The Economic Valuation of Australian

Managed and Wild Honey Bee Pollinators

in 2014 - 2015.

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"Phoebe earns her living as a keeper of honey bees. Her neighbours on all sides grow apples. Because bees pollinate apple trees as they forage for nectar, the more hives Phoebe keeps the larger the harvest will be in the surrounding orchards… Phoebe's hives constitute an external benefit or a positive externality…"

Franke, R.H. and Bernake, B.S. 2009. Principles of Economics. Brief Edition Boston: McGraw-Hill Irwin p.268.

[1] Department of Mineral and Energy Economics, WA School of Mines, Curtin University. Email: John.Karasinski@gsb.curtin.edu.au This paper benefited from presentations made to various WA bee industry groups including The Bee Industry Council of WA, the WABA and WA Farmers Bee 2017 Conference, the Centre for Integrative Bee Research at the University of Western Australia and a seminar presentation made to the Agriculture and Natural Resource Economics Society (W.A. Branch).

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Abstract.

The principle objective of this research was to measure the economic value of Australian managed and wild honey bee pollinators for 2014 – 2015 using the Partial Equilibrium Model (P.E.M.). This study comprehensively reviewed Australia's honey bee dependent agriculture crops which identified 53 agriculture crops that were subsequently integrated into the P.E.M. This number far exceeds the number of agriculture crops used in previous studies of late 1980's and early 2000's. Along with the increased number of crops, the honey bee dependency factors of those crops have been comprehensively re-examined based on prevailing Australian scientific knowledge.

In 2014 – 2015 the economic value of Australian managed and wild honey bee pollinators is estimated to lie in a range between $A 8.35 bn and $A 19.97 bn based on own price elasticities of demand of -0.526 and -1.049. The average economic value is estimated to be $A 14.2bn. This economic value excludes any livestock impacts.

Two previous studies reported an economic value for Australia. This study goes well beyond by reporting the economic values for each of the states and territories – *see Table 4.* Additionally, the power and applicability of the P.E.M. is shown by the ability to calculate for the first time, the economic value for a single agriculture crop at the regional level - *see Table 5.*

The results of this study confirm the economic importance of Australia's managed and wild honey bee pollinators are substantial and most likely far greater than most would consider.

It is hoped the results of this study will be used by industry stakeholders and government's alike to frame agriculture policy reflecting the overall economic importance of this industry.

> "The extraordinary industry of bees and the number of flowers which they visit within a short time, so that each flower is visited repeatedly… but I do not know the rate at which hive bees fly. Humble bees fly at a rate of ten miles an hour, as I was able to ascertain in the case of males from their curious habit of calling at certain fixed points which made it easy to measure the time taken in passing from one place to another."
>
> Darwin, Charles. 1876. *The Effects of Cross and Self Fertilisation in the Vegetable Kingdom*. Chapter XI pp.424 - 425.

1.0 Introduction.

The quote on the cover page of this report by economists Franke and Bernanke (2009) is sourced from their university undergraduate economics textbook which gives students a practical example of a very important theoretical economic concept. The concept of the positive economic benefit provided by an economic agent for which they are not financially compensated. This is known as an external benefit or a positive externality. The value of that benefit is its economic value.

At a theoretical level it is not difficult to understand the pollination benefits conferred by the activities of managed and wild honey bee (*Apis mellifera*) pollinators.

More than 80 years ago, American agriculture economists Voorhies, Todd, and Galbraith (1933) [2] questioned whether the (economic) value of American honey bee pollinators could be quantified and if it could they speculated those services would far exceed the industry's gross value of production when they stated:

[2] Voorhies, Edwin C, Frank E Todd, and John Kenneth Galbraith 1933 "Economic Aspects of the Bee Industry." Bulletin 555, September. University of California, College of Agriculutre, Agriculture Excperiment Station. Berkley, California p.6.

> *"*It is impossible to evaluate in dollars and cents the services of the honey bee in pollination of fruit trees and other plants. Well-informed persons believe that in California such services are of greater value than the honey and wax produced within the state*."*

Those "services" are the same postive external benefit or the postive externality mentioned by Franke and Bernanke (2009) above.

This paper reports Australian research using 2014 – 2015 Australian Bureau of Statistics data that *has* "… evaluated in dollars and cents…" the value of the positive externality provided by Australia's managed and wild honey bee pollinators.

The research confirms the view expressed by Voorhies et al (1933) that the economic value *is* far greater than the industry's gross value of production. [3]

Australian Interest in Honey Bee Pollinator Activity.

Australian interest in measuring the economic value of the honey bee industry can be traced back to the mid 1980's when the Industries Assistance Commissions (IAC), the fore-runner to the Productivity Commission, held a public inquiry into the biological control of *Paterson's Curse – Salvation Jane.* [4] In its submission to the inquiry the Victorian Department of Agriculture (1984) estimated the "economic value" of Australia's honey bee pollinators was valued at $A 158.6m. However, in its final report, the I.A.C. settled on a substantially smaller figure of $A 545,000 as the Australian "economic value."

[3] See Appendix One for background details on the Australian industry in 2014 - 2015.

[4] Industries, Commission Assistance. 1985. *Industries Assistance Commission Report on Biological Control of Echium Species (Including Paterson's Curse/Salvation Jane), 30 September 1985*, *Industries Assistance Commission Report ; No. 371*. Canberra: Australian Government Publishing Service.

The two valuations were calculated using different models of the honey bee pollinator industry. The Victorian Dept. of Agriculture's estimate calculated the crop value of honey bee production while the IAC measured the replacement cost of commercial services.

Importantly, neither of the two estimates were the correct measure of the positive externality or economic value as understood by economists.

Australian agricultural economist Roderic Gill (1989,1990, 1991a, 1991b, 1996) pioneered the application of microeconomic theory to the measure the economic value of Australian honey bees. Using mid 1980's Australian Bureau of Statistics (ABS) data, Gill determined the economic value of the Australian honey bee industry ranged between $A 604.8 m and $A 1,209.7 bn.

As recently as 2014 [5], Gill's upper estimate of $A 1.21 bn was still being quoted in government circles as the *current* estimate of economic value even though the value of Australian agriculture production increased almost 700% from $A 6.262 bn in the mid 1980's to $A 49.84 bn in 2014 - 2015.

Reliance on obsolete information has significant detrimental implications for the Australian honey bee industry and Federal and State government agriculture policy directed at that industry. It is envisaged that the estimates contained in this paper will be used to devise more appropriate government agriculture policy.

[5] Australian Government Dept of Agriculture. 2014. " Inquiry into the Future of the Beekeeping and Pollination Services Industries in Australia. Submission 79."

2.0 Review of the Australian Literature.

Since the mid 1980's there have been fourteen Australian studies into the Australian bee keeping industry including two Federal Parliamentary Committees of Inquiry, one House of Representative Committee and one Senate Committee of Inquiry as well as the IAC Inquiry of the 1980's.

Table 1 lists all the research conducted into the Australian honey bee industry since the mid 1980's. The table highlights the different measures used to calculate the so called "economic value."

Ignoring the Australian Government's *Response* which is listed as the final item in table 1, the research shows:

- One (1) Australian study used a financial model, the Net Present Value to measure the financial costs and benefits of the industry. This is not *the* measure of economic value.
- Three (3) studies calculated the replacement cost of commercial bee keeping services. This is a measure of business cost but not *the* measure of economic value.
- Four (4) studies measured the crop value of honey bee production. This is not *the* measure of economic value.
- Of the four (4) studies that correctly cited *the* economic value, two studies cited the results of other researchers.
- Only two (2) studies reported their economic measured based on the use of the Partial Equilibrium Model.

This is the third study since the mid 1980's to use the Partial Equilibrium Model to measure the economic value of managed and wild honey bee pollinators in Australia.

Table 1: Australian Research since the mid 1980's.

Country	Measurement Technique	Number of Crops	Pollinator Type	Estimated Value $A	Source and Comment
Australia	Replacement Cost of commercial services	Not Stated	Managed and Wild	$A 545,000	Industries Assistance Commission (IAC) Inquiry 1985
Australia	Bee Value of Pollination	Not Stated	Managed and Wild	$A 158.6 million	Vic Dept. of Agriculture (1984) submission to IAC Inquiry 1985
Australia	Economic Value of Bee Pollination	35	Managed and Wild	$A 604.8 m - $A 1,209.7 billion	Gill, R.A. (1989)
Australia	Economic Value of Bee Pollination	25	Managed and Wild	Cited Gill's upper estimate of $A 1.2 bn.	Gibbs & Muirhead (1998:29)
Australia	Economic Value of Bee Pollination	35	Managed and Wild	$A 604.8 m - $A 1,209.7 bn (modified Gill 1989)	Gordon & Davis (2003)
Australia	Net Present Value (NPV)	35	Managed and Wild	$A 21.3 m - $A 50.5 m p.a.	Cook et al (2007: 04)
Australia	Replacement Cost of commercial services	35	Managed and Wild	The price impact of one "business as usual" and two Varroa *Destructor* incursions calculated on a price per hive basis.	Monck et al (2008)
Australia	Bee Value of Pollination	41	Managed and Wild	$A 4.0 billion – $A 6.0 billion	Thomson RIIDDC …House of Representatives Standing Committee (2007: 23)
Australia	Bee Value of Pollination	25	Managed and Wild	$A 4.0 billion – $A 6.0 billion	Barry, S et al (2010:1) Future Surveillance needs … RIRDC
Australia	Replacement Cost of commercial services	NA	Managed and Wild	No quantification of the benefit of honey bees was made.	Keogh et al (2010:8) "The pollination services … by honey bees … being less tangible … the importance and value of these services is arguably much greater."
Australia	Bee Value of Pollination	NA	Not Stated	$A 4.0 billion – $A 6.0 billion	Dawes and Dall (2014:17) cited House of Representative Standing Committee on Primary Industries and Resources: *More Than Honey: the future of the Australian honey bee and pollination industries.* Inquiry into the Future Development of the Australian Honey Bee Industry.
Australia	Economic Value of Bee Pollination	41	Managed and Wild	$ 604.8 bn - $A 1, 726 bn (citing both Gill 1989 and Gordon and Davis 2003.)	Aust Dept. of Agriculture Submission 79 p.4 cited in: Australian Senate Standing Committee Report, *Future of the beekeeping and pollination service industries in Australia* (2014:4)
Australia	NA	Not Stated	Not Stated	"The exact benefit ... is almost certainly valued in the billions of dollars" (2015:1)	Australian Government *Response* (March 2015) to: The Senate Rural and Regional Affairs and Transport References Committee report: *Future of the beekeeping and pollination service industries in Australia.*

Four Australian Economic Studies.[6]

Between the mid 1980's and 2014 four Australian researchers reported their estimates of the economic value of honeybee pollinators. These are discussed in chronological order below.

Gill (1989,1990, 1991a, 1991b, 1996) used a partial equilibrium model (P.E.M.) along with mid 1980's Australian Bureau of Statistics (ABS) data to report the estimated economic value of honey bee pollinators in a range of $A 604.8 m and $A 1,209.7 bn.

Gibbs and Muirhead (1998) cited Gill's (1989) upper estimate of the economic value of $A 1.2 of a decade earlier and did not present their own calculation of *the* economic value. The majority of the study was based on their estimates of the crop value of honey bee production.

When this $ A 1.2 bn figure is viewed in the context of the 60% growth in the value of agriculture production between the two the mid 1980's and a decade later[7], this figure is a gross *underestimate* of the economic value.

Intuition would dictate the growth in the value of the agriculture crop would be accompanied by growth in the economic value of honey bee pollinators, however this relationship does not appear to be fixed. [8]

The economic value cited by Gibbs and Muirhead (1998) implies there has been a substantial contraction in the economic value over the ten-year period. And this is a highly questionable conclusion.

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[6] A fifth study was an international study reported by Gallai et al (2009) which included Australia as part of an eight country *Oceania* group of nations. Using the correct economic model, the estimates they generated are of little value because the report did not ascribe an economic value for Australia. Any attempt to do so for the purposes of this paper would be speculative at best.

[7] ABS Value of Agricultural Commodities Produced, Australia p.12.

[8] A study of the long-term data may reveal the existence of a statistical relationship between the two measures. Such a study is warranted.

Furthermore, there were no supply side external shocks reported over this time period such as an incursion of the *varroa mite* or colony collapse disorder which would have adversely impacted the honey bee pollinating industry. Similarly, there were no adverse shock experienced by the agriculture industry during this ten-year period. For these additional reasons the economic value reported by Gibbs and Muirhead (1998) is considered to be of dubious quality.

Gordon and Davis (2003) using 1999 - 2000 ABS data updated Gill's original study, using the same number of agriculture crops and the same honey bee dependency factors. They estimated the economic value had increased 43% from $A 1,209.7 bn to $ A 1.726 bn. [9]

in the intervening period between the time of Gill's study and that by Gordon and Davis who used 1999-2000 data, the value of Australian agriculture production increased almost 400%. [10] A 400% increase in the value of agriculture production is a substantial increase which, as with the study by Gibbs and Muirhead (1998) was not fully reflected in a corresponding growth of the economic value of honey bee pollinators.

Australian Department of Agriculture (2014). The final "study" in table 1 is the Australian Department of Agriculture's submission to the Australian Senate Standing Committee Report, *Future of the beekeeping and pollination service industries in Australia* (2014). It would appear the Department of Agriculture presented the estimates of two out-dated studies. They cited Gill's (1989) - $A 605 m estimate and Gordon and Davis (2003) $A 1.726 bn. [11]

[9] Gordon and Davis (2003:5) state that they increased the number of crops to 35 in their study compared with Gill's 25 crops. This would appear to be incorrect as Gill included 35 crops in his original study. Gordon and Davis may have confused Gill's comment, "A total of 25 alternative valuations have been estimated for the relevant ranges of assumed supply and demand elasticities." (1991:32). However, that is not the same as saying 25 agriculture crops were included in the study.
[10] ABS Value of Agricultural Commodities Produced, Australia 1999-2000
[11] This submission did not attribute the source of those estimates, implying the estimated were calculated in-house.

The two estimates were obsolete by between 14 years and 25 years. [12]

3.0 The Economic Model.

Economic Value explained.

The concept of economic value is a misunderstood term. Economic value is not a measure of the dollar costs associated with undertaking bee keeping related business activities such as the cost of replacing queen bees, netting or the cost of replacement hives.

Economists view e*conomic value* differently. It is seen as the maximum price a consumer is willing to pay for a good. This maximum price is not the same as its market price. If a consumer willingly buys a good it means they have placed a higher value on the good than its market price. The difference between the two is called the economic value (or consumer surplus) or the economic externality. [13]

The Partial Equilibrium Model (P.E.M.)

The economic model used to measure *the* economic value of honey bee pollinators is the Partial Equilibrium Model (P.E.M.) [14] which is a sophisticated and complex economic model [15] developed by German economist Carl Wilhelm Launhardt (1885)[16] and subsequently

[12] Australian Government Dept. of Agriculture. 2014. " Inquiry into the Future of the Beekeeping and Pollination Services Industries in Australia. Submission 79."
[13] Natural resources economist's Harris and Roach (2018:617) define economic value as "the value of something derived from people's willingness to pay for it."
[14] An alternate economic model is known as the General Equilibrium Model (GEM). The disadvantage of the GEM estimates is that it neglects to incorporate the all-important honey bee dependency factors into the model thereby distorting the estimates.
[15] The model developed for this study contains in excess of 3,300 variables.
[16] Launhardt, Wilhelm. 1885. Mathematische Begründung Der Volkswirthschaftslehre. W. Engelmann. Chapters 27 and 28. Laundhardt frist applied this method of analysis to measuring impact of changing freight tariffs on German railroads..

popularised by British economist Alfred Marshall (1890) in his *Principles of Economics* textbook. [17] [18] The P.E.M. is the standard analytical "tool" used by economists.

Gill (1989,1990, 1991a, 1991b, 1996) and subsequently Southwick and Southwick [19] (1992) both used the P.E.M. to calculate the economic value of honey bees in Australia and the USA respectively.

The P.E.M. integrates the contribution made by honey bee pollinators (via the individual honey bee dependency factors) along with the farm gate prices of pollinated agriculture crops and the empirically derived price elasticity of demand coefficients for fruit, nuts and vegetables to determine the economic value.

(1) Honey Bee Dependency Factors.

Gill (1989,1990, 1991a, 1991b, 1996) and Southwick and Southwick both integrated [20] the assumption that in the presence of a honey bee pollinators, the supply of agriculture crops would increase, as highlighted in the quote from Franke and Bernanke (2009) on page 1 of this report. Conversely, in the absence of honey bee pollinators due to some form of external supply side shock, such as the presence of the *varroa mite* or due to colony collapse disorder the supply of agriculture crops would be diminished.

[17] Marshall, A (1920) *Principles of Economics. An Introductory Volume* 8th Ed. Book III, Chapter 6, p.78 and footnote 88 p. 519.
[18] The P.E.M. model should be correctly referred to as the Launhardt – Marshall (LM) model.
[19] Southwick, Edward E., and Lawrence Southwick. 1992. "Estimating the Economic Value of Honey Bees (Hymenoptera: Apidae) as Agricultural Pollinators in the United States." *Journal of Economic Entomology* 85 (3): 621-633. doi: 10.1093/jee/85.3.621.
[20] Integral calculus is used to ingrate the data into the economic model. Gordon and Davis (2003) present the complex formulas used on p.30.

Determining the Honey Bee Dependency Factor.

The Partial Equilibrium Model (P.E.M.) incorporates the individual Honey Bee Dependency Factors across all honey bee pollinated agriculture crops. The level of scientific knowledge of insect crop pollination has continued to expand since the 1970's when the two authoritative sources on the subject were British crop scientist, Free (1970, 1993) [21] and on the other side of the Atlantic, American McGregor (1976) whose encyclopediac tome *Insect Pollination of Cultivated Crop Plants* spanned 845 pages became the authoritative insect pollination reference manual used crop scientists. [22]

Ongoing scientific research has necessitated updating the orthodox scientific knowledge base of the role and the contribution made by honey bee pollinators. Entomologists Kevan and Phillips (2001) recognised this by advising of the need to regularly review the knowledge base, stating: "… there is some information on pollination requirements … much of it should be completely re-evaluated because it is dated, anecdotal, and not based on scientific methods." [23]

A Review of the Crop Pollination literature.

A comprehensive review of honey bee crop pollinators was undertaken in this study. The results of that review support Kevan and Phillips' contention of the need to regularly review and update that knowledge base. To highlight this point, both Gill (1989) and Cornell University entomologists, Morse and Calderone (2000) [24] attribute a role played by honey bee pollinators

[21] Free, J.B. 1970 and 1993 Insect Pollination of Crops. Academic Press London and New York.
[22] McGregor's manual spans 849 pages and details the behaviour of insect pollinators dating back to the start of the twentieth century. On the other side of the Atlantic, Free (1970, 1993) *Insect Pollination of Crops*, which was published before McGregor detailed the pollination biology of over 40 individual crops. When the updated second edition appeared, this number was expanded to 63 crops. Neither McGregor (1976) nor Free (1970, 1993) provide any indication of the honey bee dependency factors.
[23] Kevan, Peter G, and Truman P Phillips. 2001. "The Economic Impacts of Pollinator Declines: An Approach to Assessing the Consequences." *Conservation ecology* 5 (1): 11.
[24] Morse, R.A. and Calderone, N.W. 2000. "The Value of Hney Bees as Pollinators of Us Crops in 2000 " (Report Cornell

in the pollination of grapes. But other researchers attribute no role and therefore no corresponding Honey Bee Dependency Factor value.

According to Keogh et al (2010) [25] inconsistent views among natural scientists is not uncommon as "The literature contains conflicting reports on the need for bees…" If the reason for the differing view is due to a lack of updating the knowledge base then, that is a relatively "simple" process to rectify. However, if the issue relates to disagreement among crop scientists where the crop and the time frame are both the identical, then that requires further research.

Another significant problem is the inconsistent scientific view as to what constitutes the actual percentage contribution made by honey bee pollinators to the pollination of the individual crops. Do honey bees account for 20%, 50% or 100% of the pollination requirement for a specific crop? Using the correct percentage contribution made by honey bee pollinators is critical to calculating the Honey Bee Dependency Factor for honey bee pollinated crops. Those Honey Bee Dependency Factors, in turn are required to calculate both the crop value and the economic value of honey bee pollinators. Using outdated pollination requirements will distort the results.

Source of Gill's pollinator data.

In a footnote, Gill (1989)[26] acknowledges using American honey bee pollinator data stating "*All* (emphasis added) estimates of the per cent supply shock were derived from Robinson et al (1989)." Gill's "supply shock" is interpreted to be the honey bee dependency factor.

University NY).

[25] Keogh, RC, PW Anthony, APW Robinson, and IJ Mullins 2010. "Pollination Aware. The Real Value of Pollination in Australia." *RIRDC Publication No 10/081* Rural Industries Research and Development Corporation, Canberra.p.3.

[26] Gill (1989) p.8.

Robinson et al (1989) is more than likely to have sourced their honey bee dependency factors from McGregor (1976).

Australian research since 2000.

Since the year 2000, there have been several Australian studies seeking to measure the economic value of honey bee pollinators – see Table 1. The only research paper to have reviewed the role played by honey bee pollinators as advocated by Kevan and Phillips (2001) was Keogh et al (2010). Unfortunately, their research did not attempt to calculate the economic value of honey bees.

In a footnote to their Table 5.1 Pollination responsiveness of selected crops (as percentage of yield), they say "Source: *Modified* (my emphasis added) from Monck et al 2008." [27] Monck et al (2008) [28] attribute the sources of their *Table 2.1 Honey bee dependence for pollination of selected crops (as percentage of yield)* to both Gill (1989) and "… a personal communication with the Crop Pollination Association." [29] They too, used outdated American data to arrive at an Australian estimated.

In the foreword to Gordon and Davis (2003) [30] they state that "This report was commissioned to update estimates made by Gill in 1989..." however, it would appear with closer examination the report authors reproduced Gill's table on page 6 without amendment, appearing on page

[27] Keogh, RC, PW Anthony, APW Robinson, and IJ Mullins 2010. "Pollination Aware. The Real Value of Pollination in Australia " *RIRDC Publication No 10/081* Rural Industries Research and Development Corporation, Canberra. p.44
[28] Monck, Michael, Jenny Gordon, and Kevin Hanslow. 2008. *Analysis of the Market for Pollination Services in Australia*: Rural Industries Research and Development Corporation. p.14.
[29] See Crop Pollination Association Inc website at: http://www.aussiepollination.com.au/
[30] Gordon, J., and L. Davis. 2003. "Valuing Honey bee Pollination." *RIRDC Publication No 07/077*. p.5.

32 of their paper. Gordon and Davis (2003) did however, change the terminology from Gill's "percent supply shock from removal of bees" to "Change in crop supply, percent." [31]

Honey Bee Dependency Factors used in this Study.[32]

The current study has heeded the advice advocated by Kevan and Phillips (2001) by undertaking a thorough examination and review of all Australian insect pollinator dependent agriculture crops. This three-step task was achieved with the indispensable assistance of Western Australian entomologist Manning (2016).

Using the published ABS "Value of Agricultural Commodities Produced, Australia, 2014-15" the first step was to identify agriculture crops which are insect (honey bee and non-honey bee) pollinator dependent. This review identified 53 honey bee and non-honey bee pollinator dependent agriculture crops. This number greatly exceeds the number of crops used in the Australian studies by both Gill (1989) and Gordon and Davis (2003).

The second step required the identification of those agriculture crops which are specifically honey bee pollinator dependent. And the final step proceeded to allocate a likely percentage contribution made by honey bee pollinators to each agriculture crop.

[31] p.32.

[32] I am greatly indebted to the assistance provided by entomologist Robert Manning, (2016) who assisted in identifying the honey bee pollinated crops and for updating the estimates of the Honey Bee Dependency Factors.

Deriving the Honey Bee Dependency Factor.

Table 2 shows the determination of the all-important Honey Bee Dependency Factor (HBDF) for beans. Ten percent of beans are pollinated by insects and 90% by non-insects. Of that 10%, 20% of the bean crop is honey bee pollinated. Multiplying columns 1 and 2 gives results in the honey bee dependency factor of 0.02.

Table 2: Calculating the Honey Bee Dependency Factor

Crop	Percent Pollinated by Insects (1)	Percent of Pollinators that are Honey bees (2)	Honey Bee Dependency Factor (3) = (1) *(2)
Beans	0.10	0.20	0.02

Crop Value of Honey Bee Pollinators.

The crop value of Honey Bee pollinators requires the calculation of Honey Bee Dependency Factors for all pollinated crops which is then aggregated. This measure has become the "defacto" measure of economic value as used by entomologists.

Crop Value used as the defacto measure of "economic value."

Thomson (2007) [33] in her oral submisson to the House of Representatives *Inquiry into the future development of the Australian honey bee industry* (Australian House of Representatives 2008) [34] referred to the crop value of production by informing the Committee, "… it is estimated that honey bees contribute directly to between $4 billion and $6 billion worth of agricultural production."

[33] Thomson, Margie 2007. "Transcript of Evidence."
[34] Australian House of Representatives. 2008. *More Than Honey: The Future of the Australian Honey Bee and Pollination Industries: Report of the Inquiry into the Future Development of the Australian Honey Bee Industry*. Canberra. p. 23.

The same "between $4 billion and $6 billion worth of agriculture production" subsequently appeared in the submission made by the Australian Honey Bee Industry Council Inc (2012) [35] to the Australian Department of Agriculture, Fisheries and Forestry (2012), most likely citing Gordon and Davis (2003) who used year 2000 ABS data.

A recent example of this crop value of honey bee pollination appears in the paper prepared for the Rural Industries Research and Development Corporation paper by Dawes and Dall (2014):

> "In 2011-12 the Australian honey industry had a gross value of honey and beeswax production of $79 million which was forecast to rise to $88 million in 2012-13 and $92 million in 2013-14 (ABARES, 2013). *Furthermore, it has been estimated that the industry contributes directly to between $4 billion and $6 billion worth of agricultural production"* (my emphasis added). [36]

The italicised part of the above quote implies the "$4 billion and $6 billion" range is a 2011-2012 estimate appears to be have been sourced from Gordon and Davis (2003).

From time to time, similar crop value estimates appear in the wider media (Nightingale 2012; Halter 2014) citing the crop value but this is not the economic value.

Crop Value of Australian Honey Bee Pollinators, 2014 – 2015.

This study estimates the crop value of Australian honey bee pollinators in 2014 – 2015 is $A 3.85 bn.

This estimate is at the lower end of the range $A 4 bn to $A6 bn mentioned by industry commentators and stakeholders. This estimate will also change from year to year and hence the importance of regularly revising this figure.

[35] Australian Honey Bee Industry Council Inc (2012) p.1
[36] Dawes, J and, and D Dall 2014. "Value-Adding to Honey." p. 11.

Crop Value of Australian Non - Honey Bee Pollinators, 2014 – 2015.

The crop value of Non-Honey Bee Pollinators, that is, all other pollinators [37] is estimated to be $A 5.94 bn.

Total Crop Value of Australian Pollinators, 201 4 – 2015.

This study estimates the total crop value of all pollinators (honey bee and non-honey bee pollinators) in 2014 – 2015 is $A 9.79 bn.

(2) The Price Elasticity of Demand Coefficient.

The next variable included in the P.E.M. model is the own price elasticity of demand coefficient. This coefficient determines the shape of the demand curve for individual goods, whether it's the demand for specific agriculture produce or the demand for air travel. Settling on the correct value of the coefficient presented substantial methodological difficulty for both Gill (1989) and Gordon and Davis (2003).

Gill (1991) identified five different own price elasticity of demand coefficients to model the 25 different economic valuations of honey bee pollinators in Table 2. [38] He subsequently selected two coefficients based on what he called "subjective countenance" (or professional judgement). Gill settled on two price elasticity of demand coefficients of -0.5 and 2.0, which he used to calculate the "… social value of pollination will be between $1.209.7 billion (rounded to $A 1.21 bn) and $604.8 million ($A 605 m)." [39]

[37] Non-Honey Bee pollination agents include in alphabetic order: Ants, Artificial (electronic wands), Bats, Beetles, Blowflies, Birds, Butterflies, Flies, Hawkmoths, Hoverflies, Humans (in parts of China and the Himalayan region), Maggots, Moths, Thrips, Other mammals, Water and Wind.
[38] Gill (1991) p.32.
[39] Gill (1991) p.34

It is not entirely clear where Gill sourced his elasticity coefficients but one assumes it was derived from the work of American's Houthakker and Taylor (1970) with the coefficients relating to US. [40]

Gordon and Davis (2003) incorporated a very different set of coefficients based on *Armington* and export demand elasticities [41] to estimate their economic value.

Table 3 details the price elasticity coefficients used by both Gill (1989) and Gordon and Davis (2003) to measure the economic value of honey bee pollinators in Australia.

Table 3: Price Elasticity of Demand Coefficients.

Researchers	Price Elasticity of Demand Coefficients
Gill (1989)	"… an approximation of five crops used for the complete set" (1991:34), -0.5 and 2.0
Gordon and Davis (2003) "Standard" Table B.2. p. 35.	Individual price elasticity of demand ranged between -2.0 and -2.50.
Gordon and Davis (2003) "High" p. 21	-5.0

Source: Various sources as shown.

Gordon and Davis (2003) also included two distinct sets of price elasticity of demand coefficients, to cover two different scenarios, one a "standard" scenario where the price elasticities ranged between -2.0 and -2.5 and the other, a "high" option with a price elasticity coefficient of -5.0. Both coefficients seem to be exceptionally high implying agriculture crops are luxury items with sizeable number of substitutes. This conclusion is contrary to conventional economic theory.

[40] Houthakker and Lester D Taylor. 1970. "Consumer Demand in the United States." Cambridge: Harvard University Press.
[41] Gordon and Davis (2003) p. 35.

The Price Elasticity of Demand Coefficient used in this study.

The price elasticity of demand coefficients used in this study is sourced from the recently published empirical study conducted by Deakin University researchers, Ulubasoglu et al (2010 and 2016) into Australian Food Demand Elasticities.

Using the ABS Australian Household Expenditure Survey (HES) data for the period between 1998/99 and 2003/04 they estimated own price elasticities for a wide range of food items including fresh and preserved fruit and fresh and preserved vegetables.

Ulubasoglu et al (2010 and 2016) state "Fresh fruit is estimated to have … an elasticity … of -1.049 … the demand for fresh vegetables is (price) inelastic … -0.053." [42]

[42] Ulubasoglu, Mehmet, Debdulal Mallick, Mokhtarul Wadud, Phillip Hone, and Henry Haszler. 2010. "Food Demand Elasticities for Australia."p.8.

4.0 Results and Discussion.

The Economic Value of Honey Bee Pollinators, Australia, States and Territories, 2014-2015.

Whereas both Gill (1989) and Gordon and Davis (2003 presented a single economic value for Australia, this research differs by presenting the economic values for the states, territories and in one instance, for one of the 87 ABS designated regions across Australia. The estimates of the economic values are detailed in Table 4 below.

Australia wide, the economic value of honey bees is calculated to lie between $ A 8.35 bn and $ A 19.97 bn based on the two empirical price elasticities of demand coefficients for fresh fruit and fresh vegetables used in this study. The arithmetic average economic value of honey bee insect pollinators is $A 14.2 bn in the 2015 financial year.

Table 4: The Economic Value of Honey Bee Pollinators – Australia, State and Territory 2014-2015.

	Range of Economic Value of Honey Bee Pollinators $A		**Average Economic Value $A**
Price Elasticity of Demand	-0.526	-1.049	
State and Territory			
New South Wales	3,307,982,349	1,653,178,534	2,480,580,442
Victoria	8,955,816,737	3,212,543,473	6,084,180,105
Queensland	2,890,829,333	1,349,813,889	2,120,321,611
South Australia	2,449,690,987	961,198,221	1,705,444,604
Western Australia	1,413,989,729	809,391,430	1,111,690,580
Tasmania	338,338,020	197,172,542	267,755,281
Northern Territory	614,494,955	162,304,330	388,399,643
A.C.T.	1,208,585	989,264	1,098,925
Australia – Total	**19,972,350,695**	**8,346,591,683**	**14,159,471,189**

These estimates demonstrate the significant contribution made by managed and wild honey bee honey bee pollinators across Australia.

The disparity in the economic values between the state and territories is explained by composition of agriculture crops grown across the states and territories, the volume of annual production and the prevailing farm gate price of agriculture crops in 2014 - 2015.

The agriculture industries in both the Northern Territory and the Australian Capital Territory are relatively small by comparison to other locations in Australia and are characterised by smaller or even non-existent honey bee pollination crops.

Not surprisingly, the economic valuation shown in table 4 exceeds the previous economic valuations reported by both Gill (1989) and Gordon and Davis (2003). There are many plausible reasons accounting for the differences including:

i. the number of agriculture crops included in the study, Gill (1989) used 25 crops, Gordon and Davis (2003) used 35 crops compared with 53 crops in the current study,
ii. the critical role played by updated Honey Bee Dependency Factors (HBF),
iii. the choice of the demand price elasticity coefficient,
iv. changing farming practices between the studies over the past 30 years,
v. the introduction of new agriculture crops in the intervening years, [43]
vi. the important impact of climate variability (El Niño and La Niña) on crop yields between the studies,
vii. the significant role played by continuing improvement in the level of scientific knowledge spanning the multitude of natural sciences which benefits agriculture farming,

[43] The introduction of new agriculture crops includes crops such as Chia in the Ord River region of WA. *See* Edwards (2015) and Dumas (2015)

viii. the growth in agricultural productivity over the past three decades which "… (has) underpinned by advances in technology." [44]

ix. the promotion of new farming techniques by farm industry experts and research scientists contributing to improved crop yields over the past 30 years,

x. The availability and the depth of the data collected by the ABS over the course of the various studies,

xi. Impact brought about by global macroeconomic factors impacting Australian agriculture markets.

xii. Impact of microeconomic reforms to the Australian agriculture industry which has made it more internationally competitive.

[44] Australian House of Representatives, Inquiry into Agricultural Innovation (2016:11).

Economic Value of the Strawberry industry in the Avon region.

Table 5 presents the economic value of Western Australia's Avon region strawberries. The Avon region's strawberry industry is a very important regional industry having a substantial economic value ranging between $A 4.7 m and $A 5.6 m. It also accounts for one quarter of the WA strawberry industry.

Table 5: The Economic Value of Strawberry crop in the WA Avon Region, 2014-2015.

Location	**Economic Value of Honey Bee Pollinators $A**		**Average Economic Value $A**
Price Elasticity of Demand	-0.526	-1.049	
Australia	146,563,470	126,756,234	136,659,852
Western Australia	22,175,701	18,517,608	20,346,655
Avon Valley, WA	5,570,305	4,651,430	5,110,868

By comparison, the strawberry industry's national economic value lies in a range between $A 126.8 m and $A 146.6 m, while at the state level, the economic value is approximately 14.6% the national industry ($A 18.5 m and $A 22.2 m).

5.0 Conclusion.

The principle objective of this paper was to measure the economic value of Australian managed and wild honey bee pollinators using the most recent data which was achieved by using the Partial Equilibrium Model (P.E.M.).

This study comprehensively reviewed the honey bee dependent agriculture crops which resulted in a total of 53 agriculture crops being included in the P.E.M. which far exceeds the number of crops included in previous studies. Updated honey bee dependency factors based on current scientific knowledge were assigned to those crops.

The two previous studies published in 1989 and 2003 calculated a single Australian wide economic value; this study presented the economic values for Australia as well as the states and territories. It has also calculated for the first time, the economic value of honey bee pollinators for a single agriculture crop (strawberries) at one of the 87 ABS designated Australian regionals, the Avon region in WA to demonstrate the power of the P.E.M.

Two significant by-products of this research, which are the subject of future papers, is the calculation of the economic value of Non-Honey Bee pollinators for Australia, the states and territories. As well as the calculation of the economic value of *all* Australian Crop Pollinators for Australia, the states and territories.

The results of the present research confirm the view expressed eighty-five years ago by Voorhies et al (1933) that the economic value of Australian honey bee pollinators *is* indeed far greater than the industry's gross value of production.

Appendix One: The Australian Honey Bee Industry in 2014 – 2015.

In 2014 the Australian honey bee industry comprised over 12,414 registered beekeepers and 528,031 hives producing between 25,000 and 30,000 tonnes of honey annually [45]. The industry exported $A 1.751 bn of honey in 2014-15, ranking honey exports, (grouped with sugars and molasses) the twenty-fourth largest Australian export income earner. [46]

According to the *2016 ABARES Australian Honey Bee Industry Survey*, the gross value of Australian production is estimated at $101m in 2014-2015. [47]

The Australian honey bee industry is dominated by New South Wales, Queensland and Victoria who between them have over 10,248 registered beekeepers accounting for 80% of the nation's hives. The Northern Territory has 46 registered beekeepers and 2,295 hives, while Western Australia has 1,080 registered beekeepers and 28,500 hives.

In 2014, 102,000 hives were used for paid pollination and up to another 100,000 hives provide pollination services on a mutually beneficial basis. Nearly 370,000 hives are owned by commercial and profitable apiarists who operate between 400 – 800 hives. [48] [49]

ABARES' survey found that 85% of beekeeper income in 2014 – 15 is derived from honey sales. Paid pollination services were provided by 44% of beekeepers.

[45] Australian, Honey Bee Industry Council Inc (2014:4), Submission to Senate Inquiry on The Future of the beekeeping and pollination services industries in Australia.
[46] DFAT (2016) Composition of Trade 2015-16, see Table 27 p.60.
[47] ABARES. 2016. Combing through the Honey Bee Industry ABARES. Accessed 5 January 2017, http://www.agriculture.gov.au/abares/media-releases/2016/combing-through-honey-bee-industry (ABARES 2016)
[48] RIRDC Honey Bee and Pollination.
[49] ABARES' survey identified the profitable scale of operation is more than 200 hives.

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