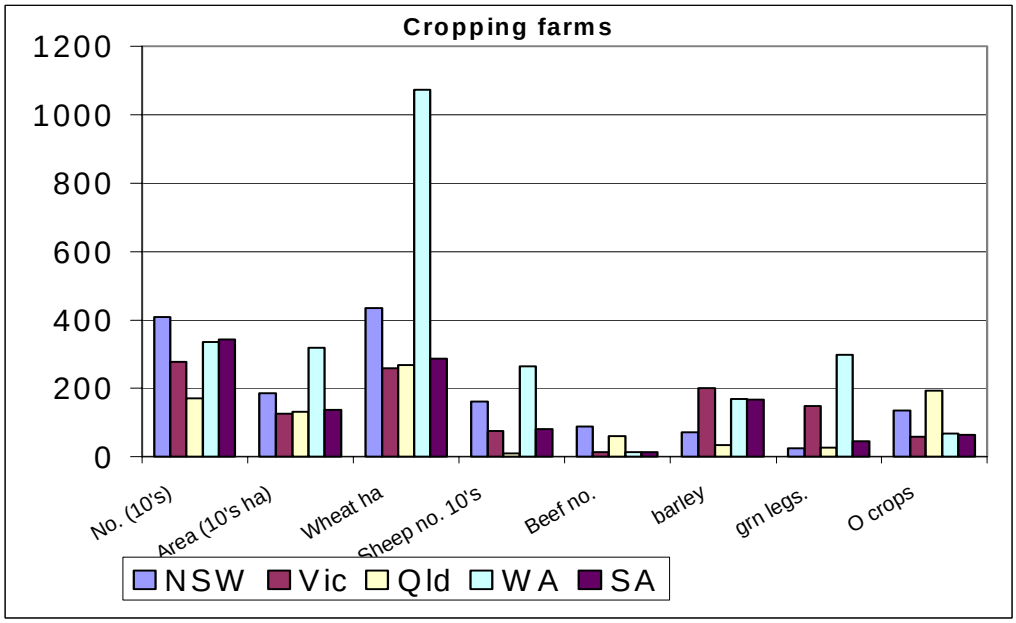
3.2 Farm structure in late twentieth century

In a 1947 enquiry, the Simpson Committee on the cost of wheat production found only 1 out of 635 farmers solely producing wheat. The Committee concluded that "We are satisfied that the pure wheat farmer has ceased to play any part in the production of wheat in Australia" (per Whitwell and Sydenham 1991, p.139).

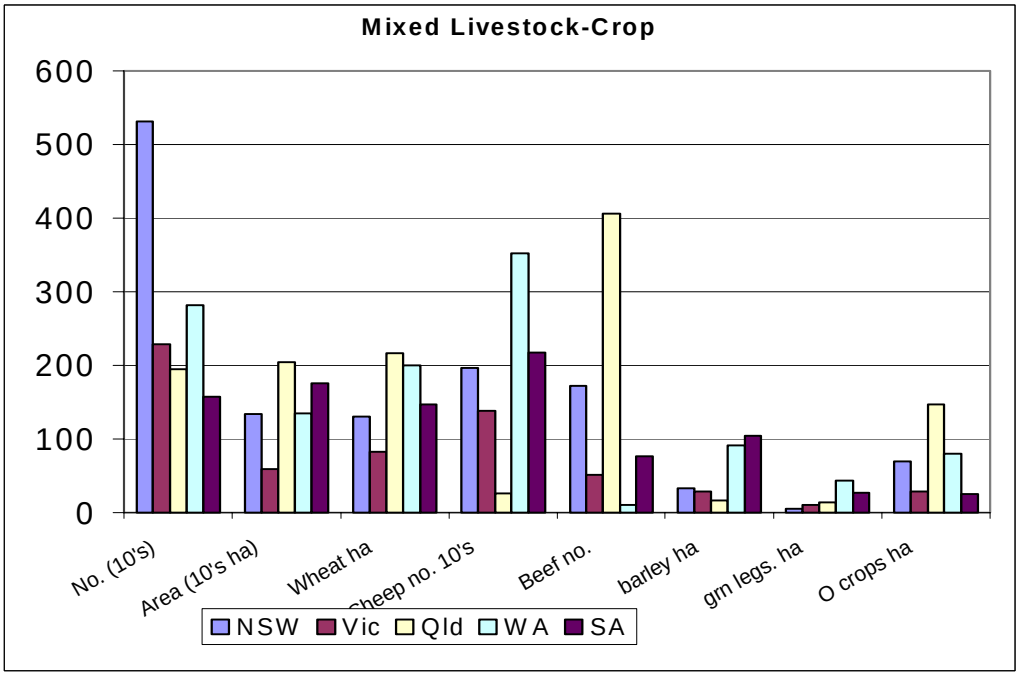
However, structure is not immutable. In 1996-97, 15,358 Australian specialist cropping farms produced an estimated 16.233 million tonnes of wheat. In the same year, 14,014 mixed livestock-cropping farms produced an estimated 4.541 million tonnes of wheat. The enterprise nature of these two farming types is shown in Figure 5.

Figure 5: Categorisation of Farms by Size and Livestock Enterprises, by State

(a) Cropping farms



(b) Mixed Livestock-cropping farms



The “mixed livestock-cropping farms” produced, as their class name suggests, a mix of crops and livestock (Figure 5b). The area of wheat grown on these farms in each state averaged 100-200 hectares in 1996-97. In NSW, Victoria and South Australia, farms of this type averaged 1500-2000 sheep, with an average of 3,500 sheep in Western Australia. Queensland farms of this type had small numbers of sheep, but averaged 400 head of beef cattle. In NSW, mixed livestock-cropping farms averaged over 150 head of beef cattle, while average beef numbers were low in the other states. About 100 hectares of grain legumes on average were grown on this farm type in South Australia and Western Australia, with 150 hectares of other crops in Queensland.

On specialist cropping farms, the area of wheat grown on these farms in each state in 1996-97 averaged 250-450 hectares in the eastern states, and approximately 1100 hectares in Western Australia (Figure 5a). Wheat area represented approximately 20 per cent of total farm area in the eastern states, and 34 per cent in Western Australia. Despite this greater cropping specialisation, the average number of sheep on these specialist cropping farms was 2600 in Western Australia (average farm area 3029 hectares) and approximately 1600 sheep and 90 head of cattle in NSW (average farm area 1870 hectares).

In states where average farm area was smaller, wheat area and livestock numbers were smaller: Victoria averaged 258 hectares of wheat and 755 sheep; Queensland averaged 268 hectares of wheat and 61 cattle; and South Australia averaged 286 hectares of wheat and 808 sheep. NSW farms also averaged 220 hectares of crops other than wheat; comparable figures for the other states were Victoria (410 hectares), Queensland (255 hectares), Western Australia (540 hectares) and South Australia (280 hectares)

In Table 4 is reported State-level breakdowns of specialist cropping farms by size of farm (measured as gross receipts) and size of sheep flock (in some cases, numbers of respondents are too small to report details).

- in NSW, 22.5% of specialist cropping farms reported no sheep although, in the largest turnover category of farms, 234 sheep were sold in the year. More importantly, in both cases, there were significant numbers of cattle. On other farms, there were significant numbers of sheep and/or cattle.
- in Victoria, 31.3% of specialist cropping farms reported no sheep although, in the smallest and largest turnover categories of farms, 170 and 225 sheep were sold in the year respectively. Only in the middle turnover category where no sheep were reported was there no obvious grazing enterprise. On average, all other categories of specialist farms reported sheep flocks averaging 270-910 head and small beef herds.
- in Queensland, most of the 1,973 specialist cropping farms reported no sheep and, on average, small to modest beef herds (30-235 head).
- in South Australia, 40.2% of specialist cropping farms reported no sheep; in the middle turnover category of these farms there were small numbers of beef and sheep sold and in the largest turnover category, modest numbers of sheep. Amongst other categories of farm there were sheep flocks averaging 660-2100 head and wool clips averaging 3600-11900 kg.
- in Western Australia, 14.7% of specialist cropping farms reported no sheep and where detailed data was available (only for the middle turnover category) there were on average modest beef herds. Amongst other categories of farm there were sheep flocks averaging 1600-4100 head and wool clips averaging 6800-23100 kg.

Table 4: Categorisation of Specialist Cropping Farms by Size and Livestock Enterprise, by State, 1997-98

NSW	**<$135,000**			**$135-335,000**			**>$335,000**		
sheep nos.	*0*	*0-650*	*>650*	*0*	*0-650*	*>650*	*0*	*0-650*	*>650*
no. farms	0	1049	216	538	372	969	533	340	742
% wheat	na	43	na	42	80	52	44	32	63
sheep 30/6	na	426	na	0	388	1693	0	320	3408
sheep sold	na	343	na	0	677	771	234	651	1685
beef 30/6	na	56	na	67	163	35	267	15	132
wool (kg)	na	1604	na	0	4516	8730	525	1052	15515

Victoria	**<$130,000**			**$130-250,000**			**>$250,000**		
sheep nos.	*0*	*0-500*	*>500*	*0*	*0-500*	*>500*	*0*	*0-500*	*>500*
no. farms	249	476	259	343	304	362	273	102	392
% wheat	22	33	50	28	25	40	30	50	32
sheep 30/6	0	158	844	0	150	899	0	378	1414
sheep sold	170	278	433	0	615	717	225	565	918
beef 30/6	28	9	7	0	24	33	62	0	68
wool (kg)	984	810	3391	0	1580	3675	259	2469	7614

Queensland	**<$65,000**			**$65-148,000**			**>$148,000**		
sheep nos.	*0*	*0-650*	*>650*	*0*	*0-650*	*>650*	*0*	*0-650*	*>650*
no. farms	549	0	0	560	38		739	51	36
% wheat	36			42	na	na	44	na	60
sheep 30/6	0			0	na	na	0	na	2378
sheep sold	0			0	na	na	0	na	1006
beef 30/6	49			30	na	na	209	na	235
wool (kg)	0			0	na	na	0	na	12353

South Aust.	**<$104,000**			**$104-293,000**			**>$293,000**		
sheep nos.	*0*	*0-1100*	*>1100*	*0*	*0-1100*	*>1100*	*0*	*0-1100*	*>1100*
no. farms	866	100	0	256	601	522	365	441	550
% wheat	33	na		43	49	59	35	50	52
sheep 30/6	0	na		0	731	1570	0	665	2138
sheep sold	4	na		129	399	558	261	860	843
beef 30/6	2	na		28	1	16	0	20	18
wool (kg)	0	na		807	3611	7713	337	4597	11952

Western Aust.	**<$445,000**			**$445-815,000**			**>$815,000**		
sheep nos.	*0*	*0-2600*	*>2600*	*0*	*0-2600*	*>2600*	*0*	*0-2600*	*>2600*
no. farms	53	684	117	240	315	458	76	221	346
% wheat	na	68	na	53	64	66	na	57	73
Sheep 30/6	na	1728	na	0	1617	3411	na	1597	4106
Sheep sold	na	566	na	0	390	1126	na	1379	1934
Beef 30/6	na	0	na	79	3	13	na	0	1
Wool (kg)	na	9014	na	0	6871	18960	na	13630	23151

Source: data from *Australian Farm Surveys*, purchased from ABARE

Note: "% wheat" is "proportion of total area cropped sown to wheat"

In summary, therefore, even most "specialist" cropping farms in Australia are not single enterprise farms. Except in northern NSW and Queensland, there are grazing enterprises in addition to cropping. Further, specialist "cropping" farms are not specialist *wheat* farms; in the eastern states and South Australia, most categories of specialist cropping farms have only a half or less of their cropped area in wheat (2 exceptions in NSW, one in Queensland and one in South Australia – in these cases, the percentage of wheat in total cropped area ranged 60-80 per cent). Western Australian specialist "cropping" farms have, on average, a higher proportion of their cropped land in wheat – 53-73 per cent.

Thus with some exceptions, wheat production still generally takes place on multi-enterprise farms in Australia. This multi-enterprise nature of farming provides an important mechanism for risk-spreading in wheat farming (and Australian agriculture more generally). Multiple outputs provide significant opportunities for risk-spreading where correlation among income streams over time is low. This correlation is likely to be lower for price risk, and likely to be higher for yield/output risk since climatic variability is likely to affect enterprises similarly. The use of genetic or varietal diversity to manage risk is likely to be less important in multi-enterprise agriculture than in mono-cropping.

3.3 Off-farm earnings

In 1997-98, "wheat and other crops" farms with gross revenue below $200,000 earned farm business income averaging -$17,200 and the top 25% of these farms earned farm business income averaging $28,600; these groups of farms obtained off-farm income of $16,800 and $20,900 respectively (Table 5). In 1997-98, 40 per cent of "wheat and other crops" farms had a gross revenue below $200,000. On average, off-farm earnings provided a very substantial proportion of household income and, for these farms, off-farm income fulfils the role of another farm enterprise. This income is likely to form an important element of the farm's risk management strategies. As with other farm enterprises, off-farm

income will reduce the need for risk management strategies within the farm enterprise generally, and within the wheat enterprise in particular. Similarly, for the 34 per cent of all "wheat and other crops" farms which had gross revenue between $200,000 and $400,000, off-farm income comprised on average 25 per cent of farm business income in 1997-98. Again, off-farm income is likely to have played an important role in risk management strategies. The situation was similar for "mixed livestock-crops farms (Table 5).

Table 5: Farm Characteristics, 1997-98

(a) Wheat and other crops

	GR<$200,000		**GR $200-400,000**		**GR>$400,000**	
	Average	*Top 25%*	*Average*	*Top 25%*	*Average*	*Top 25%*
Cropped area (ha)	244	260	553	392	1650	1742
Wheat proportion (%)	46	45	47	44	57	51
Farm business income ($'000)	-17.2	28.6	28	49.8	160.0	313.2
Rate of return (%)	-1.9	4.4	4.1	8.3	8.7	16.9
Off-farm income ($'000)	16.8	20.9	6.7	6.8	11.6	10.1
Industry population (%)	40	10	34	8	26	7
Industry GVFP (%)	12	3	28	7	60	17

(b) Mixed livestock-crops

	GR<$100,000		**GR $100-200,000**		**GR>$200,000**	
	Average	*Top 25%*	*Average*	*Top 25%*	*Average*	*Top 25%*
Cropped area (ha)	80	81	208	229	653	701
Wheat proportion (%)						
Farm business income ($'000)	-25.2	-10.0	-17.1	23.6	27.0	80.5
Rate of return (%)	-3.0	0.9	-0.7	3.5	2.9	8.0
Off-farm income ($'000)	14.5	9.2	9.2	10.5	10.9	14.0
Industry population (%)	28	7	28	7	44	11
Industry GVFP (%)	8	2	18	5	74	20

Source: Martin, P. (1999, Tables 16-17)

In summary, therefore, not only does the availability of other farm enterprises contribute to wheat farms' risk management strategies, but so too does the availability of off-farm income. These opportunities are likely to reduce the importance of risk management strategies such as genetic diversity within the wheat production enterprise as a form of risk management.

4. The policy environment

This section commences with a brief discussion of why the policy environment is important to the Australian wheat industry. The section then briefly surveys the nature of government in Australia, the evolution of the Australian economy and economic policy in the second half of the twentieth century, and key policy changes in the agricultural and related sectors in these decades.

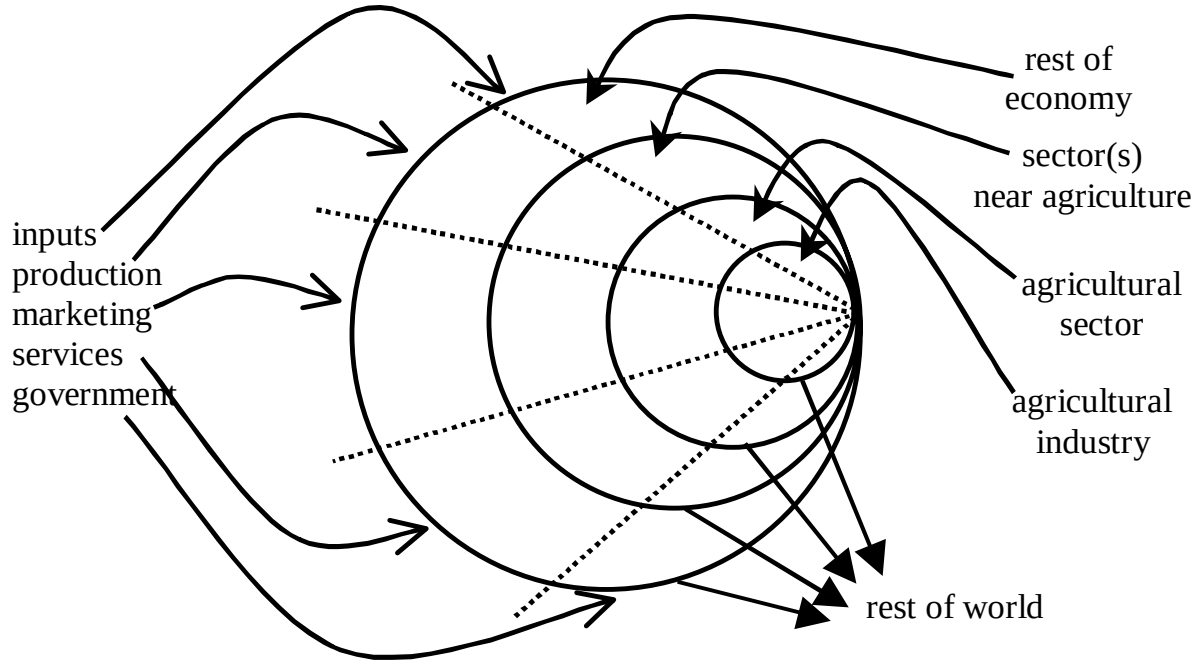
4.1 Wheat policy and government structure

4.1.1 Wheat industry

Wheat exports are important both to the Australian wheat industry and to the Australian economy, although the latter "importance" has declined substantially over the second half of the twentieth century. In the late 1950s, about 60 per cent of annual Australian wheat production was exported, rising to about 80 per cent in the early 1980s, and falling to about 75 per cent in the early 1990s – the actual percentage of wheat exports varies substantially because of substantial variation in wheat production. Around 1960, Australian wheat exports comprised some 15 per cent of the total value of Australian merchandise exports; by the mid-1990s, this level had fallen to about 5 per cent. In the mid-twentieth century, therefore, the wheat industry had macroeconomic importance – and therefore macroeconomic *policy* importance – because of its contribution to exports (cf. the "grow more wheat" campaign of 1930). As the contribution of wheat to national export income fell, but the importance of wheat exports to the wheat industry grew, macroeconomic performance and policy became increasingly important to the wheat industry.

The complex interactions, and changing interactions over time, imply that evaluation of the policy context of wheat production and variability– and thus the role of genetic diversity in managing risk and uncertainty – cannot be simply confined to the wheat industry itself. As indicated in Figure 6, a specific agricultural industry such as wheat is "nested" within the agricultural sector, which itself is nested within near-agricultural sectors (other natural resource industries, and input supplying and farm output using industries), which are themselves embedded in the national economy. Each of the "levels" in this model uses inputs supplied by itself and other sectors, produces outputs which are used by itself and other sectors, and connects to the rest of the world via exports and imports. These successive embeddings imply a complex series of inter-industry and inter-sectoral relationships which may be represented by a general equilibrium model of the economy. Most importantly, each of these relationships is affected by government policy of both economic and non-economic character.

Figure 6: Policy Context for the Australian Wheat Industry

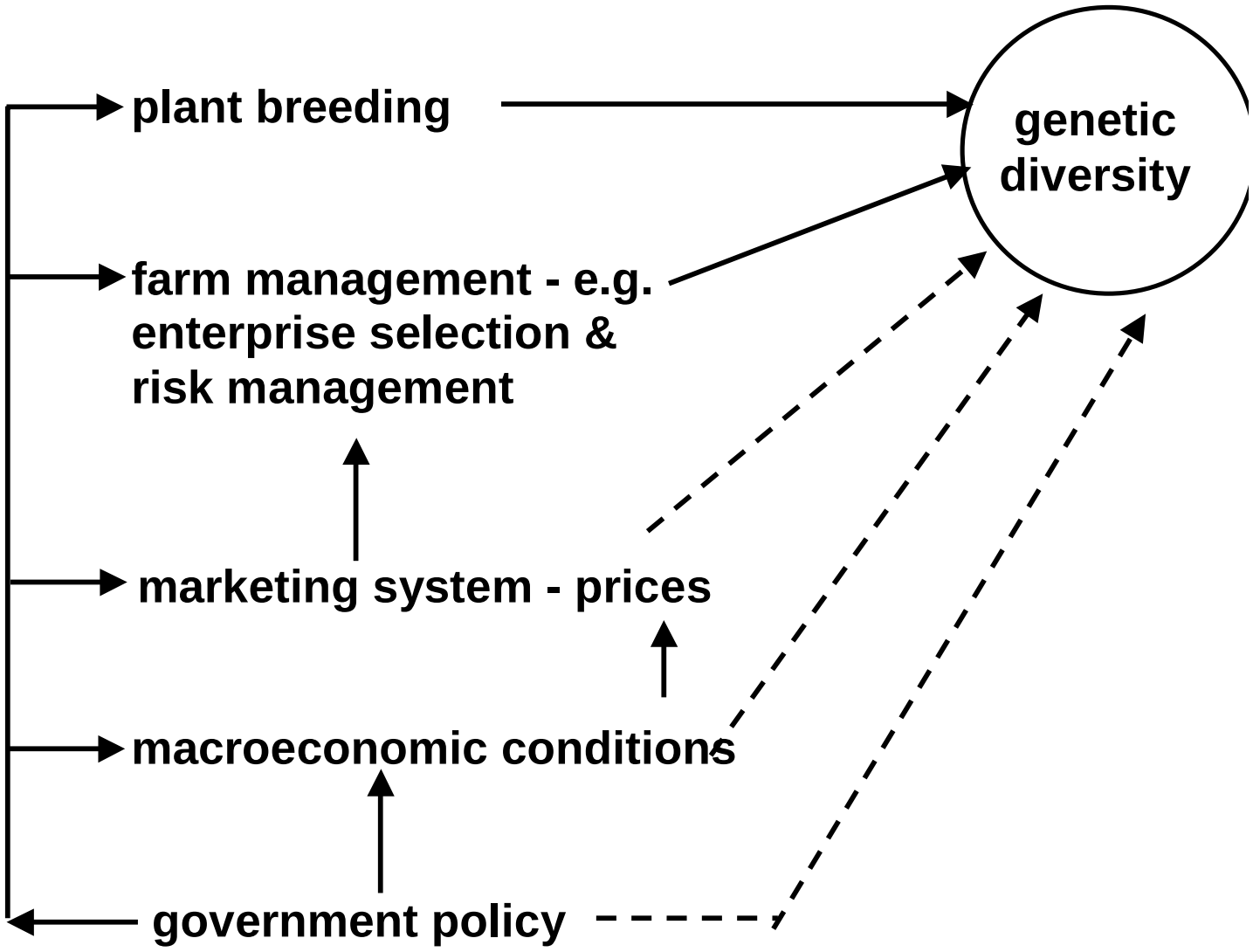


The ways in which government policy affect genetic diversity are summarised in Figure 7. In the context of the wider project of which this paper forms a part, the modelling of the supply of and demand for genetic diversity may be represented by measured "genetic diversity", and the influences

of “plant breeding” and “farm management”, the latter of which is also affected by the “marketing system”.

Each of these activities is, however, strongly influenced by government policy – e.g. wheat plant breeding has largely been a publicly-funded activity; farm management has been strongly influenced by government extension activity and direct financial measures such as taxation; and the wheat marketing system was a statutory system from 1949 until the late 1990s. Moreover, macroeconomic conditions –and government attempts at macro- and micro-economic management – had effects which flowed through to the wheat marketing system and directly to farm management and plant breeding. The remainder of this paper is directed towards a better understanding of these direct and indirect influences of government policy which ultimately might affect genetic diversity in wheat production.

Figure 7: The ways in which Government policy afffect genetic diversity



4.1.2 Australian government

Australia is a federation of six states and two territories, with a national government whose bicameral parliament is ostensibly modelled on the United States. In reality, however, government is closer to that of the United Kingdom. Five of the six states also have bicameral parliaments (Queensland abolished its “upper” house in 1923); the two territories are unicameral. The powers of the national (or “Commonwealth” or “Federal”) Government are defined explicitly in the Constitution and, superficially, all other powers remain with the States. In practice, however, a combination of constitutional interpretation (by the High Court), increasing financial dominance by the Federal Government, and innovative use of some constitutional provisions (especially the “states grants” and “external affairs”

powers) have greatly increased the Commonwealth's real powers as compared to its apparent constitutional powers (cf. Godden 1997, chapter 3).

In the particular case of the wheat industry – and for agriculture generally – this constitutional structure and its limitations are of major significance. Agriculture generally, and agricultural marketing specifically, are not mentioned in the Australian constitution. Hence the power to regulate the wheat industry appears to remain with the states. However, the power of the Commonwealth to regulate exports and interstate trade – but not intrastate production and trade – provides a significant but not comprehensive power to regulate the wheat industry. Marketing schemes – particularly those involving pooling of income and disbursement at a common payment rate across individuals – most easily operate via a system of levies and bounties; however, these instruments are the exclusive preserve of the Commonwealth.

Thus, a national wheat marketing scheme of this form requires cooperation between national and state governments, in the form of complementary Commonwealth-State legislation to create a suitable instrument. Bicameral parliaments where the governing party did not control the upper house increased the difficulty of achieving uniform legislation across national and state legislatures. Even where producers were willing to create such schemes, it took considerable legislative trial and error – the latter discovered through the courts – to construct a relatively robust form of national marketing intervention (cf. section 2.4, and greater detail in Whitwell and Sydenham 1991). Conversely, however, the dismantling of a national marketing scheme could be effected by a single disaffected government. Thus, for example, the Commonwealth Government decided in the late 1980s that it would deregulate the domestic marketing of wheat, and did so against considerable opposition from the states and wheatgrower organisations.

4.2 The wider economy

4.2.1 Macroeconomic evolution

The contemporary setting of Australian agriculture is a function of its evolution. Australian agriculture now makes about the same contribution to Gross Domestic Product as the Australian mining industry. Agriculture contributes about as much to the aggregate economy as do the electricity, gas and water industries combined; or the entire transport industry; or the entertainment, hotel and club industries combined. Agriculture makes about one-quarter of the contribution of manufacturing to GDP; about one-third the contribution of services from dwellings; and about one-half the contribution to GDP of either wholesale or retail trade. Agriculture's contribution to the Australian economy has changed markedly over the past five decades, and the current institutional framework and policies for agriculture and resources reflect this change.

The key features of Australia's macroeconomic evolution intimately related to agriculture in the period 1950-90 were (cf. Godden 1997, pp.4-11):

- change away from agriculture as the dominant export sector and a key national production sector;
- development of mining as a major natural resources exporting sector (and also tourism and elaborately-transformed manufactures);
- re-orientation of trade from Western Europe (especially the UK) to East Asia as a consequence of negative factors (UK entry to the European community) and positive factors (substantial economic growth in East Asia);
- public rejection of the benefits of "protection all round", facilitated by establishment of the IAC and the NFF's abandonment of this principle in the early 1980s;
- international economic dislocation in the 1970s precipitated by the first oil price shock of 1973, and the subsequent pervasive effects on governments' commitment to all-embracing social welfare programs coincident with and reinforced by the rise of intellectual and political libertarianism from the late 1970s.

The first act of the incoming ALP Government in 1983 was, as a consequence of an exchange rate crisis, to take the initial step in deregulating the Australian financial sector, a process which had been commenced by the previous conservative government's commissioning of a major enquiry into this sector. Although there were other contemporaneous pressures for deregulation, deregulation of the financial sector beginning in late 1983 was the catalyst for a sequence of as-yet-unended deregulations affecting large parts of the Australian economy.

Once the financial sector was deregulated, some forms of government intervention became increasingly difficult to manage (e.g. the Wool Reserve Price Scheme).

Other forms of regulation also became increasingly difficult to justify; in agriculture, there was deregulation of the domestic marketing of wheat, and substantial deregulation of the storage, handling and transport of grain (see below). As deregulation of the financial sector proceeded, the deregulatory fervour it invoked increasingly acquired the air of a religious crusade. The effects of financial sector deregulation were superimposed on two other processes of the 1980s. The first was an international economic boom. The second, specific to agriculture, was the rapid increase in US agricultural protectionism from the mid-1980s, ostensibly as a bargaining chip to induce West Europeans to reduce agricultural protection.

This increased protectionism resulted in greater levels of world agricultural trade, and greater competition for markets, culminating in depressed prices for many agricultural products. Depressed commodity prices, exacerbated by the collapse of farm-gate wool prices with the demise of the Reserve Price Scheme in 1990 and the effects of high interest rates resulting from international economic conditions and domestic macroeconomic policy, financially weakened many agricultural producers just as much of Queensland and northern NSW entered a long drought in 1991.

Attempts to remove or even limit distortions to international trade that breached at least the spirit of the GATT were unsuccessful in the Kennedy round. Accession of the UK to the EEC simply exacerbated the problem (Harris 1982, p.393). Harris (1982, p.399) noted, however, that without the forum provided by the GATT "agricultural protection might have been more extensive." In the mid-1980s, and as a response to the failure of previous attempts to liberalise world agricultural trade, the Cairns Group of Fair Traders was established with Australia as a principal sponsor and participant. The objective of the Cairns Group was to argue for agricultural trade reform in the Uruguay Round of GATT which was concluded in 1994.

These negotiations had a domestic parallel: the national government took the first steps towards participation in this freer trade by reducing import barriers into Australia by, for example, replacing the import ban on sugar with an initially-high but reducing tariff. Anderson (1998, p.3) argued that only "a little more than a standstill" in national protection of agricultural industries was achieved in the Uruguay Round. The principal features of the agricultural agreement were reductions in farm export subsidies, increases in import market access (including conversion of some non-tariff barriers to tariffs), and reductions in producer subsidies. The sanitary (human and other animal) and phytosanitary (plant) agreement sought to limit the use of quarantine-related measures to real health issues. Anderson argued that the ensuing liberalisation of trade was not great and that in some cases there are considerable opportunities to maintain (or even increase) effective agricultural protection.

In the big picture, there was the ostensible determination of the Federal Labor Government of 1983-96, and the subsequent Coalition government, to deregulate the Australian economy, even to the extent of pushing the States to deregulate significant portions of their own domains. Until 1993, the Federal Opposition Coalition had promoted even more extensive structural change in the Australian economy. Most State governments also paid at least lip service to the need for further deregulation of or structural reform in the economy. The evolution of the former Industries Assistance Commission into the Industry Commission (and, later, Productivity Commission) via absorbing the functions of the Inter-State Commission, gave the national Government a public process for investigating areas of the economy formerly beyond the purview of the IAC. Additionally, the Federal Government - following an agreement with the States and Territories, commissioned a review of "national competition policy" (Hilmer 1993) to accelerate the progress towards increasing competitiveness; this process was formalised in the National Competition Policy Agreement of 1995.

From 1996, the incoming Liberal-National coalition government continued the "national competition policy" reform agenda which had been agreed to by the previous Federal Government and the states in 1995. The new national government's principal macroeconomic focus in its first term (to October 1998) was reduction of government debt by reducing national government expenditure, and its principal microeconomic focus was labour market reform. In its second term, the coalition government's focus shifted to tax reform via a GST and reform of business taxation.

Other important elements of national economic evolution in the 1980s-90s were Australia's participation in key international agreements. These agreements included the increasing focus by governments and individuals on environmental degradation. Australia participated in the UN Conference on Environment and Development ("Earth Summit") in Rio de Janeiro in 1992 which developed international treaties on global warming and biodiversity. Both topics had serious

implications for Australia as it was a large per capita emitter of greenhouse gases, and the latter because it was linked to intellectual property rights in living material. The current Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement excludes the patentability of plants and animals, but this exclusion is open to renegotiation in 1999-2000 (DFAT 1998, p.208). The developing international harmonisation of intellectual property regimes, and the rapid privatisation of the plant genepool, has significant implications for plant breeding in small countries like Australia.

4.2.2 Intellectual foundations for smaller government

The "economic rationalist" agenda – a feature of English-speaking democracies from the late 1970s – included a demand for smaller government which had separate philosophical, financial and economic dimensions. The philosophical dimension was that big government is bad because it oppresses the individual, and that individuals had become too reliant on the financial support of the state (the "welfare state"). The financial dimension was that, in the wake of the economic upheavals of the 1970s, governments had accumulated large and putatively unsustainable visible debt levels. One means of reducing this debt was to divest government of saleable assets at both national and State levels. An alternative to the debt reduction strategy via asset sales – and one which frequently preceded such sales – was the corporatisation of government-owned producing assets. In this strategy, public authorities such as airlines, electricity generators, grain handlers and water utilities were reconstructed as profit-making business entities rather than as cost-recovering service providers. Apart from preparing these entities for sale, corporatisation had the added financial benefits of reducing the call on government for capital works and/or providing a (greater) revenue stream to government as the owner of the enterprise.

The economic dimension to the "economic rationalist" agenda was that government occupied too-large a role in the economy, and had entered areas where there was no justification for government activity, or where a rationale for government intervention had disappeared due to economic development. This excessive role led to crowding out in physical (e.g. electricity generation) and financial markets as governments borrowed to finance their commodity-producing activities. The new view of appropriate government activities focussed on excessive transactions costs and market failure as the principal justification for government intervention in markets. Not only was a substantial prima facie case of market failure required to justify government intervention, but this intervention ought to occur efficiently.

4.2.3 Environmental change

Contemporary concern about the state of natural resources had its origins in isolated debates about the protection of particular environmental resources. This concern evolved into a wider concern about the state of environmental resources generally, and was mirrored in growing international concern about both particular issues (e.g. trans-boundary acid rain, the ozone layer, global warming, deforestation, disappearing fisheries, global population, biodiversity) and the more general issue of global "sustainability" (e.g. Brundtland 1987). By the mid-1990s, comprehensive reports on the "state of the environment" were beginning to appear at both national and state levels (e.g. anon. 1996).

4.2.4 Summary

The general implications of these macroeconomic changes for the wheat industry were that governments of both political persuasions, and at both State and Federal levels, were slowly reducing the degree of government intervention in the economy. The effects of these reductions in intervention for the wheat industry were not, however, necessarily clear-cut. Depending on the locus of intervention, the termination of "bad" intervention might increase or decrease the returns of some or all wheat producers, and might increase or decrease wheat producers' variability of returns. Similarly, if government terminated "good" intervention – e.g. intervention which reduced market failure or market imperfections – the level and variability of wheat producers' returns might increase or decrease. The consequent effects of these changes on the demand for genetic diversity in wheatgrowing as a risk management strategy are unclear.

Conversely, macro-environmental change in general increased the degree of government intervention in the economy. As government – and indeed society – had generally under-valued environmental assets which were associated with significant market failures, increasing the economic efficiency of these assets' use required increased government intervention, even if only via the creation and distribution of appropriate property rights.

4.3 Near agriculture

4.3.1 Natural resource base

Before 1970, the principal concern with the natural resource base was how to further exploit it to increase national income. Even where there had been concern about resource damage – e.g. concern in the 1930s about soil erosion – this had principally been in the context of reduced productivity. Particular manifestations of the development ethos were continued land clearing (which persisted into the 1990s) and development of water resources (despite debate over its economic value, this development also continued into the 1990s). Added to this exploitation of natural resources was the development of large-scale forest clearing for woodchipping, and more intensified use of fisheries resources.

By the early 1980s, widespread concern was being registered over increasing salinity from irrigation (salinisation of both irrigated land, and of its wastewater) and subsequently dryland salinity, and soil acidification. The Landcare movement began as a cooperative, grass-roots based but government-supported initiative to attack land degradation – both in agriculture and outside – at the local level. In the early 1990s, it was recognised that some problems required a large-scale focus; this recognition spawned the Murray-Darling Basin Agreement, and subsequently catchment management trusts.

A second aspect of environmental protection was the management of exotic pests and diseases, especially their introduction in an era of increasing travel and greater international trade. The traditional approach to this problem was control via prohibition – thus, for example, prohibition on food or agricultural commodity imports such as wheat grain were ostensibly based on quarantine requirements. Where some commodities – e.g. oilseeds – were admitted, they were processed at port of entry. Maintenance of a prohibition system became increasingly costly as travel increased and more entry ports opened, and came under increased international pressure following the Uruguay Round of GATT as a trade protection measure.

4.3.2 Property rights

Two major changes in property rights occurred from the late 1980s. In 1987, the Federal Government finally enacted a specific law for intellectual property rights (IPR) in plant varieties.[4] This law – initially called Plant Variety Rights and, in a major 1994 revision, Plant Breeder's [sic] Rights (PBR) – potentially had major ramifications for Australian agriculture as most varieties in broadacre agriculture were publicly bred. Partly because of temporary inhibitions in applying PBR to all plant kinds, and partly because of some initial reluctance to apply PBR for varieties which had been produced using growers' funds contributed to the agricultural research and development corporations (RDCs), it took some years for PBR to affect broadacre agriculture.

There are several possible implications of PBR for genetic diversity. The first is that PBR were intended to provide a stimulus to plant breeding by encouraging (greater) private plant breeding. Whether or not this stimulus occurs appears to depend on plant kind, and there appears to be a substantial time lag for some plant kinds (particularly self-pollinating winter cereals like wheat). Even if this private stimulus occurs, it may replace public breeding in some plant kinds rather than augment existing breeding effort; or the stimulus to private breeding may encourage public breeders to shift away from finished varieties towards more basic germplasm evaluation activities. A second possible implication of PBR for genetic diversity is that, even where it occurs, additional private breeding primarily encourages "me too" breeding – i.e. similar advances in plant breeding are made as would have been made without PBR, but competition within the private sector results in morphologically differentiated but genetically similar varieties.

A third possible implication of PBR for genetic diversity is that the existence of IPR facilitates concentration in the plant breeding industry – with or without a competitive fringe – and that this concentration especially facilitates non-price competition which may or may not increase numbers of released varieties and/or genetic diversity in these varieties. In this case, an additional possible implication of PBR for genetic diversity is that the availability of IPR facilitates horizontal integration in agricultural input supply – e.g. among firms supplying new varieties and agricultural chemicals – and there is less incentive to seek genetic diversity to combat pests and diseases where chemical

[4] Prior to the *Plant Variety Rights Act 1987*, IPR in plants was possible through the patent regime.

solutions to these problems exist and tolerance genes may be inserted into varieties of commercial plants.

There is a potential serious problem of interpreting empirical data relating to the effect of PBR on wheat breeding intentions and/or results. The effect of PBR on wheat breeding occurred contemporaneously with the breakdown of the regulated wheat marketing environment where varietal development and release had been managed as one component of the managed wheat market. Thus the effect of PBR is likely to be strongly confounded with wheat market deregulation and it is likely to be difficult to disentangle their separate effects.

The second major property rights change involved the recognition, after two centuries, that Australia's original inhabitants had, and might continue to have, ownership rights in land and other natural resources. The High Court in *Mabo*, adjudicating on a land ownership dispute in the Torres Strait, outlined the general principles that the Court would use in determining the existence of "native title" throughout Australia. In an attempt to provide a minimally-litigious process for discovering where native title had survived the Federal Government – and some State Governments – enacted native title acts. A series of subsequent cases, in both the High Court and the Federal Court, increasingly unravelled the meaning and extent of native title.[5]

Since non-indigenous Australians had assiduously ignored the issue of indigenous land ownership, *Mabo* and subsequent judgments (especially *Wik*) introduced a significant element of perceived uncertainty into private and public land management. This perceived uncertainty was repeatedly manipulated for squalid political purposes. However, since (i) native title exists only where it has not been extinguished, (ii) wheat production occurs largely on freehold land, and (iii) freehold extinguishes native title, the implications of native title for wheat production, including the riskiness of production, are at best minor. There are therefore unlikely to be any implications of native title for genetic diversity in wheat production.

5. Implications for genetic diversity

The integration of the foregoing to evaluate its effect on the supply of and demand for genetic diversity in Australian wheat production requires an organising framework. One such framework is provided by de Janvry's (1978) description of a system providing technological and institutional innovations (cf. Godden 1997, figure 5.2 incorporating private sector agricultural research). Applying this framework to recent decades of the wheat industry in the context of genetic diversity suggests a complex web of detail, with changing policy decisions having possible effects interacting in a variety of ways.

5.1 Socio-economic structure

5.1.1 Land tenure and property rights

As noted above, the principal change affecting land tenure in the second half of the 20th century was the High Court's native title decisions in the 1990s, and consequent legislation. These tenure changes had, however, little impact on wheat production as native title initially affected only Crown lands and subsequently pastoral leasehold, neither of which were of major significance for wheat production.

Some attenuation of freehold tenure began to develop in response to concerns about the effect of land clearing on biodiversity maintenance and degradation of terrestrial carbon sinks. These changes also had little impact on principal cropping areas because land was either continuously cropped or was in rotations with sufficiently short pasture phases as not to be affected by land clearing controls. Cropping land likely to be affected by clearing controls was in marginal areas with opportunity cropping. These changes, while potentially affecting large cropping areas, were unlikely to translate into effective changes in the demand for wheat genetic diversity.

Other changes in natural resources property rights included strengthening property rights in irrigation water but again wheat production was unlikely to be affected as only a small proportion of the crop is produced under irrigation.

In summary, therefore, property rights changes were unlikely to affect wheat production, and there was unlikely to be any subsequent effect on the demand for genetic diversity in wheat production.

[5] see Padgett (1999).

5.1.2 State of technology

In the second half of the 20th century, the "state" of technology in wheat production evolved in four principal phases. In the first phase, genetic resistance to major diseases – especially the rusts – became effective across the entire wheat crop. In the second phase, to about 1980, the scale of farm machinery increased dramatically as tractor size increased and was accompanied by technical innovations such as hydraulics. In the third phase, semi-dwarf wheat varieties largely replaced taller varieties. In the fourth phase, mechanical cultivation for weed control increasingly replaced herbicides. The second and fourth of these phases were primarily imported technologies as Australia had lost its earlier comparative advantage in agricultural machinery innovation and had never had a significant chemical industry.

The chemical revolution was, however, modified by domestic policy considerations regarding occupational health and safety, concern as to environmental effects and eventually concerns about developing resistance to herbicides. While the germplasm enabling both the disease resistance and semi-dwarf advances was imported, its transformation into commercial varieties was substantially influenced by the (predominantly public) domestic plant breeding and research funding institutions.

An additional technological factor, in part stimulated by the wheat industry crisis at the end of the 1960s, was the search for alternative dryland cropping enterprises. While only a small proportion of possible alternative species ultimately proved widely successful – e.g. canola in eastern Australia and lupins in Western Australia – these species provided both substitutes to wheat and valuable species in rotations.

The effects of this technological evolution on the supply of and demand for wheat genetic diversity, and production variability, was complex. Some of the elements include:

- both the rust resistance and semi-dwarf phases increased genetic diversity in the narrow sense that additional specific genes were incorporated into commercial varieties to express these particular characteristics. Brennan *et al.*. (1999a) showed the extent by which Australian wheat breeders considered genetic diversity in their activities, and the mechanisms they utilised. Brennan *et al.* (1999b) reported a first attempt to model Australian farmers' demand for genetic diversity in wheat production.
- large-scale machinery improved the timeliness of operations, enabling production in more marginal areas, thus increasing the demand for greater range of cultivars with new qualities (e.g. Whitwell and Sydenham 1991, p.79), however the relative homogeneity of the new wheat lands and the large scale of operations may have led to a low demand for genetic diversity *within* these new areas; the larger areas grown probably increased opportunities for natural selection of diseases, and thus implicitly increased the latent demand for genetic improvement if not greater diversity.
- improved chemicals – particularly in concert with larger machinery – similarly enabled expansion into more marginal areas and enabled larger cropping areas, with similar effects as to machinery; new chemicals (e.g. for weed control) also allowed previously uncompetitive species – e.g. canola – to become competitive with existing enterprises.
- the clover-ley farming revolution of the mid-20th century in southern Australia ultimately encouraged development of acid soils, and thus the demand for (wheat) varieties tolerant of less-favourable soil conditions.

Partly induced by the above changes, the average size of wheat farms grew by 2 per cent p.a. in the period 1967-87 (Whitwell and Sydenham 1991, p.123). These changes were promoted and sustained by government policies – and supporting mechanisms such as research, extension and finance – which recognised and/or asserted that farm business survival depended on increasing farm size. Farm size growth, measured in terms of inputs (land, machinery) or outputs (wheat production), was not necessarily accompanied by increased farm profitability, but simply may have been required to preserve real living standards of surviving farm households. Cropping farms, like farms generally, now comprise relatively small proportions of farms contributing large proportions of gross value of farm production (GVFP). For example, 26 per cent of "wheat and other crops" farms are "large", and produce 60 per cent of GVFP for this industry; similarly, 44 per cent of "mixed livestock-crops farms" produce 74 per cent of GVFP (Table 5).

The implications of these changes in farm size, and the concentration of production in a small number of farms, for the demand for genetic diversity are unclear. While smaller farmers are more likely to be risk averse, it is not clear in the case of wheat production as to whether or not this translates into greater demand for resilient income and thus greater genetic diversity. Small farms are relatively more dependent on off-farm income (Table 5), and are more likely to have relatively higher costs of accessing and managing greater genetic diversity. Thus while they may have a greater demand for resilient income, they may have a lower effective demand for genetic diversity.

5.1.3 Product/factor prices

Marketing structure

From a marketing policy perspective, the wheat industry worked under four five-year plans, from the first plan of 1948-49–1952-53, a six-year plan (1968-69–1973-74); and three subsequent five-year plans (1974-75–1978-79 to 1983-84–1987-88) on which the Industries Assistance Commission was required to report prior to enactment of a succeeding plan. Following the IAC's and Royal Commission reports in 1988, an open-ended plan commenced in 1989 (ABARE Outlook). The following review does not canvas the details of the plans nor the process by which they were developed (cf. Whitwell and Sydenham 1991). Rather, the present objective is to discern the likely impact of these successive plans on the demand for – and possibly supply of – genetic diversity in the Australian wheat industry.

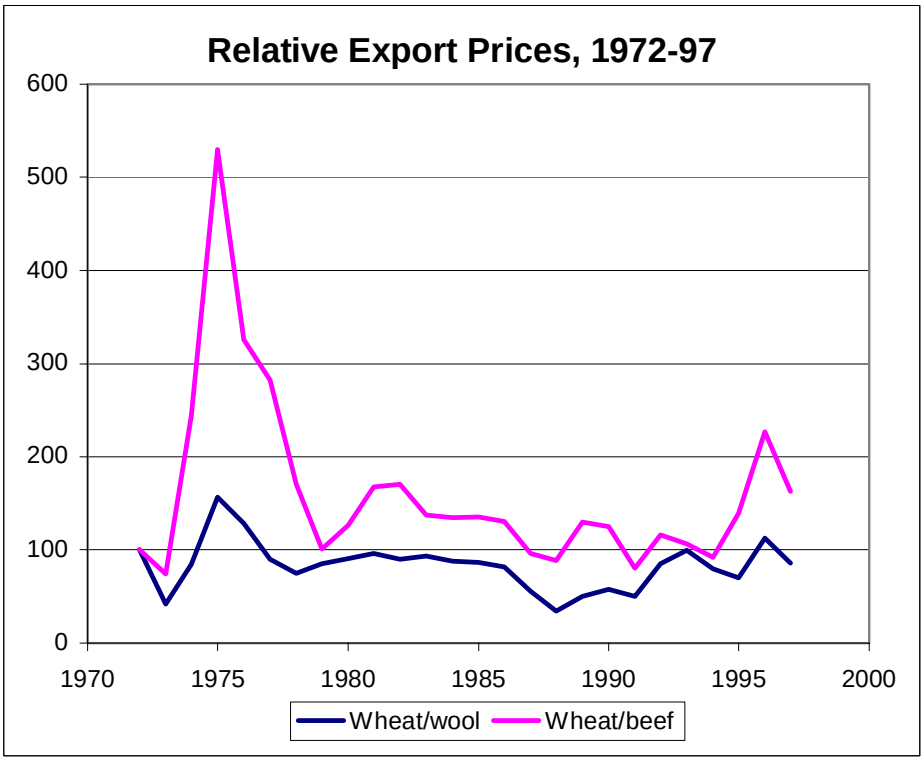
Whitwell and Sydenham (1991, p.134) summarised Miller and White as arguing that the objectives of the wheat marketing legislation were:

- *with respect to income* – "increase and secure the standard of living of wheat farmers, to maintain comparability between farm and non-farm incomes, to assist low-income producers, and to stabilise farm incomes"
- *with respect to price* – "guard against 'ruinous' prices, to generate prices fair to producers and consumers, to avoid excessive fluctuations in prices, and to provide 'orderly marketing' (that is, to moderate the forces of economic competition between producers)"
- *with respect to production* – "produce enough wheat to meet domestic requirements, to stimulate export production, to encourage efficient production, and to orient production towards more-favoured areas"
- *with respect to national policy* – "earn more export income, to constrain the federal government's fiscal liability, and to encourage the development of rural areas".

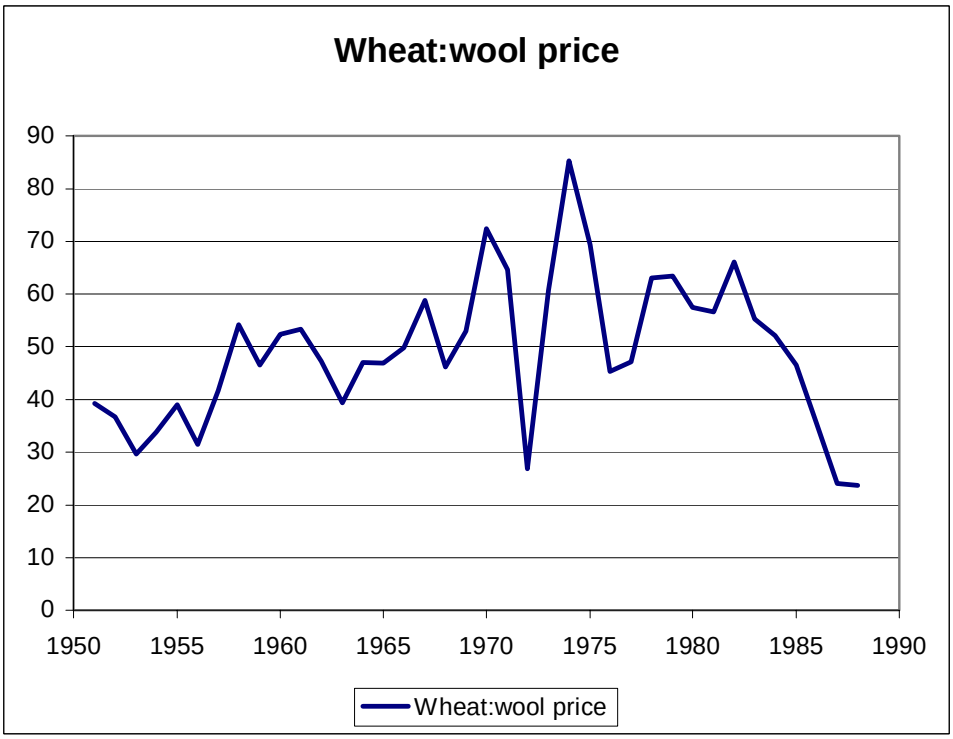
The means by which these objectives were initially implemented were a guaranteed minimum price for specified export quantity whose starting point was assessed cost of production including "objective" and "imputed" elements, the latter being a "thinly disguised 'political' component" providing government and the Australian Wheatgrowers' Federation room for negotiation over the actual guaranteed price (Whitwell and Sydenham 1991, pp.137ff). While there was some re-ordering of objectives over time, the basic structure was resilient (Whitwell and Sydenham 1991, p.134). This resilience lasted until the early 1980s when tentative domestic market deregulation commenced, followed by effective domestic market deregulation in 1989 at the Commonwealth's insistence over the objections of the States and the wheat industry. The Australian Wheat Board was privatised, using the Wheat Industry Fund as its capital base, in July 1999. The export monopoly was retained, overseen by the Wheat Export Authority, and is currently being reviewed under national competition policy guidelines (cf. Irving *et al.* 2000).

The effects of the pricing formula, in concert with wheat marketing conditions, are reflected in Figure 8. Over the period of the first five plans, the average price of wheat relative to wool rose 56 per cent over the period 1951-52–1955-56 to 1966-67–1969-70. The international wheat glut of the early 1970s followed by the mid-1970s commodities boom (except in beef) also show clearly. Relative wheat prices declined during the 1980s but, despite continuing low real wheat prices induced by international wheat protectionist policies, relative wheat prices were high in the mid-late 1990s because of low wool and meat prices.

Figure 8: Relative Export Prices



Source: ABARE data



Source: Whitwell and Sydenham (1991, Table A.6); ABARE

While modifying wheat prices was a principal objective of the post-1949 wheat plans, there has been substantial debate as to its efficacy. There are two dimensions to this debate: did wheat marketing stabilisation" actually *stabilise* prices; and/or did stabilisation stabilise price *upwards*. On the first of these, the evidence summarised by Whitwell and Sydenham (1991, pp.150-5) suggested that, for prices up to 1974 at least, the stabilisation scheme did not stabilise prices relative to what wheat prices would have been in the absence of the scheme.

Indeed, because of factors beyond the Australian wheat industry's control, international wheat prices were relatively stable over the period 1948-74. On the second issue of stabilisation upwards, the key issue in terms of efficient resource allocation was how wheat prices moved relative to major competitive enterprises at the farm level (e.g. wool, and sheep and cattle meats) and relative to competitive grains produced both in Australia and on world markets. In the first half of the period (to 1970), the vehemence of economists' opposition to "orderly" wheat marketing – in particular because of the effect of managed wheat price on land values (Whitwell and Sydenham 1991, p.143) – suggests that economists believed that the AWB had successfully raised prices. There is little subsequent evidence that the AWB was successful in maintaining wheat prices above otherwise-achievable levels.

In the context of within-crop genetic diversity and yield variability, however, the average level of the wheat price, and its relationship with alternative enterprises, is of less immediate interest than variations in and relativities of the prices of different kinds of wheat. Prior to about 1970, Australian wheat was sold – largely – under the "FAQ" system. The initial FAQ system was described by Whitwell and Sydenham (1991, p.104) as:

> *All wheat grown in a given area was mixed and a weighted average sample was declared FAQ for that season and region by the local Chamber of Commerce.*

Local FAQ committees were replaced by State committees in 1958 (Whitwell and Sydenham 1991, p.106), and the system ended in 1974. While the FAQ system did not explicitly encourage within-paddock diversity, FAQ also did not penalise within-paddock diversity as long as this heterogeneity was within the limits of the local FAQ declaration.

However, even with the FAQ system, buyers were aware of varying characteristics of wheats sourced from different areas, and purchased accordingly. That is, if (domestic) buyers knew where to source "premium" quality wheats, they could do so at FAQ prices.[6] This disjunction between price and "quality" could even operate to the advantage of the Wheat Board in regulated international markets. For example, Connors (1972, p.61 cf. p.63-4) argued that, because of putative constraints on international wheat marketing under the International Grains/Wheat Agreements, "Sales of hard wheat were stimulated by selling it under the F.A.Q. range, hence offering a hidden price discount." Moreover, while the FAQ system might be regarded as monolithic, it clearly was not (Whitwell and Sydenham 1991, pp.104-9).

The Queensland Wheat Board had segregated wheats from the early 1950s (Whitwell and Sydenham 1991, p.107; see also p.105 on Japanese speciality purchasing of Queensland wheat in 1954-55), and the emergence of the Premium Wheatgrowers Association in northern NSW in 1956, aided by Grain Elevators Board segregation of members' wheat and a special payments system for this wheat within the Australian Wheat Board, indicated partial crop segregation. Thus, in the prime hard wheat growing areas of northern NSW and Queensland initially, and subsequently elsewhere, there were opportunities to benefit from partial segregation, and thus encouragement of varietal specialisation. To the extent that this varietal specialisation occurred, it represented a greater diversity of *cultivars* of wheat grown and the move to greater segregation may have encouraged greater genetic diversity.

However, there was a contemporaneous and contrary force working in the opposite direction. Especially for wheat entering industrial production – both food for direct human consumption (bread, biscuits, pasta etc.) and (to a lesser extent) industrial wheat used for processing into starch and its derivatives, and gluten – there was an increasing demand for uniformity of wheat batches (Whitwell and Sydenham 1991, pp.262-3). This demand for uniformity imposed greater pressures on the grain handling system to increase segregation and, once segregation could be assured in the handling and storage system, then greater demands for uniformity in farmer deliveries. This latter demand led to an increasing demand for within-crop uniformity and thus a reduced tolerance of within-crop diversity.

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[6] cf. Whitwell and Sydenham 1991, p.149: "The price differential normally associated with variations in quality – in terms of both the prices paid to growers and by consumers – was suppressed."

Thus the move from FAQ to increasingly tight specifications of class or grade is likely to have decreased within-paddock diversity while encouraging the diversity of varietal types between regions as they increasingly specialised in the production of types most suited to the local environment. Local, inter-paddock genetic diversity is likely to have been constrained by the availability of locally-adapted, genetically-diverse cultivars.

Prices

Changes in the prices of wheat relative to output prices of other enterprises that could be undertaken on wheat farms led to substantial, and often-rapid, switches in farm output. These switches indicate that the "wheat" farmers' principal form of defence against price variability was through enterprise diversification, especially until the 1970s. There was a substantial switch into wool from wheat after wool prices rose before and especially during the Korean war price boom (e.g. Connors 1972, Table 3), and back again into wheat when that boom collapsed (e.g. Figure 2 and Whitwell and Sydenham 1991, p.166-8). The increased specialisation of wheat-growing – in part stimulated by the rapid increase in machinery size in the 1960s-70s – constrained the availability of livestock enterprises as biological or economic complements to wheat growing. Other cropping enterprises, especially the development of oilseed production stimulated by the over-production crisis of the late 1960s (e.g. Whitwell and Sydenham 1991, pp.180-8), remained as a form of defence against price variability – and the lower the correlation between the wheat price and prices of these other grains/oilseeds, the more effective the stabilisation. Other cropping enterprises did not, however, provide much defence against rainfall-induced variability in wheat yields and production – except, possibly, for summer-growing crops.

5.2 Politico-bureaucratic structure

5.2.1 Social pressure system

The FAQ scheme reflected a more deep-seated attitude to the wheat industry than simply a wheat pricing mechanism. FAQ reflected a social pressure system which emphasised egalitarianism, also represented by attempts to even out returns over space (e.g. grain pooling and cost averaging) and time (the stabilisation fund). This egalitarianism diminished over time as both as egalitarianism diminished in the wider Australian community, and within the wheat industry itself. This egalitarianism represented an external attempt to manage a risky environment. To the extent that it was successful, it would have meant that farmers were less reliant on internal risk management mechanisms.

For example, State-wide cost averaging in wheat pools until 1978 favoured growers more distant from domestic markets or seaboard terminals. To the extent that more distant growers were on the drier margins, cost averaging encouraged increased production variability, and possibly the demand for varieties more suited to the drier margins, possibly increasing the demand for greater genetic diversity.

5.2.2 Research levies (Appropriation/legislative reward system)

Beginning in the mid-1950s, the wheat industry in concert with government established wheat industry research funding arrangements based on a production levy and matching grants from Commonwealth consolidated revenue. This system involved research funding disbursed from both a national Wheat Research Council and state-based wheat research committees. Funding thus provided supplemented core funding of research activities by public sector institutes (principally CSIRO, the universities and state agriculture departments) and was used to support a wide range of wheat research including plant breeding. These arrangements lasted until 1989 when the Grains Research and Development Corporation replaced the existing arrangements for wheat research, and also incorporated previously-separate crop funding arrangements for barley etc.[7] The GRDC has been very proactive in managing its research portfolio and has also been active in consolidating its research portfolio especially for wheat breeding. The impact of the public funding of plant breeding since the mid-1950s for genetic diversity is unclear. Brennan *et al.* (1999a) noted that Australian wheat breeders reported that changes to the wheat research funding arrangements in the 1990s had "become more skewed towards short-term outcomes" and does not encourage breeding strategies leading to genetic diversity.

[7] GRDC now provides for Wheat; Coarse Grains (barley, oats, sorghum, maize, triticale, millets/panicums, cereal rye, canary seed); Pulses (lupins, field peas, chickpeas, faba beans, vetch, peanuts, mung beans, navy beans, pigeon peas, cowpeas, lentils); and Oilseeds (canola, sunflower, soybean, safflower, linseed)

5.3 Innovation production

5.3.1 Public sector

Up to the 1970s, consistent economic growth, adequate Commonwealth and State funding for agricultural research, the evolution of the rural industry research funds mechanism, and general optimism about the future of agriculture[8] sustained a generally buoyant attitude to agricultural research. While the marginal return from additional research expenditure was likely still to have been positive, wheat breeding programmes were well maintained. For example, into the 1970s the NSW government sustained three wheat breeding programmes (Tamworth, Temora and Wagga), and there was also a nationally-funded programme through the University of Sydney. While there were critics of the efficacy of the wheat breeding effort (e.g. Campbell 1977), the rate of progress in yield for comparable classes of wheat were similar to the UK (Godden and Brennan 1994). Institutional constraints on the types of varieties that would be accepted by the Wheat Board limited breeders to releasing wheats for human consumption, and prevented breeders from making the kinds of yield gains that were being made elsewhere in feed wheats.

The general constraints on government expenditure noted above began to constrain research activities from the late 1970s. Partly as a consequence of funding constraints, and partly exogenously, government research organisations increasingly developed formal, integrated research planning and management mechanisms. The time horizons of public servants lessened from the 1970s, and those of politicians have always been short. These management and funding changes reinforced those changes that were occurring in the research funding bodies during the 1980s and which were stimulated by the new research funding arrangements under the *Primary Industries and Energy Research and Development Act 1989.*

The effects of these changes is likely to have reinforced the changes reported by plant breeders as noted above that there were increasing constraints on the type of work that might lead to increased genetic diversity.

5.3.2 Private sector

Prior to the Plant Variety Rights Act 1987, there had been several decades of private plant breeding in Australia focussed on the development of F1 hybrid varieties by the Tamworth wheat breeder Dekalb Shand. However, there had been no successful releases of commercial varieties primarily, it is thought, because an insufficient yield margin could be developed between public varieties and F1 hybrids to justify their additional seed costs. PVR have been granted in Australia for 37 wheat varieties. The first application for PBR for wheat was in 1991 and was granted in 1992. The subsequent pattern of applications and grants was (applications, grants): 1993 (8,0); 1994 (1,0); 1995 (4,2); 1996 (18,2); 1997 (9,10); 1998 (5,21); 1999 (to 9 October) (1,1). The applications have been from WA Department of Agriculture (16), Queensland (10), Victoria (3), South Australia (3), NSW (2), CSIRO (5), University of Sydney (5), and private (3).[9] Public breeders appear to be increasingly using companies and/or joint ventures to market their varieties, possibly to increase the effectiveness of marketing, possibly to quarantine revenue from normal funding processes, and possibly to protect the public organisation from litigation in case of disputes. More recently, intellectual property rights in new wheat varieties is held jointly with GRDC.

Brennan *et al.* (1999a) reported that Australian wheat breeders considered that, to date, genetic diversity had not been affected by PBR/PVR.

[8] Despite the acknowledged small farm problem.

[9] One of the South Australian government's and one private variety were withdrawn.

6. Conclusions

This study is part of a wider study of genetic diversity in wheat production in Australia and China. Part of this study involved the econometric estimation of the supply and demand for genetic diversity in the Australian wheat industry. Especially since 1945, government policy has had a major impact on the marketing of Australian wheat, and also on the research and development process. The modelling of the supply and demand for genetic diversity therefore has government policy as a possible shifter of the supply and demand curves, and therefore some "policy" variable would be required to test the significance of this hypothesis.

Construction of such a policy variable required the preliminary analysis of the likely forms of government policy that might eventually affect the supply and demand for genetic diversity. While it is probable that the dominant impact might come from specifically wheat industry policy, the importance of agricultural exports in the early part of the post-war period, and the importance of wheat exports within agricultural exports, meant that – for part of the period at least – wheat industry policy might have been a part of macroeconomic policy.

The dominance of government policy over the wheat industry in the first half of the post-war period meant that it was not necessarily easy to discern the influence of policy on genetic diversity. Hence the development of the wheat industry prior to 1945 was reviewed to provide a context for the later analysis.

While the importance of agriculture in the macro-economy declined over the post-war period, the emphasis on reducing government intervention in the economy in the second half of the period meant that the deregulation that was occurring in wheat policy was part of a much larger policy agenda which needed accounting for.

The possible effects of government policy change on the supply and demand for genetic diversity in Australian wheat production are diverse and often subtle. Implemented policies may be synergistic with existing policy, or (partially) neutralise existing policy. It is unlikely that a single "policy" variable could be constructed to represent all the possible effects of government policy on supply of and demand for genetic diversity. However, in the post-War period, there have been three broad periods of policy regimes that affected varietal diversity:

(a) Pre-1971: Characterised by regulated marketing through the AWB; wheat breeding in the public sector; wheat graded as FAQ;

(b) 1972-1989: Characterised by the continued dominance of regulated marketed marketing through the AWB; wheat breeding in the public sector; multiple grades (ASW, APH, etc) with differing prices;

(c) Post-1990: Characterised by market deregulation and the ABB's loss of powers; more specialised grades and payments for protein; increasingly commercialised breeding, influenced by the role of the GRDC; and increased numbers of varieties released.

These broad periods define times at which various government and industry policies have had varying influences on genetic diversity in Australian wheat. It is likely that with the current rapid rate of policy change that further influences will take place in the future.

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