PATENTS AND GENDER: A BIG DATA ANALYSIS OF 15 YEARS OF AUSTRALIAN PATENT APPLICATIONS

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Recent recommended changes to Australia's patent laws could narrow the scope of patentable inventions. We argue this could have a comparatively bigger impact on female inventors who we find clustered in the life sciences. We examine 309,544 patent applications filed with IP Australia (the majority from international applicants) across a 15-year period (2001–15) and attribute a gender to 941,516 inventor names. Only 23.6% of patent applications in this dataset include at least 1 female inventor. The average overall success rate irrespective of gender was 75.0%, but the odds of success increased with increasing numbers of male inventors on a team. The addition of female inventors to a team did not have the same effect. We propose that the gender disparity could arise from implicit gender effects (examiner or patentee) during patent prosecution.

I INTRODUCTION

For the past two decades, successive Australian[1] and overseas[2] governments have sought to increase the participation of women in fields of science, technology,

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1 'Women in STEM Decadal Plan', *Australian Academy of Science* (Web Page, April 2019) <http://www.science.org.au/womeninSTEMplan> ('Women in STEM'); Department of Industry, Science, Energy and Resources, 'Advancing Women in STEM Strategy: 2020 Action Plan', *Australian Government* (Web Page, 2020) <https://www.industry.gov.au/data-and-publications/advancing-women-in-stem-strategy/2020-action-plan> ('2020 Action Plan'). See also 'About Us', *SAGE* (Web Page, 2020) <https://sciencegenderequity.org.au/about/>.

2 See, eg, Willie Pearson, Lisa M Frehill and Connie L McNeely (eds), *Advancing Women in Science: An International Perspective* (Springer, 2015) <https://doi.org/10.1007/978-3-319-08629-3>. See also Intellectual Property Office (UK), *Gender Profiles in Worldwide Patenting: An Analysis of Female*

engineering and mathematics ('STEM').[3] One reason for this is the promotion of social equality;[4] another anticipates that STEM-based innovation and labour will be a key driver of future economic growth.[5] A measure of the outputs of these policies is female participation in the patents system as an inventor.[6] Patents are a well-known measure of the output of STEM-based industries[7] and are seen as indicators of success in research and development.[8]

Historically, investigating female patenting was difficult because patent data would need to be retrieved one application at a time, making research into aggregate trends extremely costly. More importantly, gender is not a required disclosure when applying for a patent.[9] Fortunately, owing to advances in computing technology[10] and government open data policies,[11] there have been significant improvements in large-scale analyses of patent data.[12] In both the United States ('US') and Europe, big data analyses[13] of patent data[14] are being used as a 'good source of evidence to inform the wider gender debate', and 'provide a sound basis for evidence-based policy within government and industry'.[15] To our knowledge, this is the first study to use big data analysis on patents to be published in Australian legal scholarship.[16]

Inventorship (2019 Edition) (Report, September 2019) 5 ('*Gender Profiles in Worldwide Patenting*'); UNESCO Bangkok Office, *STEM Education for Girls and Women: Breaking Barriers and Exploring Gender Inequality in Asia* (Report, 9 December 2020) ('*STEM Education for Girls and Women*').

3 Department of Industry, Science, Energy and Resources, *STEM Equity Monitor* (Summary Report, 2020) 5.

4 Denise Cuthbert and Leul Tadesse Sidelil, 'Gender Equity Instrumentalism and (Re)Building the Nation through Innovation: Critical Reflections on Women in STEM Policy in Australia' in Deane E Neubauer and Surinderpal Kaur (eds), *Gender and the Changing Face of Higher Education in Asia Pacific* (Palgrave Macmillan, 2019) 57, 58 <https://doi.org/10.1007/978-3-030-02795-7>.

5 Department of Industry, Innovation and Science, *Advancing Women in STEM* (Report, 2019) 1.

6 *Gender Profiles in Worldwide Patenting* (n 2) 26.

7 Ibid.

8 IP Australia, *Australian Intellectual Property Report 2021* (Report, 2021) ch 2 <https://www.ipaustralia.gov.au/ip-report-2021/chapter-2-patents> ('*Report 2021*').

9 *Gender Profiles in Worldwide Patenting* (n 2) 26.

10 See generally Raghavendra Kune et al, 'The Anatomy of Big Data Computing' (2016) 46(1) *Software: Practice and Experience* 79 <https://doi.org/10.1002/spe.2374>.

11 IP Australia, 'IP Government Open Data', *Australian Government* (Web Page, 29 April 2021) <https://www.ipaustralia.gov.au/about-us/research-and-data/ip-government-open-data>. Similar initiatives operate in the United States ('US'): Samantha Grassle, 'Open Patent Data: A Report on the Roundtable with the US Patent and Trademark Office (USPTO)', *THEGOVLAB* (Blog Post, 20 April 2015) <https://blog.thegovlab.org/post/od500-the-u-s-patent-and-trademark-office-uspto>.

12 United States Patent and Trademark Office, 'Why USPTO Open Data?', *USPTO* (Web Page, 21 April 2021) <https://developer.uspto.gov/about-open-data>.

13 Big data refers to a 'massive amount of information in different data formats': Chloé Margulis, 'The Application of Big Data Analytics to Patent Litigation' (2017) 99(2) *Journal of the Patent and Trademark Office Society* 305, 308.

14 'Open data' is big data 'that is structured in a way that enables the data to be fully discoverable and usable by end users': 'Why USPTO Open Data?' (n 12).

15 *Gender Profiles in Worldwide Patenting* (n 2) 26.

16 See generally Arho Suominen and Arash Hajikhani, 'Research Themes in Big Data Analytics for Policymaking: Insights from a Mixed-Methods Systematic Literature Review' (2021) 13(4) *Policy and Internet* 464 <https://doi.org/10.1002/poi3.258>. For cautionary perspectives, see Caryn Devins et al, 'The Law and Big Data' (2017) 27(2) *Cornell Journal of Law and Public Policy* 357.

There is some evidence that Australian patent applications with female inventors have increased over the past 30 years.[17] This mirrors international trends found by the World Intellectual Property Organization ('WIPO')[18] and the United Kingdom Intellectual Property Office ('UKIPO').[19] Note that international trends are relevant because the majority of patent applications to IP Australia[20] come from overseas (particularly from the US)[21] via the *Patent Cooperation Treaty* ('*PCT*')[22] (note that close to half of Australian resident filings also come via the *PCT*).[23] These studies show that worldwide, participation of female inventors in the patent system (while still lower than that of men) has grown significantly over the past 20 years.[24]

Although applications have increased, it is unclear whether women are as successful as men in proceeding to patent grant. Studies of United States Patent and Trademark Office ('USPTO') data reveal that inventors with a female forename are less successful at having their patent granted than inventors with a male forename.[25] In a widely reported study, Jensen, Kovács and Sorenson analysed 2.7 million US patent applications (2001–14) and found that women had a much lower probability of proceeding to grant than men did.[26] In addition, the researchers found that once granted, women inventors had 'a smaller fraction of their claims allowed'[27] and 'had more words added during prosecution, thus reducing their scope and value'.[28] The researchers attributed most of the gender disparity to examiner-side bias and suggested examination become 'more "blind" to the identity of participants'.[29]

17 IP Australia, 'Australia Is Closing the Gender Gap on Female Inventors', *Australian Government* (Web Page, 8 March 2018) <https://www.ipaustralia.gov.au/about-us/news-and-community/news/australia-closing-gender-gap-female-inventors>.

18 Gema Lax Martinez, Julio Raffo and Kaori Saito, 'Identifying the Gender of PCT Inventors' (Working Paper No 33, Economics and Statistics Series, World Intellectual Property Organization, November 2016) 8.

19 *Gender Profiles in Worldwide Patenting* (n 2) 26.

20 See IP Australia, 'About Us', *Australian Government* (Web Page) <https://www.ipaustralia.gov.au/about-us>.

21 Of all standard patent applications in 2020, 92% (a total of 26,894) of all standard patent applications were filed by nonresidents. In 2020, the top 5 foreign countries of origin for standard patent applications were the US (13,122 applications), China (2,358), Japan (1,643), Germany (1,344) and the United Kingdom (1,253). These countries accounted for 67% of patent applications in Australia in 2020. Australian residents were named on 8% (2,399 applications): IP Australia, *Report 2021* (n 8) ch 2.

22 As an example, in 2020, IP Australia received 29,293 standard patent applications, with approximately 72% processed under the *Patent Cooperation Treaty* ('*PCT*') as opposed to direct filing: IP Australia, *Report 2021* (n 8) ch 2. Note that *PCT*-filed patent applications are assessed via national laws when they enter the 'national phase' of examination: see Sam Ricketson et al, *Intellectual Property: Cases, Materials and Commentary* (LexisNexis Butterworths, 6th ed, 2019) 971.

23 See, eg, 'Statistical Country Profiles: Australia', *WIPO* (Web Page, March 2021) <https://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=AU>. WIPO reveals that in 2020 in relation to *PCT* National Phase Entry applications, 1,100 applications came from Australian residents and 20,025 came from nonresidents.

24 Martinez, Raffo and Saito (n 18) 8.

25 Kyle Jensen, Balázs Kovács and Olav Sorenson, 'Gender Differences in Obtaining and Maintaining Patent Rights' (2018) 36(4) *Nature Biotechnology* 307, 309 <https://doi.org/10.1038/nbt.4120>.

26 Ibid.

27 Ibid 307.

28 Ibid.

29 Ibid 309.

It is critical to understand whether patent examination at IP Australia suffers from this type of gender bias. This need is particularly acute because the Australian Government,[30] on recommendations from the Productivity Commission (the 'Commission'),[31] is passing legislation to change Australia's patent laws. These changes are intended to make it more difficult to obtain a patent,[32] and we argue these changes could have a differential impact on female inventors.

The background to this article is set out in Part II, which describes recent changes to Australian patent law and the extant literature on women and patenting that was ignored during the law reform process. Part II(B) reviews studies of gender and patents in other jurisdictions that we use to frame our hypotheses. Part III describes our methodology. This is followed by Part IV, 'Results', and Part V, 'Discussion', which explores our results and discusses limitations. Finally, in Part VI, 'Conclusion', we discuss the implications of our findings and areas for future research.

II BACKGROUND

A The Australian Patent System

1 What Is a Patent?

In Australia, under the *Patents Act 1990* (Cth) (the '*Act*'), a standard patent confers a 20-year exclusive right to exploit an invention and protect it from unauthorised use by third parties.[33] In exchange for this limited legal monopoly,[34] the patent owner discloses the workings of the invention by submitting a patent specification into the public domain. In this way, patents are said to stimulate collective benefits by enabling others to build upon innovative knowledge,[35] while the monopoly rights provide some 'incentives for firms and individuals to develop and commercialise innovations'.[36] Innovation can and does occur in the absence of patents.[37] However,

30 Department of Industry, Innovation and Science, 'Australian Government Response to the Productivity Commission Inquiry into Intellectual Property Arrangements' (Response Paper, August 2017) ('Government Response to the Productivity Commission').

31 Productivity Commission, *Intellectual Property Arrangements* (Inquiry Report No 78, 23 September 2016).

32 The Productivity Commission (the 'Commission') believes that 'a significant percentage of Australian patents are of relatively low value': ibid 201.

33 *Patents Act 1990* (Cth) ss 13, 67.

34 'A legal monopoly is not necessarily an economic monopoly; if close substitutes exist for a patented product, the patent may confer little power over price': Richard A Posner, 'Intellectual Property: The Law and Economics Approach' (2005) 19(2) *Journal of Economic Perspectives* 57, 68 <https://doi.org/10.1257/0895330054048704>. See also *Calidad Pty Ltd v Seiko Epson Corporation* (2020) 94 ALJR 1044. Kiefel CJ, Bell and Keane JJ held that 'the monopoly rights given by statute do not confer a "positive authority" on a patentee. The rights granted are better understood as negative in nature, a right to exclude others from exploiting the patent. This is what the exclusive or monopoly rights granted by statute are and no more': at 1064 [85] (citations omitted). For further discussion of the scope of the monopoly, see 1075–9 [152]–[166] (Nettle, Gordon and Edelman JJ).

35 *Intellectual Property Arrangements* (n 31) 199–200.

36 Ibid.

37 Ibid 635.

patents are critical and often lucrative in fields where there are large sunk costs (eg, due to research and development) and where invention is 'relatively easy to imitate, such as [in] pharmaceuticals, biotechnology and machinery'.[38]

Once an application is submitted, the applicant can request an examination and pay the relevant fees. A patent examiner from IP Australia will then assess the application according to the tests for legal validity. These include whether the invention is a 'manner of manufacture', is 'useful', and – when compared with the prior art base – is 'novel' and involves an 'inventive step'.[39] The boundaries of these rules are often tested in case law, but generally a patentable invention will be new, inventive, be of the useful arts and be the product of 'human action'.[40] Typically excluded from patentability are the fine arts, mere discoveries and mere schemes.[41]

For the successful applicant, patents provide recognition for inventive skill and labour, as well as the exclusive right to exploit the patent for a limited time.[42] At its simplest, a patent serves to protect the invention against unauthorised copying.[43] However, in addition to this utilitarian function, a patent signals value in the information disclosed by the patent[44] and heralds expertise on the part of the inventor. For many in both industry and academy, a patent is a career milestone, which is important for professional advancement and access to government grants. For example, in Australia, significant government incentives exist to patent and commercialise both university research[45] and innovation from industry.[46]

From a market perspective, a patent also serves an important economic function as an asset or security.[47] For example, patent ownership 'lowers barriers to market entry' by 'enabling firms that possess only intangible assets to enter' the innovation supply chain.[48] Patents also increase 'the salvage value of failed firms'.[49] For small to medium enterprises that dominate the Australian economy, patents are important in attracting the necessary strategic alliances for commercialisation and marketing.[50] A survey of Australian inventors estimates that the presence of

38 Ibid 204.
39 *Patents Act 1990* (Cth) s 18(1).
40 *National Research Development Corporation v Commissioner of Patents* (1959) 102 CLR 252, 276–7 (Dixon CJ, Kitto and Windeyer JJ) ('*NRDC*'), cited in *D'Arcy v Myriad Genetics Inc* (2015) 258 CLR 334, 339–40 [6] (French CJ, Kiefel, Bell and Keane JJ) ('*D'Arcy*').
41 IP Australia, '2.9.2.1 Legal Principles', *Patent Manual of Practice and Procedure* (Web Page, 13 December 2021) <https://manuals.ipaustralia.gov.au/patent/2.9.2.1-legal-principles>.
42 *Patents Act 1990* (Cth) s 13.
43 Ibid. See also sch 1 (definition of 'exploit').
44 Clarisa Long, 'Patent Signals' (2002) 69(2) *University of Chicago Law Review* 625 <https://doi.org/10.2307/1600501>.
45 See, eg, Department of Education, Skills and Employment, 'University Research Commercialisation Package', *Australian Government* (Web Page, 2 February 2022) <https://www.dese.gov.au/university-research-commercialisation-package>.
46 See, eg, 'Projects', *AMGC* (Web Page) <https://www.amgc.org.au/projects/>.
47 Hyo Yoon Kang, 'Patent as Credit: When Intellectual Property Becomes Speculative' (2015) 194 (November/December) *Radical Philosophy* 29, 30.
48 *Intellectual Property Arrangements* (n 31) 200.
49 Ibid.
50 Paul H Jensen and Elizabeth Webster, 'Firm Size and the Use of Intellectual Property Rights' (2006) 82(256) *Economic Record* 44, 54 <https://doi.org/10.1111/j.1475-4932.2006.00292.x>.

a patent increases the return to an invention by around 40 to 50% irrespective of how value is defined.[51] Kang has argued that patents can act as investment vehicles in more speculative contexts such as 'patent portfolios, financial valuations, and market hedges'.[52] In other words, beyond the utilitarian function of the patent as instrument, the grant of a patent as an asset can provide access to critical strategic alliances and capital markets.

2 Recent Law Reform

The balance between patent monopoly holders and the interests of the public is often reviewed and recalibrated.[53] The most recent large scale review was the 2016 report of the Commission, which found 'Australia's patent system remains tipped in favour of rights holders and against the interests of the broader community.'[54] The Commission was particularly concerned with Australia's 'multitude of low-value patents',[55] which were seen to 'frustrate follow-on innovators and researchers who are forced to invest in costly workarounds'.[56]

To strike a better balance and 'shield the system against further expansion in the scope and strength of rights',[57] the Commission recommended a suite of reforms including: inserting a statutory objects clause; reforming the test for inventive step; and abolishing Australia's second tier innovation patent system.[58] These initiatives will ostensibly make it more difficult to secure a patent (particularly those deemed 'low-value') and reduce Australia's acceptance rate to the levels observed in Europe.[59] Of these, in 2020 the government enacted legislation to introduce an objects clause, and agreed to phase out the innovation patents system from 26 August 2021.[60]

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51 Paul H Jensen, Russell Thomson and Jongsay Yong, 'Estimating the Patent Premium: Evidence from the Australian Inventor Survey' (2011) 32(10) *Strategic Management Journal* 1128, 1137 <https://doi.org/10.1002/smj.925>.

52 Hyo Yoon Kang, 'Patents as Assets: Intellectual Property Rights as Market Subjects and Objects' in Kean Birch and Fabian Muniesa (eds), *Assetization: Turning Things into Assets in Technoscientific Capitalism* (MIT Press, 2020) 45, 52 <https://doi.org/10.7551/mitpress/12075.003.0004>.

53 Ricketson et al (n 22) 658–9, summarising the numerous reviews since the *Patents Act 1952* (Cth).

54 *Intellectual Property Arrangements* (n 31) 13. For a critical review of the patent law aspects of the report, see Jane Nielsen and Dianne Nicol, 'Patent Law and the March of Technology: Did the Productivity Commission Get It Right?' (2017) 28(1) *Australian Intellectual Property Journal* 4.

55 *Intellectual Property Arrangements* (n 31) 13, 200, 205, 239, 252.

56 Ibid 13.

57 Ibid 218.

58 Ibid 219, 228. See recommendations 7.1 and 7.2.

59 Ibid 228.

60 'Government Response to the Productivity Commission' (n 30) 8, 10; *Patents Act 1990* (Cth) s 2A, objects clause assented to 26 February 2020. See also *Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Act 2020* (Cth) sch 1 ('*Intellectual Property Laws Amendment Act*').

3 The Objects Clause

Public scrutiny of the 'objectives' of the *Act* arguably stem from concerns over gene patents and related health technologies at the turn of the century.[61] In 2010, the then Advisory Council on Intellectual Property ('ACIP') proposed the introduction of an objects clause to the *Act*.[62] The ACIP stated that the objects clause and other recommendations were in response to the '[r]ecent debate … on the patenting of genetic materials, computer software and business methods' and the concern 'that undesirable, unethical or offensive inventions can be patented'.[63]

While the government accepted the recommendation for an objects clause in 2011,[64] agreement on the wording of the clause was fraught and public consultations on the wording failed to provide consensus.[65] In 2014, New Zealand passed new patents legislation with a 'purpose clause' which was culturally sensitive and non-prescriptive.[66] Nevertheless, when the Commission re-agitated the issue of an objects clause in 2016, it was drafted to reflect the more prescriptive wording found in article 7 of the *Agreement on Trade-Related Aspects of Intellectual Property Rights* ('*TRIPS*').[67] Again, there were many vigorous objections to the wording of the objects clause, but after various reviews and redrafts,[68] the objects clause was introduced on 26 February 2020 as:

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61 See, eg, Australian Law Reform Commission, *Essentially Yours: The Protection of Human Genetic Information in Australia* (Report No 96, 28 March 2003). See also Australian Law Reform Commission, *Genes and Ingenuity: Gene Patenting and Human Health* (Report No 99, 29 June 2004) ('*Genes and Ingenuity*').

62 Advisory Council on Intellectual Property, *Patentable Subject Matter* (Final Report, December 2010) 5 ('*Patentable Subject Matter*').

63 Ibid 1.

64 IP Australia, 'Government Response: Patentable Subject Matter', *Australian Government* (Web Page, 21 April 2016) <https://www.ipaustralia.gov.au/about-us/public-consultations/archive-ip-reviews/ip-reviews/government-patentable-subject>.

65 See IP Australia, 'Consultation on Proposed Objects Clause and Patentability Exclusion', *Australian Government* (Web Page, 2013) <https://www.ipaustralia.gov.au/about-us/public-consultations/archived-public-consultations/consultation-proposed-objects-clause-and-patentability-exclusion>.

66 *Patents Act 2013* (NZ) s 3:

> The purposes of this act are to
>
> (a) provide an efficient and effective patent system that
>
> (i) promotes innovation and economic growth while providing an appropriate balance between the interests of inventors and patent owners and the interests of society as a whole; and
>
> (ii) complies with New Zealand's international obligation.

67 *Marrakesh Agreement Establishing the World Trade Organization*, opened for signature 15 April 1994, 1867 UNTS 3 (entered into force 1 January 1995) annex 1C ('*Agreement on Trade-Related Aspects of Intellectual Property Rights as Amended by the 2005 Protocol Amending the TRIPS Agreement*') art 7 ('*TRIPS Agreement*').

68 Senate Standing Committees on Economics, 'Submissions to the Inquiry into the Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2019', *Parliament of Australia* (Web Page, 15 August 2019) <https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Economics/ProductivityCommission/Submissions>. Submissions closed on 15 August 2019. For responses to the public consultation questions, see also IP Australia, 'IP Australia Public Consultation Submissions: 2018', *Australian Government* (Web Page, 7 August 2020) <https://ipaustralia.libguides.com/c.php?g=404687&p=6100348#s-lg-box-wrapper-23338113>.

> The object of this *Act* is to provide a patent system in Australia that promotes economic wellbeing through *technological innovation* and the transfer and dissemination of technology. In doing so, the patent system balances over time the interests of producers, owners and users of technology and the public.[69]

The pairing of the qualifier 'technological' with 'innovation' was of significant concern to patent attorneys,[70] lawyers,[71] universities,[72] and industry.[73] This is because Australian law has been notorious for its flexible definition of a patentable invention.[74] Under section 18(1)(a) of the *Patents Act 1990* (Cth), the definition of patentable subject matter is 'a manner of manufacture within the meaning of section 6 of the *Statute of Monopolies*'. The *Statute of Monopolies* dates back to 1624[75] and requires the invention be 'not contrary to the Law, nor mischievous to the State … or generally inconvenient…'.[76] The manner of manufacture test, although circular and nebulous, has received praise for allowing the 'development of a broad, open-ended and policy-orientated approach to the concept of invention that has generally been capable of meeting new technological and scientific developments as they have arisen.'[77]

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69 *Intellectual Property Laws Amendment Act* (n 60) s 2A (emphasis added).

70 Institute of Patent and Trade Mark Attorneys of Australia, Submission No 50 to Senate Standing Committees on Economics, Parliament of Australia, *Inquiry into the Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2019* (15 August 2019) 8–9 ('IPTA Submission'):

> The chief advocate for the introduction of an object clause into the *Patent Act* is the economist, Dr Hazel Moir. … Seemingly, on the basis of Dr Moir's submission, the Productivity Commission amended the proposed object clause to include the term 'technological innovation'. This strongly suggests that the intended purpose of the object clause, or at least the purpose intended by the Productivity Commission, is to restrict at least patent eligible subject matter in Australia.

'In summary, while IPTA does not agree that an object clause is required, if such a clause must be inserted into the *Patents Act 1990*, then we strongly urge that the word "technological" be deleted': at 10.

71 Davies Collison Cave, Submission No 37 to Senate Standing Committees on Economics, Parliament of Australia, *Inquiry into the Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2019* (15 August 2019).

72 Macquarie University, Submission No 22 to Senate Standing Committees on Economics, Parliament of Australia, *Inquiry into the Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2019* (14 August 2019).

73 Medicines Australia, Submission No 35 to Senate Standing Committees on Economics, Parliament of Australia, *Inquiry into the Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2019* ('Medicines Australia Submission').

74 *Patentable Subject Matter* (n 62) 8.

75 *Statute of Monopolies 1624*, 21 Jac 1, c 3.

76 For a history, see Chris Dent, '"Generally Inconvenient": The 1624 *Statute of Monopolies* as Political Compromise' (2009) 33(2) *Melbourne University Law Review* 415, 429–30 n 104.

77 Ricketson et al (n 22) 689.

Many stakeholders[78] saw the addition of 'technological innovation' to earlier drafts of the objects clause[79] as a violation of judicial warnings against express fetters on the concept of manner of manufacture.[80] Although 'technological innovation' resonates with article 7 of the *TRIPS Agreement*,[81] many shared the view that the inclusion was a 'surreptitious means to narrow patent-eligible subject matter in Australia',[82] despite contrary assurances expressed in the Explanatory Memorandum.[83]

In particular, there was significant concern that the life sciences and the nascent field of software patents would be affected.[84] Patenting of 'genetic materials, computer software and business methods' have long been debated in Australia for reasons including the proscription against patenting mere

78 Anita Cade and Ted Talas, 'Government Takes (Some) Steps to Implement Intellectual Property Law Reforms Recommended by the Productivity Commission' (2019) 31(9) *Australian Intellectual Property Law Bulletin* 170. See also Law Institute of Victoria, Submission to IP Australia, *Public Consultation on Exposure Draft of Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2018* (30 August 2018) 3 <https://ipaustralia.libguides.com/ld.php?content_id=44331732> ('Law Institute of Victoria Submission'); David Webber, Submission to IP Australia, *Public Consultation on Exposure Draft of Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2018* (31 August 2018) <https://ipaustralia.libguides.com/ld.php?content_id=44331763>; Aristocrat Lesiure Ltd, Submission to IP Australia, *Public Consultation on Exposure Draft of Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2018* (31 August 2018) <https://ipaustralia.libguides.com/ld.php?content_id=44331510>.

79 See Productivity Commission, *Intellectual Property Arrangements* (Draft Report, April 2016) 189 <https://www.pc.gov.au/inquiries/completed/intellectual-property/draft/intellectual-property-draft.pdf>. See also *Patentable Subject Matter* (n 62) 5; IP Australia, 'Patentable Subject Matter: Consultation on an Objects Clause and an Exclusion from Patentability' (Consultation Paper, July 2013) 4–5 <https://www.ipaustralia.gov.au/sites/default/files/consultation_objects_clause_final_paper.pdf>.

80 'To attempt to place upon the idea the fetters of an exact verbal formula could never have been sound. It would be unsound to the point of folly to attempt to do so now': *NRDC* (n 40) 271 (Dixon CJ, Kitto and Windeyer JJ), affd *D'Arcy* (n 40) 339 [5], 346 [20] (French CJ, Kiefel, Bell and Keane JJ). 'We think that to erect a requirement that an alleged invention be within the area of science and technology would be to risk the very kind of rigidity which the High Court warned against': *Grant v Commissioner of Patents* (2006) 154 FCR 62, 71 [38] (The Court).

81 *TRIPS Agreement* (n 67) art 7.

82 Grant Shoebridge, 'The Government's Response to the Productivity Commission Report Signals Significant Changes to Intellectual Property Laws in Australia' (2018) 31(1–2) *Australian Intellectual Property Law Bulletin* 8. 'IP Australia and patent attorneys know that the introduction of the term "technological" does restrict the type of innovation and will most likely exclude certain subject matter from being patentable, despite what is said in the Explanatory Memorandum': Webber (n 78) 1. See also 'IPTA Submission' (n 70).

83 Explanatory Memorandum, Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2019 (Cth) 12 cl 20 ('Explanatory Memorandum'). See 'IPTA Submission' (n 70) 8:

> [D]espite comments suggesting the contrary in the Explanatory Memorandum, it is clearly intended to significantly change the manner in which judicial patent decisions are made in relation to many aspects of patent validity, including the assessment of patent eligible subject matter and inventive step. In particular, the introduction of the word 'technological' to qualify the term 'innovation' has the potential to cause significant misunderstandings and significant harm.

84 See, eg, IP Australia, 'IP Australia Response to Public Consultation on Exposure Draft of Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Matters) Bill 2018' (Response, 2020) 4.

discoveries or mathematical algorithms.[85] In relation to software patents, some stakeholders were concerned that the word 'technological' could hinder[86] or indeed help[87] software patentees. In contrast and relevant to this article, there was significant concern that a narrow interpretation of 'technological innovation' could adversely affect the life science industries,[88] which dominate patent applications worldwide.[89]

Inventions in the life sciences risk non-patentability if the invention is perceived as a mere discovery of nature (eg, genetic material)[90] or a mere plan or scheme (eg, therapeutic treatments or methods of diagnosis).[91] Although the High Court has held these kinds of inventions as theoretically patentable,[92] the life science industries have often pressed the boundaries of the manner of manufacture concept,[93] which requires the invention have 'a practical application of [the discovery] to a useful end'.[94]

85 *Patentable Subject Matter* (n 62) 1. See, eg, Intellectual Property and Competition Review Committee, *Review of Intellectual Property Legislation under the Competition Principles Agreement* (Final Report, September 2000) 152. See also *Genes and Ingenuity* (n 61); *Patentable Subject Matter* (n 62) 2.

86 Webber (n 78). See also Law Institute of Victoria (n 78) 2.

87 IPTA, Submission to IP Australia, *Public Consultation on Exposure Draft of Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2018* (31 August 2018) 8 <https://ipaustralia.libguides.com/ld.php?content_id=44331659>. However, a contrary view on software is found in James Ellsmore and Chris Wziontek, 'Implement This: Full Federal Court Provides Further Guidance on Computer-Implemented Inventions in *Encompass Corp Pty Ltd v InfoTrack Pty Ltd*' (2019) 22(5–6) *Internet Law Bulletin* 58.

88 'It has also been suggested by some that limiting inventions to those which are technological could "clarify" that certain inventions relating to methods of treatment or diagnosis, or to isolated biological materials, are not patentable': see, eg, Michael Caine and Suzy Roessel, 'Government Takes First Steps to Implement Productivity Commission's Recommendations' (2018) 31(7) *Australian Intellectual Property Law Bulletin* 122, 122.

89 For a discussion of the history of the 'emergence and global dominance' of the life science industries, see Graham Dutfield, *Intellectual Property Rights and the Life Science Industries: A Twentieth Century History* (Routledge, 2003). Note he defines the life science industries as those 'which specialize in elucidating, synthesizing, manipulating and commercially exploiting the molecular properties of microorganisms, plants, animals – including humans – and other organic raw materials': at 7.

90 See, eg, *Genes and Ingenuity* (n 61).

91 *Apotex Pty Ltd v Sanofi-Aventis Australia Pty Ltd* (2013) 253 CLR 284 ('*Apotex*').

92 *NRDC* (n 40) 276–7 (Dixon CJ, Kitto and Windeyer JJ), applied in *Apotex Pty Ltd* (n 91) and in *D'Arcy* (n 40).

93 For example, in *D'Arcy* (n 40) 350 [27] (French CJ, Kiefel, Bell and Keane JJ), the High Court framed a patent product claim for an isolated nucleic acid coding for the BRCA1 gene (which disclosed features indicative of predisposition to breast and ovarian cancer) as 'not within the established boundaries' of manner of manufacture. French CJ, Kiefel, Bell and Keane JJ proposed that 'wider considerations than Myriad's characterisation of them as an "artificially created state of affairs of economic utility" come into play': at 350 [27].

94 *NRDC* (n 40) 264 (Dixon CJ, Kitto and Windeyer JJ). See also IP Australia, '2.9.2.5 Discoveries, Ideas, Scientific Theories, Schemes and Plans', *Patent Manual of Practice and Procedure* (Manual, 20 January 2021) <https://manuals.ipaustralia.gov.au/patent/2.9.2.5-discoveries-ideas-scientific-theories-schemes-and-plans>.

Stakeholders were concerned that the word 'technological' would be used to privilege inventions of an electronic[95] or computer-based nature,[96] or affect the life sciences by requiring integration or addition of a computer-based or electronic tool. For example, the New Zealand Institute of Patent Attorneys Inc submitted that inventions in the life sciences would be affected 'because these might not naturally be thought of as "technological innovations"', and that the wording 'raises a question about whether methods and processes that do not involve "technological" equipment would be patentable'.[97] Medicines Australia submitted that 'the definition of "technological" is unclear and arguments could arise claiming that certain therapies are not of a "technological" nature.'[98] AusBiotech pointed out that the word 'technology' has been appropriated by the information and communications technology industry.[99] The Australian Federation of Intellectual Property Attorneys Australia[100] and the Law Institute of Victoria[101] noted that the term 'technological' had caused problems in Europe, particularly 'in relation to the protection of human therapies'.[102]

The response to these concerns by the Commission 'appeared to place considerable weight on the role of explanatory materials'.[103] For example, the Explanatory Memorandum states that the objects clause will not change the scope of patentability[104] and exists only 'to assist courts in interpreting the *Patents Act* in cases where the text of the legislation is uncertain or ambiguous'.[105] However, as pointed out by legal observers, 'it is difficult to see how this position is consistent with the High Court's decision in *D'Arcy v Myriad Genetics Inc* which placed the objects of the *Act* at the heart of assessing whether novel inventions constitute a "manner of manufacture"'.[106]

It is important to note that in academic literature, 'technology' is a contested term. However, in this article we focus on the debates surrounding the objects

95 New Zealand Institute of Patent Attorneys Inc, Submission to IP Australia, *Public Consultation Exposure Draft of the Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2018* (31 August 2018) 2 <https://ipaustralia.libguides.com/ld.php?content_id=44331827> ('NZIPA Submission').

96 AusBiotech, Submission to IP Australia, *Public Consultation on Exposure Draft of Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2018* (31 August 2018) <https://ipaustralia.libguides.com/ld.php?content_id=44331518> ('AusBiotech Submission').

97 NZIPA Submission (n 95) 2 (emphasis omitted).

98 Medicines Australia Submission (n 73) 3.

99 AusBiotech Submission (n 96) 2.

100 Australian Federation of Intellectual Property Attorneys Australia, Submission to IP Australia, *Public Consultation on Exposure Draft of the Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2018* (5 September 2018) 3 <https://ipaustralia.libguides.com/ld.php?content_id=44331566> ('FICPI Australia Submission').

101 Law Institute of Victoria Submission (n 78) 2–3.

102 FICPI Australia Submission (n 100) 3.

103 Mark Summerfield, Submission to IP Australia, *Public Consultation on Exposure Draft of Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Bill 2018* (31 August 2018) 6 <https://ipaustralia.libguides.com/ld.php?content_id=44331550>.

104 Explanatory Memorandum (n 83) 12.

105 Ibid 11.

106 Cade and Talas (n 78).

clause where 'technological innovation' is defined as 'the applications of scientific knowledge for practical purposes'.[107] We recognise but do not deal with the significant scholarship examining the valorisation of objects, services and people controlling the meaning of 'technology', nor the impact this has on fortifying power hierarchies and deepening racial, class and gender divides.[108] For the purpose of this article we restrict our definition of 'technology' to the submissions and debates closely related to the objects clause.

In relation to these submissions, some discussed the need to protect Indigenous intellectual property rights,[109] but no mention was made by the Commission, or by the submissions related to the objects clause, to women. This is despite the various high-profile initiatives of the Australian and other governments to acknowledge and remedy gender inequity in STEM.[110] This is a critical omission as any laws that could reduce the participation of women in the patents system could be seen as running counter to those initiatives to increase female participation in STEM.[111]

B Scholarly Critiques of Patentability and Gender

A number of empirical studies have shown that female inventors are grossly underrepresented in the patent system. Studies of patents worldwide,[112] all show that female inventorship is growing but that female inventors apply for fewer patents

107 Explanatory Memorandum (n 83) 12.

108 See, eg, Sandra Harding, 'Postcolonial and Feminist Philosophies of Science and Technology: Convergences and Dissonances' (2009) 12(4) *Postcolonial Studies* 401 <https://doi.org/10.1080/13688790903350658>; Ruth Oldenziel, *Making Technology Masculine: Men, Women and Modern Machines in America, 1870–1945* (Amsterdam University Press, 1999) <https://doi.org/10.5117/9789053563816>; Kara W Swanson, 'Rubbing Elbows and Blowing Smoke: Gender, Class, and Science in the Nineteenth-Century Patent Office' (2017) 108(1) *Isis* 40 <https://doi.org/10.1086/691396>; Ronald R Kline, 'Technological Determinism' in James D Wright (ed), *International Encyclopedia of the Social and Behavioral Sciences* (Elsevier, 2nd ed, 2015) 109; Kara W Swanson, 'Intellectual Property and Gender: Reflections on Accomplishments and Methodology' (2015) 24(1) *American University Journal of Gender, Social Policy and the Law* 175 ('Intellectual Property and Gender'); Judy Wajcman, 'Feminist Theories of Technology' (2010) 34(1) *Cambridge Journal of Economics* 143 <https://doi.org/10.1093/cje/ben057>; Kara W Swanson, '"Great Men," Law, and the Social Construction of Technology' (2018) 43(3) *Law and Social Inquiry* 1093 <https://doi.org/10.1111/lsi.12313>; Brad Sherman and Lionel Bently, *The Making of Modern Intellectual Property Law* (Cambridge University Press, 1999); Wiebe E Bijker, Thomas Parke Hughes and Trevor Pinch (eds), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (MIT Press, 1987).

109 Law Council of Australia, Submission to IP Australia, *Public Consultation on Exposure Drafts of Intellectual Property Laws Amendment (Productivity Commission Response Part 1 and Other Measures) Bill and Regulations* (17 November 2017) 8–9 [21]–[25] <https://ipaustralia.libguides.com/ld.php?content_id=38410065>. See also New Zealand Institute of Patent Attorneys Inc, Submission to IP Australia, *Public Consultation: Amending the Inventive Step Requirements for Australian Patents* (24 November 2017) 2 <https://ipaustralia.libguides.com/ld.php?content_id=38410071>.

110 See, eg, Australian Academy of Science, 'Women in STEM' (n 1). See also Department of Industry, Science, Energy and Resources, '2020 Action Plan' (n 1).

111 Pearson, Frehill and McNeely (n 2). See also *STEM Education for Girls and Women* (n 2).

112 See, eg, Martinez, Raffo and Saito (n 18) 11; *Gender Profiles in Worldwide Patenting* (n 2) 26; United States Patent and Trademark Office, Office of the Chief Economist, *Progress and Potential: A Profile of Women Inventors on US Patents* (Report No 2, February 2019) <https://www.uspto.gov/sites/default/files/documents/Progress-and-Potential-2019.pdf> ('*Progress and Potential*').

than men.[113] The majority of research into gender disparities examines the 'socio-cultural and institutional reasons why women do not or cannot seek patents'.[114] However, more recently, legal scholars have begun to challenge the patent law's veneer of objectivity to argue that the law itself is gendered.[115] For example, several scholars have argued that patent law protects 'male-dominated areas more than female-dominated areas', and standards for what is patentable often assume an exclusively male point of view.[116]

1 Feminist Legal Scholarship

The arguments of feminist legal scholars parallel the concerns from stakeholders about the objects clause and inclusion of the phrase 'technological innovation'. These scholars argue that the *TRIPS* objectives advance a narrow concept of patentability and focus too much on 'mechanical, technical and industrial aspects' of 'products and processes'[117] thereby excluding domains of female inventorship. For example, Yanisky-Ravid argues that privileging 'technological inventions discriminates against a majority of women who are responsible for the welfare achieved through inventions in other non-technical and "non-machine" fields'.[118] These scholars argue that inventing is gendered for a multitude of social, historic, cultural and innate reasons,[119] and the result is that women innovate in welfare-promoting or caring sciences and these fields are not rewarded by the patent law

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113 Waverly W Ding, Fiona Murray and Toby E Stuart, 'Gender Differences in Patenting in the Academic Life Sciences' (2006) 313(5787) *Science* 665, 665 <https://doi.org/10.1126/science.1124832>; Kjersten Bunker Whittington and Laurel Smith-Doerr, 'Women Inventors in Context: Disparities in Patenting across Academia and Industry' (2008) 22(2) *Gender and Society* 194 <https://doi.org/10.1177/0891243207313928>.

114 Jessica C Lai, 'Patents, Knowledge Governance and Gender' (2020) 42(10) *European Intellectual Property Review* 623, 623. See, eg, Kara W Swanson, 'Getting a Grip on the Corset: Gender, Sexuality, and Patent Law' (2011) 23(1) *Yale Journal of Law and Feminism* 57. See generally Swanson, 'Intellectual Property and Gender' (n 108).

115 Jessica C Lai, 'Patents and Gender: A Contextual Analysis' (2020) 10(3) *Queen Mary Journal of Intellectual Property* 283, 283 <https://doi.org/10.4337/qmjip.2020.03.01> ('Patents and Gender'). See, eg, Dan L Burk, 'Feminism and Dualism in Intellectual Property' (2007) 15(2) *American University Journal of Gender, Social Policy and the Law* 183; Dan L Burk, 'Do Patents Have Gender?' (2011) 19(3) *American University Journal of Gender, Social Policy and the Law* 881; Shlomit Yanisky-Ravid, 'Eligible Patent Matter: Gender Analysis of Patent Law' (2011) 19(3) *American University Journal of Gender, Social Policy and the Law* 851.

116 Miriam Marcowitz-Bitton, Yotam Kaplan and Emily Michiko Morris, 'Unregistered Patents and Gender Equality' (2020) 43(1) *Harvard Journal of Law and Gender* 47, 50; Swanson, 'Intellectual Property and Gender' (n 108) 182.

117 Yanisky-Ravid (n 115) 860. See also Sharmishta Barwa and Shirin M Rai, 'Knowledge and/as Power: A Feminist Critique of Trade Related Intellectual Property Rights' (2003) 7(1) *Gender, Technology and Development* 91 <https://doi.org/10.1080/09718524.2003.11910065>.

118 Yanisky-Ravid (n 115) 873 (citations omitted).

119 See, eg, Dan L Burk, 'Diversity Levers' (2015) 23(1) *Duke Journal of Gender Law and Policy* 25 <https://doi.org/10.31235/osf.io/tm6er>. See also Allie Porter, 'Where Are the Women? The Gender Gap within Intellectual Property' (2020) 28(3) *Texas Intellectual Property Law Journal* 511; Fiona Murray and Leigh Graham, 'Buying Science and Selling Science: Gender Differences in the Market for Commercial Science' (2007) 16(4) *Industrial and Corporate Change* 657 <https://doi.org/10.1093/icc/dtm021>.

system.[120] There is much empirical evidence to support the theory that women prefer and occasionally dominate fields associated with 'care' or non-machine sciences.[121] For example, in Australia, of the 2016 labour force with STEM degrees, females had the highest representation in medical science (65% of that population) but the lowest in physics (19%).[122]

There are of course many 'downstream' reasons (outside the legal definition of a patent) to explain why so few women participate in the patents system. In academic scholarship, these theories generally fall into two broad themes. The first is that there are fewer females working in STEM fields[123] and even fewer in what are considered 'patent-intensive fields' such as engineering.[124] Therefore, the goal of policy should be to encourage women to work in those fields and transform those workplaces historically hostile to women.[125]

The second theme is that rather than make women change, the law itself should change. The law was developed to favour 'Western-male-centric modes of invention and innovation'.[126] And the law itself needs to change to better reflect female innovation.[127] Therefore, rather than impose male-centric qualifiers such as 'technological innovation', the law should expand its definition of patentable subject matter and include fields that are traditionally female dominated.[128]

This is a simplified summary, and there are many well-developed feminist critiques of scientific epistemology that inform these discussions, but these are beyond the scope of this article.[129] Nevertheless, it is possible to discuss the problems underlying the heart of both positions. In terms of the 'more women in STEM' argument, there is much evidence that even in scientific fields with

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120 Lai, 'Patents and Gender' (n 115) 295. See also Cassidy R Sugimoto et al, 'Bibliometrics: Global Gender Disparities in Science' (2013) 504 *Nature* 211, 211 <https://doi.org/10.1038/504211a>; Jessica C Lai, 'The Role of Patents as a Gendered Chameleon' (2021) 30(2) *Social and Legal Studies* 203, 216 <https://doi.org/10.1177/0964663920916237> ('The Role of Patents').

121 Office of the Chief Scientist, *Australia's STEM Workforce* (Report, July 2020) 203.

122 Ibid.

123 See David Beede et al, *Women in STEM: A Gender Gap to Innovation* (ESA Issue Brief No 04-11, August 2011).

124 '[E]lectrical and mechanical arts are the most patent-intensive fields': Porter (n 119) 522; Jennifer Hunt et al, 'Why Are Women Underrepresented amongst Patentees?' (2013) 42 *Research Policy* 831, 832 <https://doi.org/10.1016/j.respol.2012.11.004>.

125 AM Dockery and Sherry Bawa, 'Labour Market Implications of Promoting Women's Participation in STEM in Australia' (2018) 21(2) *Australian Journal of Labour Economics* 125. See also Porter (n 119) 524.

126 Lai, 'The Role of Patents' (n 120) 206 (citations omitted).

127 For example, Jessica Lai argues, '[r]ather than trying to "fix" patent law and expand a system based on Western and masculine presumptions to the knowledge systems of women, including non-Western women, we should think about how to legally support the diversity of ways in which creation occurs': Lai, 'Patents, Knowledge Governance and Gender' (n 114) 641.

128 Lai, 'The Role of Patents' (n 120) 210. See also Laura A Foster, 'Situating Feminism, Patent Law, and the Public Domain' (2011) 20(1) *Columbia Journal of Gender and Law* 261.

129 For a discussion of radical and cultural feminism, see Yanisky-Ravid (n 115) 854–7. For an overview of essentialist, existentialist, liberal, postcolonial, psychoanalytical and socialist feminist views, see Sue V Rosser, 'The Gender Gap in Patenting: Is Technology Transfer a Feminist Issue?' (2009) 21(2) *National Women's Studies Association Journal* 65, 72–9. For an 'overview of the various approaches to conceptualising the link between gender and technology, both past and present', see Wajcman (n 108) 143.

near gender parity such as biology and medicine,[130] women are disproportionately underrepresented in research grants,[131] laboratory leadership roles,[132] senior academic roles,[133] research publications[134] and commercialisation of ideas.[135] In other words, mere disparity in the number of women in STEM fields cannot alone account for the gender gap in patenting.[136] Indeed as argued by Lai, 'the issue of not enough "women in STEM" is an aesthetic, superficial problem' which distracts from deeper considerations of power and knowledge governance.[137]

The problem with the second argument, which contemplates expanding the scope of patentability, is that this would reduce the scope of the public domain.[138] Policymakers hesitate to expand private legal monopolies because there is a strong belief that innovation and creativity are cumulative and need a healthy public sphere.[139] Expanding the patentable domain may also exacerbate patent thickets – a web of patents a company is forced to negotiate or license through to commercialise their own technology – raising barriers to entry and creating an anti-commons.[140] Although, as Nielsen and Nichol point out 'whether these theoretical concerns exist in practice is yet to be fully resolved in the Australian context'.[141]

An overarching problem with these two themes which arguably focus on the 'aesthetic [and] superficial'[142] or are kneejerk responses to alter the public domain,

130 *Australia's STEM Workforce* (n 121). Similar figures exist in the US: see Beede et al (n 123).

131 Women are underrepresented 'in NHRMC schemes, in particular the Research Fellowship scheme and the Project Grant scheme': National Health and Medical Research Council, *NHMRC's Gender Equality Strategy 2018–2021* (Report, December 2018) 3 ('*NHMRC's Gender Equality Strategy*'). Australian female scientists are also underrepresented in Australian Research Council schemes: see Tabitha Carvan, 'Why Aren't Women in Science Applying for Grants?', *ANU College of Science* (Blog Post, 2020) <https://web.archive.org/web/20220329133156/https://science.anu.edu.au/news-events/news/why-aren%E2%80%99t-women-science-applying-grants>. See also Holly O Witteman et al, 'Are Gender Gaps Due to Evaluations of the Applicant or the Science? A Natural Experiment at a National Funding Agency' (2019) 393(10171) *Lancet* 531 <https://doi.org/10.1016/S0140-6736(18)32611-4>.

132 Benoit Macaluso et al, 'Is Science Built on the Shoulders of Women? A Study of Gender Differences in Contributorship' (2016) 91(8) *Academic Medicine* 1136, 1136 <https://doi.org/10.1097/ACM.0000000000001261>. See also Cassidy R Sugimoto and Vincent Larivière, 'Unraveling Gender Disparities in Science: Analysis of Contributorship and Labor Roles' (Research Paper, OECD Directorate for Science, Technology and Innovation, 2016).

133 Marc J Lerchenmueller and Olav Sorenson, 'The Gender Gap in Early Career Transitions in the Life Sciences' (2018) 47(6) *Research Policy* 1007, 1007 <https://doi.org/10.1016/j.respol.2018.02.009>.

134 Sugimoto et al (n 120) 211.

135 Jennifer Hunt et al, 'Why Don't Women Patent?' (Working Paper No 17888, National Bureau of Economic Research, March 2012) 1.

136 Marcowitz-Bitton, Kaplan and Morris (n 116) 61.

137 Jessica C Lai, *Patent Law and Women: Tackling Gender Bias in Knowledge Governance* (Routledge, 2021) 5 ('*Patent Law and Women*').

138 Reducing the public domain would also affect 'women currently reaping the benefits' of the status quo: see Porter (n 119) 529. Whether the public domain can be co-opted for egalitarian purposes has been discussed: see, eg, Foster (n 128); Lai, *Patent Law and Women* (n 137) ch 7.

139 Productivity Commission, *Intellectual Property Arrangements* (n 31) 4. But see Lai, 'Patents, Knowledge Governance and Gender' (n 114) 623, arguing that that the concept of a healthy public domain is also gendered.

140 Productivity Commission, *Intellectual Property Arrangements* (n 31) 252.

141 Nielsen and Nicol (n 54) 7.

142 Lai, *Patent Law and Women* (n 137) 5.

is that attention is diverted away from the more difficult causes of gender inequity in patents. That is, gender and patent issues reflect the systematic, cultural and institutional inequities that hinder women's access and progress in science.[143] They also reflect centuries of legal history that sustain patent law's status as a tool of male-centric mechanical industry. For example, at common law since inception, industrial property rights (patents) were distinguished from cultural property rights such as copyright.[144] This historical categorisation between industry (considered male-centric) and the decorative arts still exists today. Even in the late 20th century, the term 'industrial property' was used in relation to patents, whereas 'intellectual property' was used only in relation to 'rights in literary and artistic creations'.[145]

2 Empirical Studies of Gender and Patents

For scholars and governments to neglect the intellectual contributions of arguably half the population is not sound policy and many governments have taken initiatives to address the issue of female participation in STEM. The common focus of policymakers is on the 'leaky pipeline'. This refers to the phenomenon that although many women participate in STEM education, the retention of female scientists at postgraduate level, in the labour market and in senior management is poor.[146] This 'leaky pipeline' is a common problem worldwide.[147]

While a lot of focus has been on gendered aspects of education,[148] workplaces[149] and grants,[150] less is understood about the transition from working scientist to inventor. That is, less is known about the 'natural next step in this progression',[151] from the laboratory to the patenting of ideas. It is important for policymakers to know whether low levels of female patenting are a natural consequence of the leaky pipeline or whether something more insidious is occurring at the bridge between research and inventing,[152] or at the patent prosecution stage.[153]

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143 Sugimoto et al (n 120) 211.

144 Ricketson et al (n 22) 5–6, discussing copyright's origin in the *Statute of Anne 1710* and patent law's origin in the *Statute of Monopolies 1624*, and later of the *Paris Convention for the Protection of Industrial Property 1883* art 1(2), which entrenched definitions of industrial property as 'patents, utility models, industrial designs, trademarks'.

145 Ibid 5.

146 Martinez, Raffo and Saito (n 18) 3; *Gender Profiles in Worldwide Patenting* (n 2) 3.

147 Gender Profiles in Worldwide Patenting (n 2) 3.

148 See *STEM Equity Monitor* (n 3). See also *Advancing Women in STEM* (n 5).

149 Australian Academy of Science, 'Women in STEM' (n 1). See also Department of Industry, Science, Energy and Resources, '2020 Action Plan' (n 1); Dockery and Bawa (n 125); Bronwyn Evans, 'Urgent Need to Address the Lack of Women in Engineering', *Engineers Australia* (Web Page, 8 March 2022) <https://www.engineersaustralia.org.au/news/2022/03/bronwyn-evans-am-international-womens-day>.

150 See, eg, *NHMRC's Gender Equality Strategy* (n 131). See also Australian Research Council, *Gender and the Research Workforce: Excellence in Research for Australia (ERA) 2018* (Report, 2019) <https://dataportal.arc.gov.au/ERA/GenderWorkforceReport/2018/>.

151 *Gender Profiles in Worldwide Patenting* (n 2) 5.

152 See, eg, Lerchenmueller and Sorenson (n 133).

153 'Patent prosecution' is a term of art in intellectual property law. Typically, a patent application is drafted, filed by a patent attorney (applicant's agent), and then prosecuted with a patent examination office.

For example, in Australia, are there gender differences in relation to patent applications and success rates? Given there is evidence that women are as capable as men,[154] if women are less successful in obtaining a patent, is it because they participate in less patentable fields such as the life sciences? Or, could there be implicit bias during patent prosecution that favours male inventors? Will the introduction of the objects clause lower the acceptance rates of standard patents? Will that have a greater impact on the life sciences or female inventors? An empirical understanding of current gender and patent issues will help shape policy initiatives and provide a baseline to compare the longer-term impact of the objects clause and other planned changes to the *Act*.

As discussed in Part I, progress in big data analyses has enabled researchers to examine not just female application data, but also whether female inventors succeed in having their patent proceed to grant. In their study, Jensen, Kovács and Sorenson analysed 2.7 million US patent applications over a 15-year period (2001–14). In the aggregate, they found that 'women inventors were 21% less likely than men inventors to have their application accepted, but that difference declined to 7% after technology-class fixed effects were included'.[155]

Lower success rates for female-named inventors were found even in fields of near gender parity such as the life sciences.[156] For example, 'in the life sciences, a team of all-women inventors was found to be 11% less likely than a team of all men to have its patent application accepted'.[157] Subsequent studies of USPTO data, using a range of methodologies, have found results consistent with these findings.[158]Jensen, Kovács and Sorenson concluded that 'approximately two-thirds of the lower probability of acceptance for applications with women inventors stemmed from the examiner side'.[159]

In Australia, given the investment and policy focus on female STEM participation, it is imperative to understand whether the patent system itself serves as a barrier for women. Unfortunately, in Australia unlike other jurisdictions, the relationship between gender, patent law and STEM innovation are rarely (if ever)

Prosecution involves the patent examiner examining the patent, conducting relevant searches and communicating with the applicant or their agent: see IP Australia, 'Glossary', *Patent Manual of Practice and Procedure* (Manual, 2 December 2020) <https://manuals.ipaustralia.gov.au/patent/Glossary>.

154 Ding, Murray and Stuart (n 113) 666. See also Kjersten Bunker Whittington and Laurel Smith-Doerr, 'Gender and Commercial Science: Women's Patenting in the Life Sciences' (2005) 30(4) *Journal of Technology Transfer* 355, 355 <https://doi.org/10.1007/s10961-005-2581-5> ('Gender and Commercial Science').

155 Jensen, Kovács and Sorenson (n 25) 307.

156 Ibid 308.

157 Ibid.

158 Michael W Schuster et al, 'An Empirical Study of Patent Grant Rates as a Function of Race and Gender' (2020) 57(2) *American Business Law Journal* 281, 311 <https://doi.org/10.1111/ablj.12159>. See also Evelina Gavrilova-Zoutman and Steffen Juranek, 'Female Inventors: The Drivers of the Gender Patenting Gap' (Research Paper, 16 April 2021) 3; Jane Jungeun Choi, 'Essays on Innovation and Public Policy' (PhD Thesis, Massachusetts Institute of Technology, June 2019) 76; *Progress and Potential* (n 112) 13.

159 Ibid 309.

discussed together.[160] We hope to advance this conversation through this article by examining whether gender (eg, being a female-named inventor) affects the chances of being granted an Australian patent. In doing so, we are the first (to our knowledge) to apply big data analysis techniques in relation to Australian legal scholarship. We therefore set out our methodology in detail.

III METHODOLOGY

A Data Processing

We examined 309,544 standard patent applications filed during the 15-year period from 1 January 2001 to 31 December 2015 using data sourced from the Intellectual Property Government Open Data Set ('IPGOD') 2019.[161] The IPGOD patents dataset does not include inventor names,[162] so these were provided to us by IP Australia. Because IPGOD is a work in progress, some fields were not well populated, particularly for older patents. We found that a dataset from 2001 to 2015 provided the most complete data for this study. Figure 1 provides an overview of our data processing. All data are sourced from IPGOD 2019 but owing to the time lag involved between patent file and grant, we used December 2015 as the cut-off point.[163] In our dataset, the mean time from filing date to grant date was 1,171 days or 38.5 months, where $n = 230{,}717$ successful grants.[164]

Provisional, innovation and petty patent applications were excluded because they are not examined or are assessed with different rules. On the advice of IP Australia, we removed self-filers from the dataset and were told that adverse outcomes were more likely due to administrative rather than substantive errors.

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160 For example, the Commission report on patents and intellectual property does not mention gender as an issue: Productivity Commission, *Intellectual Property Arrangements* (n 31). Likewise, the STEM Equity Monitor does not include the word patent: *STEM Equity Monitor* (n 3). By contrast, in the US, gender and patents is a live issue: see, eg, Hunt et al, 'Why Don't Women Patent?' (n 135); *Progress and Potential* (n 112). See also 'Remarks by Director Michelle K Lee at the "Invention: Does Gender Matter?" Roundtable', *USPTO* (Web Page, 10 November 2015) <https://www.uspto.gov/about-us/news-updates/remarks-director-michelle-k-lee-invention-does-gender-matter-roundtable>.

161 IP Australia, '[Superseded] Intellectual Property Government Open Data 2019', *data.gov.au* (Web Page, 26 January 2022) <https://data.gov.au/data/dataset/intellectual-property-government-open-data-2019>.

162 The name(s) of the inventor(s) must appear on the patent request and transliterations from other alphabets are required: see IP Australia, '2.6.2.3 Name of the Applicant and Inventor', *Patent Manual of Practice and Procedure* (Manual, 16 December 2020) <https://manuals.ipaustralia.gov.au/patent/2.6.2.3-name-of-the-applicant-and-inventor>. See also *Patents Regulations 1991* (Cth) reg 3.2C(2)(aa). There are similar requirements in other jurisdictions, such as US patents: see 37 CFR § 1.63(a)(1) (2019).

163 Fields relate to the nomenclature found in IP Australia, 'Intellectual Property Government Open Data 2019' (Data Dictionary, 16 June 2019) <https://data.gov.au/data/dataset/a4210de2-9cbb-4d43-848d-46138fefd271/resource/8d2855ce-8e39-4bc0-9d6d-e19a4d9e2183/download/ipgod-2019-data-dictionary.pdf> ('IPGOD Data Dictionary').

164 On advice from IP Australia, for *PCT* applications we used the date of entry to the national phase. For the small number of innovation patents converting to standard we used the conversion date.

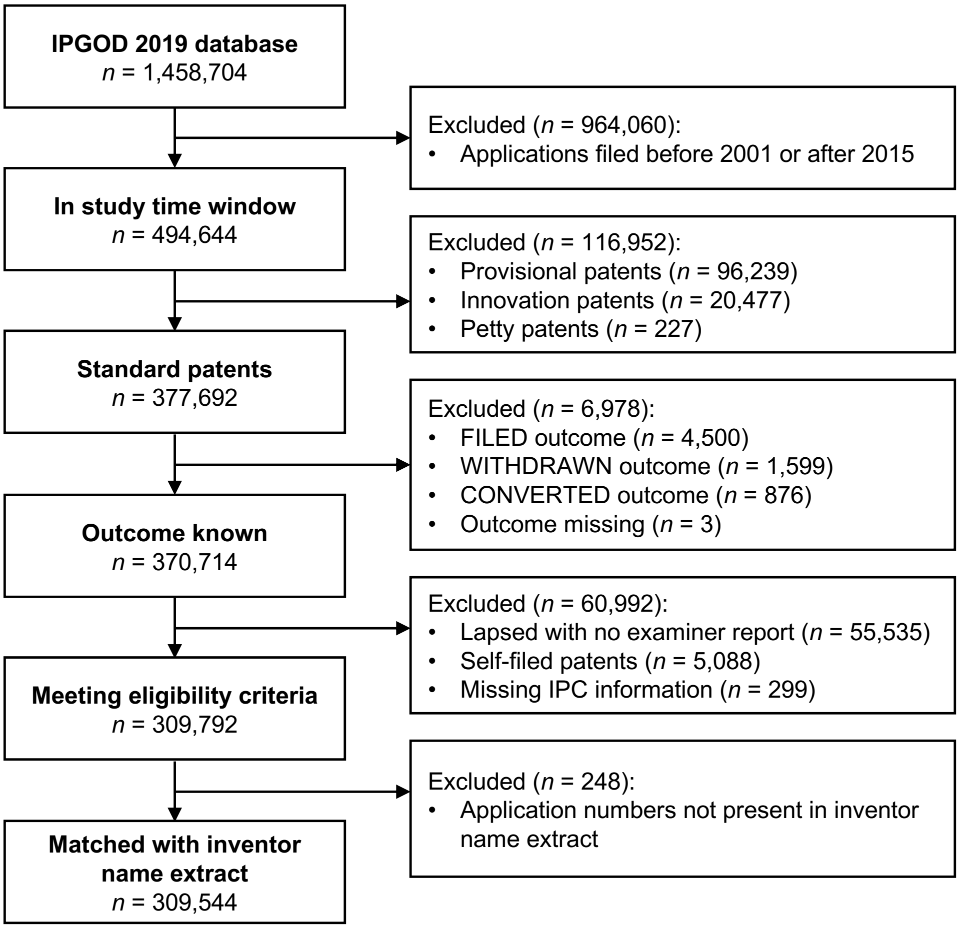

Figure 1: Data processing

B Coding

1 Outcome: Patent Success and Lapsed Patents

The IPGOD database codes outcomes in multiple ways. We collapsed the outcomes of a patent application to 'granted'[165] or 'not granted', where 'granted' includes IPGOD codes 'granted', 'accepted', 'ceased' and 'expired' patents. 'Not accepted' includes outcomes coded as 'lapsed', 'refused' or 'revoked'.

We found that around 1/3 of applications (132,664) were coded as 'lapsed'. After discussions with IP Australia, we were advised that patents can 'lapse' for a dozen different reasons. For example, many applications lapse prior to examination due

165 'Granted' is used synonymously with 'Sealed': see 'IPGOD Data Dictionary' (n 163).

to a failure to pay fees after filing.[166] Many applications lapse after examination for reasons such as failing to overcome an examiner's objection.[167] Given the goal of this project was to assess the outcomes of examination, we excluded 55,535 patents that lapsed prior to examination. This exclusion explains the high overall success rate of 75.0%. When we include the subset of lapsed but unexamined patents the overall success rate is 63.6%. We found that the gender name distribution of the lapsed (without examination) and lapsed (with examination) subsets to be very similar.

2 Gender

As with most jurisdictions,[168] IP Australia does not require an inventor's gender[169] to be disclosed in a patent application but does require a full name.[170] An inventor name may be used by the examiner to cross reference other works involving that inventor.[171] Therefore, consistent with previous studies,[172] we coded gender based on forename gender probabilities available from the US Social Security Administration ('SSA').[173] The SSA database contains the gender distributions for close to 90,000 unique forenames collected from 1932 to 2012. For example, the forename 'Roger' is recorded by the SSA as being associated with a male (at birth) 99.6% of the time. There is no equivalent publicly available dataset for forenames of Australian residents. Given the linguistic and cultural similarities between the US and Australia, the SSA provided a good proxy for names that we assumed would be familiar to the average Australian patent examiner.

Using the SSA database, we coded the gender of each inventor as 'female', 'male', 'not identified' or 'ambiguous'. To minimise coding error, we adopted a high threshold for inferring gender. Only names with a 0.9 probability or greater of being male were assigned 'male'; names with a 0.1 probability or less of being male were coded as 'female'. Names with probabilities between 0.1 and 0.9 were identified as 'ambiguous'. For example, an inventor with a name such as 'Casey', which has a probability of 0.565 of being male, was coded as 'ambiguous'. Names outside of the SSA dataset, for example, uncommon names, foreign-language names or initials, were categorised as 'not identified'. Where there was more than one forename (for example, a first name and a middle name), the name with the

166 *Patents Regulations 1991* (Cth) reg 22.2B.

167 *Patents Act 1990* (Cth) s 142(2)(e).

168 *Gender Profiles in Worldwide Patenting* (n 2) 26.

169 Our coding of gender into binary outcomes is for statistical reasons only. The gender information we use relies on US Social Security data, which for the period of interest did not include non-binary or other gender identities of inventors. We recognise that male/female may not adequately capture those who identify outside those identities.

170 See, eg, *Patent Regulations 1991* (Cth) reg 3.2C(2)(aa).

171 See IP Australia, '4.1.3.6 Applicant and/or Inventor Name Searching', *Patent Manual of Practice and Procedure* (Manual, 16 December 2020) <https://manuals.ipaustralia.gov.au/patent/4.1.3.6-applicant-and-or-inventor-name-searching>.

172 Daniel Müller, Pratiksha Jain and Yieh-Funk Te, 'Augmenting Data Quality through High-Precision Gender Categorization' (2019) 11(2) *Journal of Data and Information Quality* 8:1–18 <https://doi.org/10.1145/3297720>.

173 'Beyond the Top 1000 Names', *Social Security Administration* (Web Page) <https://www.ssa.gov/oact/babynames/limits.html>.

most extreme probability was used to code gender. For example, where a first or middle name had a 0.9 or greater probability of being 'male', the inventor was coded as male.

3 Technology

To identify the technology area for each filing, IP Australia suggested we use 'primary_ipc_mark_value' from IPGOD101 cross-referenced with WIPO concordance tables.[174] This classified the patent applications into 35 fields of technology.

4 Other Variables of Interest: Unavailable or Missing Data

Some information was not available to us for the period of interest (2001–15). We did not have quality information as to entity type (eg, university or industry), entity size, or country of origin. We also sought data relating to office actions, claim revisions, and forward citations, which have been shown to go against female inventors,[175] but this was not available. We did not have indicators of divisional applications or patents of addition.

We also sought demographic information on patent examiners, but this was not released by IP Australia for privacy reasons. We estimate that most patent attorney/agents and patent examiners are male.[176] We note that previous studies of US examiners show that examiner gender has no impact on outcome,[177] nor that female examiners are harsher towards female inventors than are male examiners.[178]

IV RESULTS

A Descriptive Statistics

1 Gender of Inventors

Of the 941,516 inventor names, 69.3% (652,891) of inventors were coded as male, 11.2% (105,058) were coded as female, 4.1% (38,468) were coded as ambiguous and 15.4% (145,099) were coded as not identified. Because patent inventors often work in teams, we wanted to examine the gender of inventors per patent application. We found 23.6% of patent applications included at least

174 'IPC: Technology Concordance Table', *WIPO* (Web Page, January 2013) <https://econpapers.repec.org/software/wipeccode/8.htm> ('Technology Concordance Table').

175 Jensen, Kovács and Sorenson (n 25) 308.

176 Rock estimates that 'in 2001 females comprised 16.6% of registered Australian patent attorneys. In late 2016 female representation was 28.2%': Katherine Rock, 'Gender (Im)balance in the Patent Attorney Profession in Australia: Myths and Evidence-Based Recommendations for Change' (2018) 28(2) *Australian Intellectual Property Journal* 64, 64. Although patent examiners are not required to be patent attorneys, they share similar features because both must have a graduate degree in a patentable field and are required to undergo further training in patent law. We therefore infer that the gender representation of patent examiners would not widely differ from that of patent attorneys.

177 Gavrilova-Zoutman and Juranek (n 159).

178 Choi (n 159) 76.

one female inventor. However, of these, only 1.4% of applications listed a sole female inventor, and only 0.4% of patent applications listed an all-female team of inventors. Therefore, in total, only 1.8% of patent applications in Australia listed female-only inventors.[179]

We found that 21.8% of applications included at least 1 female in a mixed team (ie, with at least 1 other inventor coded as male, ambiguous or unidentified). These findings indicate that when female inventors participate in the patent system, they overwhelmingly do so as part of a mixed team. Given the low and fairly constant number of patent applications with female-only inventors (1.8%), any growth in rates of overall female inventorship is likely driven by participation in mixed gender teams.[180]

In contrast, we found 89.3% of applications included at least 1 male inventor. Of these, 21.5% were patents with sole male inventors and 28.6% were patents with all-male teams. In other words, 50.1% of all patent applications were uniquely male. Only in 39.3% of applications was a male part of a mixed team (with at least 1 other female, ambiguous or unidentified name). Hence, male inventors are included in a vast majority of applications (89.3%), and 50.1% of all applications were identified as only male.

2 Technology Fields

To examine the gender distribution across areas of patentability, we examined the data according to predefined categories of 'Sector' and 'Field'. The Australian Patent Office classifies patent applications according to WIPO's 5 broad technology sectors and 35 International Patent Classification ('IPC') fields.[181] We found that over 40% of patent applications related to the 'chemistry' sector (40.4%).[182] This sector covers fields such as 'organic fine chemistry', 'biotechnology' and 'pharmaceuticals'. The next biggest sector was 'instruments'(18.8%), which predominately reflects applications in 'medical technology'.[183] The next most popular sectors were the 'mechanical engineering' sector (15.7%), for example, 'machine tools';[184] then the 'electrical engineering' sector (14.9%), for example,

179 Through our gender coding, we found that 1.8% of applications had only female inventor names. We also found that 3.2% of applications had only female or ambiguous inventor names.

180 These findings are consistent with *Progress and Potential* (n 112) 12.

181 'Technology Concordance Table' (n 174).

182 The chemistry sector includes the fields of organic fine chemistry, biotechnology and pharmaceuticals, as well as macromolecular chemistry, polymers, food chemistry, basic materials chemistry, materials, metallurgy, surface technology, coating, microstructure and nanotechnology, chemical engineering, and environmental technology: Ulrich Schmoch, *Concept of a Technology Classification for Country Comparisons* (Final Report, June 2008) 9–10.

183 Instruments includes optics, measurement, analysis of biological materials, control and medical technology: ibid 9.

184 This sector includes handling, machine tools, engines, pumps, turbines, textile and paper machines, other special machines, thermal processes and apparatus, mechanical elements, and transport: ibid 10.

'computer technology';[185] and then the 'other fields' sector (10.3%), which includes 'civil engineering'.[186]

(a) *Technology Field and Success Rate*

Overall, 75.0% of applications in the dataset were successful in proceeding to grant. In addition to differences in popularity of sector (above), we also find important differences in success rates across IPC fields. Figure 2 plots summary data based on each of the 35 IPC fields. For each of these fields, the percentage of successful applications is plotted along the vertical axis. Along the horizontal axis, we plot the volume of applications in that IPC field as a percentage of total applications. This gives us the ability to examine each IPC field to see which are popular among inventors versus the success rate in that field.

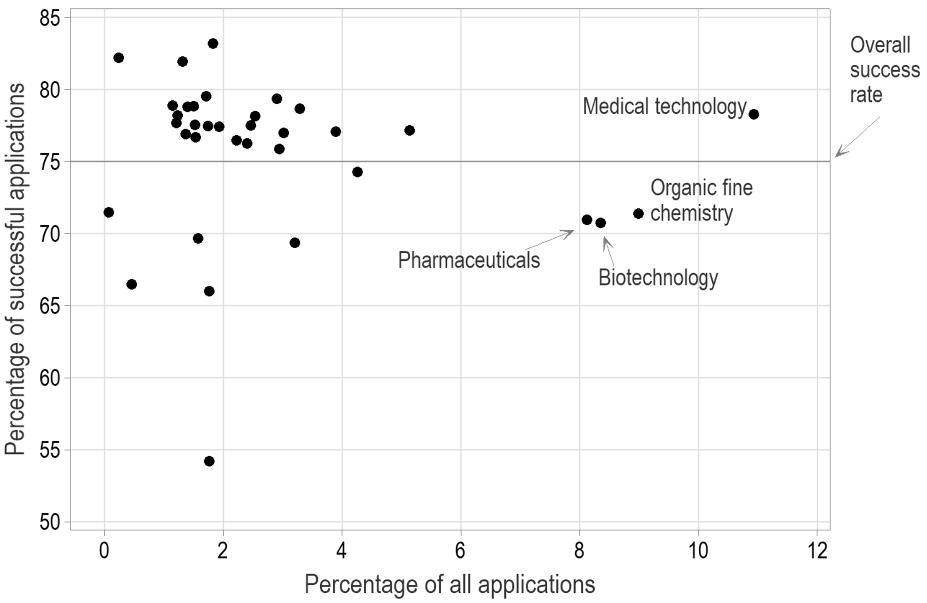

Figure 2: Scatterplot of IPC field percentage success versus percentage of applications*

* Each point on the graph corresponds to a particular IPC field.

Further details are provided in Appendix A.

In Figure 2, looking at the higher percentages of all applications (horizontal axis), we see that four IPC fields represent a large percentage of total applications. These popular fields are medical technology, pharmaceuticals, organic fine chemistry and biotechnology (the 'top 4 fields'). Although applications in these top 4 fields are comparatively frequent, 3 of the 4 fields report less success than

185 This sector includes electrical machinery, apparatus, energy, audiovisual technology, telecommunications, digital communication, basic communication processes, computer technology, IT methods for management, semiconductors: ibid 9.

186 This sector includes furniture, games, other consumer goods, civil engineering: ibid 10.

the average success rate of 75.0%; for example, pharmaceuticals (71.0%), organic fine chemistry (71.4%) and biotechnology (70.2%). Only applications in medical technology (78.3%) surpass the average success rate. Therefore, the most popular fields for inventors are not the fields that attract the most success. These findings support anecdotal evidence that in Australia, patent success is lower than average for popular life sciences, such as biotechnology and organic chemistry.

Looking at the vertical axis, we see that there are some fields that are clearly above the average success rate. The top 3 fields in terms of application success correspond to the physical sciences (as opposed to life sciences). The top 3 fields (with success rates) are 'basic communication processes' (82.2%), 'materials and metallurgy' (83.2%) and 'thermal processes and apparatus' (82.0% success). Looking along the horizontal axis, we can see that there were comparatively fewer applications in these fields. For example (with application rates), 'basic communication processes' (0.2% of all applications), 'materials and metallurgy' (1.8% of all applications), and 'thermal processes and apparatus' (1.3% of all applications). Therefore, the three most successful fields represent a relatively low percentage of applications.

(b) Technology Field and Gender

We next examine the gender distribution across fields to see whether female inventors cluster in the life sciences. To gain an understanding of team size, gender distributions and IPC fields, for each IPC field we ascertained the average number of female inventors and the average number of male inventors per patent application. This is shown in Figure 3.

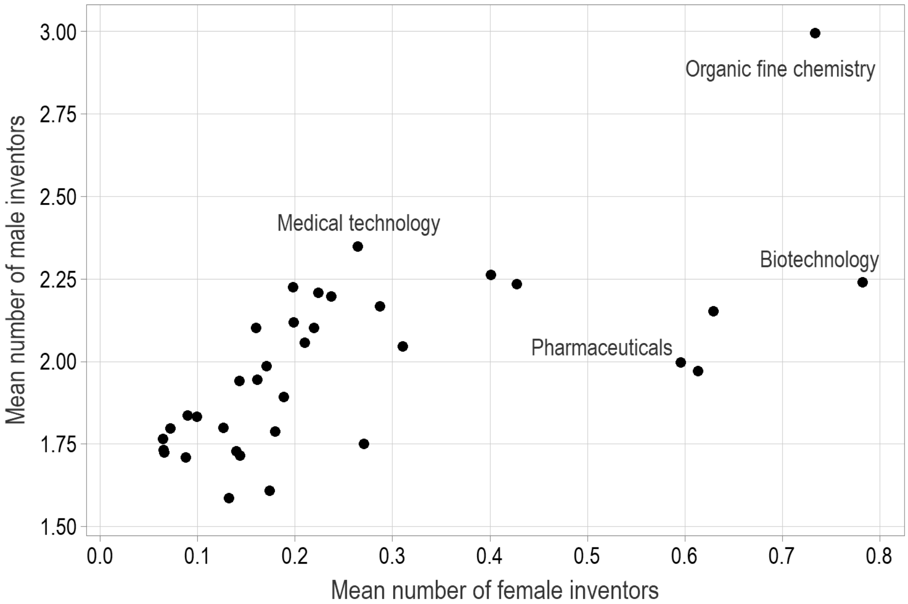

Figure 3: Scatterplot of mean number of female inventors versus mean number of male inventors*

* Each point on the graph corresponds to a particular IPC field.

Further details are found at Appendix A.

Figure 3 shows the average number of female inventors (number of female inventors divided by total inventors) plotted against the average number of male inventors (number of male inventors divided by total inventors). The top 4 fields in terms of the number of applications are labelled. This plot shows that patent applications in organic fine chemistry, on average, listed larger inventor teams of 3.0 males and 0.73 females. This plot also shows that applications with more male inventors tend to have more female inventors; that is, the overall pattern shows a positive association.[187] Fields closer to the vertical axis of the graph have fewer female inventors than fields further from the vertical axis. Fields in the bottom left corner of Figure 3 have relatively few male or female inventors, but on average more males.

In summary, Figure 3 shows that when female inventors do appear on patent applications, they do so in mixed teams and cluster in the life sciences with 61.4% of all female inventors in the top four most popular fields of medical technology, organic chemistry, pharmaceuticals and biotechnology. Note that over 50% (52.9%) of all female inventors were in 3 fields – biotechnology, pharmaceuticals or organic fine chemistry – and Figure 2 shows that these fields have lower than average rates of success at IP Australia.

B Statistical Modelling of Patent Application Success

A key goal of this article was to analyse the effect of inventor gender on the success rate of a patent application. To do this, we used logistic regression analysis where the odds of patent success ('granted' vs 'not granted') are modelled. In a logistic regression, the 'odds of success' represent the probability of success divided by the probability of failure. When the 'odds of success' are one, the probability of success is the same as the probability of failure. We can consider how the odds might be influenced by other characteristics of the application by including explanatory variables such as gender in our statistical models.

In our models, we always include the four primary explanatory variables of interest ('gender variables'). These are the number of:

- female identified inventors;
- male identified inventors;
- ambiguously named inventors; and
- gender-not-identified inventors.

Each of these four gender variables is continuous. Model 1 provides the odds of a patent being granted in relation to the four gender variables. In other words, 'how does gender relate to the odds of patent success?'.

Our discussions with IP Australia as well as the literature, indicate that other factors besides gender have an influence on the odds of a patent being granted. The year of application may have an impact; for example, legislative reforms in 2013 raised the quality threshold for patent grants and triggered a surge in patent

187 There are 2 IPC fields with an average of more than 0.6 female inventors in Figure 3 that are not labelled; these are Food Chemistry (mean = 0.61 females per application) and Analysis of Biological Materials (mean = 0.63 females per application).

applications prior to implementation.[188] Other factors could be whether the patentee is internationally oriented (as indicated by a *PCT* application), and whether the application is in a particular technology field. We therefore include these variables in Models 2 and 3.

Model 2 includes 4 gender variables, the year of application (2001–15) and *PCT* application (yes or no). Model 3 includes all variables in Model 2 plus the IPC technology field (35 fields). By presenting these 3 models, we can examine the effect of gender alone (Model 1), and investigate the effect when adjusted for other, potentially confounding variables (Models 2 and 3).

Table 1: Odds ratios for four gender variables in three main effects logistic regression models

Number of:		**Model 1**	**Model 2***	**Model 3***
female inventors	Odds ratio	0.94	0.93	0.99
	95% CI	0.93, 0.95	0.92, 0.93	0.98, 1.01
	p-value	<0.001	<0.001	0.237**
male inventors	Odds ratio	1.02	1.02	1.03
	95% CI	1.02, 1.03	1.01, 1.02	1.02, 1.03
	p-value	<0.001	<0.001	<0.001
ambiguous names	Odds ratio	1.05	1.04	1.06
	95% CI	1.03, 1.07	1.01, 1.06	1.03, 1.08
	p-value	<0.001	0.002	<0.001
not identified	Odds ratio	1.08	1.08	1.09
	95% CI	1.07, 1.09	1.07, 1.09	1.08, 1.11
	p-value	<0.001	<0.001	<0.001

* Model 2 adjusts for year and PCT application; Model 3 adjusts for year, PCT application and IPC technology field.

** For the effect of the number of female inventors in Model 3, the *p*-value was 0.237; this suggests that the observed odds ratio is consistent with the null hypothesis of no effect of the number of females on the odds of patent application success.

For Models 1, 2 and 3, we report the estimated odds ratio for each of the primary gender variables in Table 1. These odds ratios quantify the change in the odds of patent success for a 1-point increase in the value of an explanatory variable, such as

188 'The *Intellectual Property Laws Amendment Act 2012 (the Raising the Bar) Act* came into effect on 15 April 2013. It has a number of broad objectives, including raising the standards required to support the grant of a patent in Australia and making them more consistent with those applying in other countries. As a result, the "inventive step" required to receive a patent in Australia is now more closely aligned with that in other major IP jurisdictions': IP Australia, *Report 2021* (n 8) ch 2 n 3.

the number of female inventors. In reporting these models, we focus on the effects of the 4 gender variables, without detailing the other explanatory variables where present.[189] With a large dataset like the one considered here, small *p*-values can arise even if the magnitude of the effects under consideration are small; hence, we report but do not focus on the *p*-values obtained in the analyses.[190] Instead, we focus on the magnitude of the effects (odds ratios) observed, with their confidence intervals.

1 Model 1: Unadjusted Gender Model

The first row in Table 1 shows the odds ratios for the number of female inventors. Model 1 considers patent success as a function of gender only. In Model 1 the odds ratio is 0.94, meaning that the odds of a patent being granted decreases as the number of female inventors increases. For example, the odds for 3 female inventors being granted a patent are reduced by about 6% relative to the odds for 2 female inventors. In contrast, the odds ratios for the number of male inventors, ambiguous inventors and not identified inventors are all greater than one, indicating increasing odds of success with increasing numbers of non-females.

In other words, in the unadjusted model, increasing numbers of females in an application reduces the odds of success, whereas increasing numbers of males increases the odds of success. In this model, there are also increasing odds with increasing numbers of ambiguous or unidentified names; this may reflect the effects of increasing team size in general, although this is difficult to ascertain.

2 Model 2: Gender, Year and PCT Model

Model 2 considers patent success as a function of gender, plus year of application and whether it is a *PCT* application (yes or no). The odds ratios for the 4 gender variables (reported in Table 1) are substantively similar to those for Model 1 – the gender effects described above do not change when year and *PCT* application are also considered. Hence, Model 2 provides evidence similar to Model 1 in relation to gender effects.

3 Model 3: Adding Technology Field

Model 3 considers gender, plus year of application (2001–15), application type (*PCT* or non-*PCT*) and primary IPC technology field. In Model 3, the odds ratios for the number of non-female inventors (males, ambiguous and unidentified inventors) are substantively similar to those in Models 1 and 2. The odds ratio for the number of females is, however, now 0.99. When compared to Models 1 and 2, the impact of adding a female to the odds of success is still negative but the degree of the negative impact (on the odds of success) is much smaller.

189 Ibid.

190 A *p*-value is provided in Table 1 in relation to each explanatory variable considered in each model. The *p*-value is for a test of the null hypothesis that there is no effect of the explanatory variable under consideration on the odds of patent application success. A small *p*-value suggests that the odds ratio observed (or 1 more extreme) is implausible, if there is no effect as assumed under the null hypothesis. An almost universal criterion for small *p*-values is a significance level, set a priori, of 0.05.

Model 3 shows that even when controlling for technology field, adding more males, or adding more (ambiguous or unidentified) team members, increases the odds of success, but increasing numbers of female team members does not substantively change the odds of success. This can be interpreted as a gendered effect.

This gender effect applies across both single-gender and mixed-gender teams. To assist in understanding Model 3, we present a single-gender plot in Figure 4. This plot shows the probability of application success predicted by Model 3 for teams of the same gender, where team size is between 1 and 5 inventors.[191]

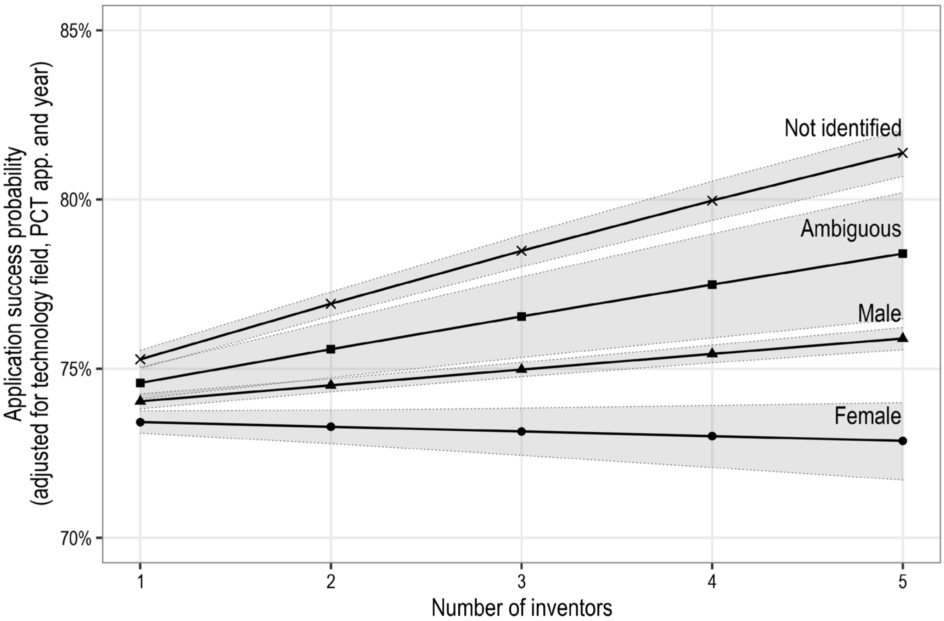

Figure 4: Application success probability for single-gender teams*

* Figure 4 shows the model's predicted probability of success for single-gender teams, averaged over year, *PCT* status and IPC field.

Figure 4 shows that when the number of inventors is 1, female inventors have a probability of success of 73.4%. This is slightly lower than for lone male inventors (74.0%) and other non-female inventors. If we add another member to the team (of the same gender), the probability of success for 2 females does not substantially change (73.3%). In contrast, the probability of success for male inventors rises (74.5%), as does the probability of success for other non-female inventors. The shading in the graph represents 95% confidence intervals around the estimates; these intervals will tend to be wider where there are fewer inventors in a gender

191 The number of inventors could be greater than five but is restricted in the plot to between one and five to illustrate our point.

class. Model 3 indicates that increasing team size relates to increased odds of success unless the additional team member is a female inventor.

4 Summary of Logistic Regression Analysis

Models 1, 2 and 3 support the hypothesis that female inventors have lower odds of success in being granted a patent than male, and other non-female inventors. Importantly, the female gender effect seen in Models 1 and 2 is diminished in Model 3 when IPC technology field is included as an explanatory variable. Therefore, Model 3 indicates that the gender effect in Models 1 and 2 may be partly explained by the fact that females work in technology fields with lower odds of success. We illustrate this effect in Figure 5.

Figure 5 shows the average number of women per application versus the odds of application success for each of the 35 IPC technology fields. Recall that 52.9% of all female inventors were in only 3 fields – biotechnology, pharmaceuticals or organic fine chemistry – fields which had high popularity but lower than average success rates.

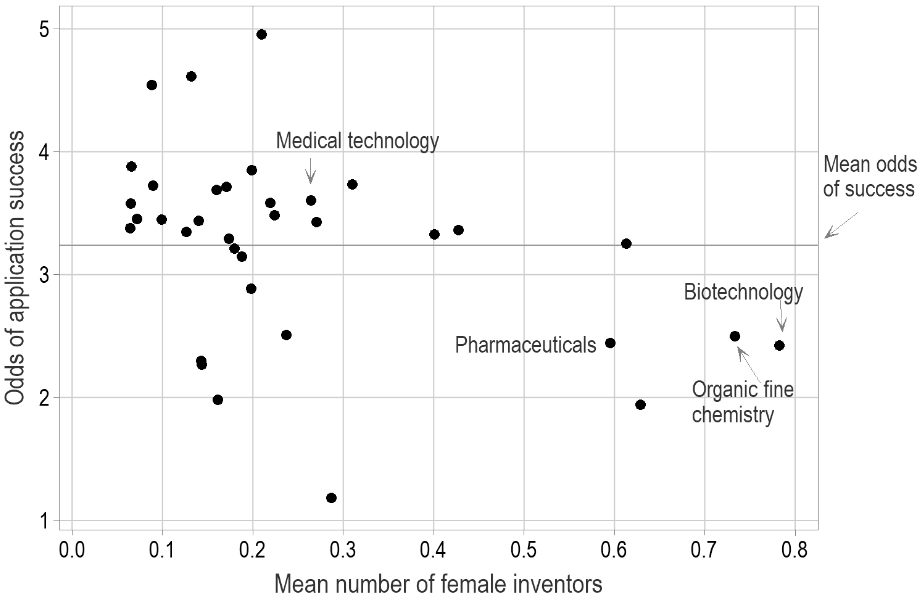

Figure 5: Scatterplot of mean number of female inventors versus odds of application success*

* Each point on the graph corresponds to a particular IPC field. The odds refers to the number of successful applications divided by the number of unsuccessful applications.

The mean odds of success across all 35 IPC fields were 3.24. We can see from Figure 5 that the highest mean number of female inventors per application was for biotechnology (0.78) and organic fine chemistry (0.73), but these fields had odds of success lower than the average of 3.24. In other words, female inventors are applying for patents in fields where there is less success.

This confounding effect is consistent with USPTO studies, and supports the argument made by Jensen, Kovács and Sorenson that the lower odds for female success may stem from 'women applying at higher rates than men to technology classes with lower acceptance rates. In those classes, it is more challenging for anybody to get a patent approved, regardless of gender.'[192]

Nevertheless, it is important to note that this fact does not explain away all of the gender disparity. Model 3 shows that, even when we control for the effect of technology field, a gender effect can still be found where adding a male or non-female member to a team increases the odds of success (irrespective of technology field) but adding a female does not. Therefore, although there is some support for the argument that – women don't succeed in patents because they work in less patentable fields – Model 3 shows that even when we control for this effect, a gender bias remains.

C Limitations

In addition to the assumptions and limitations noted in the method, a limitation of the data is that 15.4% of names were coded as 'not identified' as against the SSA database. It could be that these were foreign names attached to an important number of female inventors. We hope to examine this population once country of origin codes become available from IP Australia and we can conduct foreign name matching.

The results also prompt a second question. That is, do the life sciences attract lower odds of success because females participate in those fields, and females are less successful? Or, as Jensen, Kovács and Sorenson assume, would those fields be less patentable regardless of the gender of inventors? This is something that we cannot resolve in this study.

In this study we were unable to segregate Australian from non-Australian patent applications. Therefore, we cannot draw inferences or connections between Australian or non-Australian policies used to increase female participation in STEM and whether these impact participation in the patents system. We hope to examine this in future work in parallel with advancements in the public disclosure of Australian patent data.

V DISCUSSION

Our first two models (controlling for *PCT* and year of application) indicate a gender bias whereby increasing the number of female inventors related to decreasing odds of success. These models also showed that increasing the number of non-female (ie, male, ambiguous or not identified) inventors, related to increasing odds of success. In Model 3, which also adjusted for technology field, the 'disadvantage' relating to female applicants (in Models 1 and 2) was diminished. This indicates that the gender effect in Models 1 and 2 comes partly from females working in less

192 Jensen, Kovács and Sorenson (n 25) 307–8.

patentable technology fields which we find are the life sciences. However, even after controlling for this confounding effect we find a gender bias remains. This is because Model 3 (which controls for technology field) shows that increasing non-female inventors to a team still relates to increasing odds of success.

A Attributing the Gender Effect

It would be incorrect to simply attribute the gender effects in Model 3 to implicit bias of a patent examiner ('examiner effects'). This is because we do not have sufficient data to rule out other proximal causes within the patent prosecution process, namely, 'patentee effects'. A patent application does not simply proceed to grant; rather, patent prosecution is 'a process of contestation and negotiation'.[193] As argued by Chien, 'both examiner and applicant behavior matter: the examiner determines whether or not and how to reject an application, and the applicant decides how to respond, and whether to continue pursuing the patent.'[194]

We define the 'patentee effect' as the collective behaviour of the inventor, applicant (typically a company or a university) and the agent (such as the patent attorney). We note that (according to IP Australia) Australian patent examiners typically deal with the applicant's agent and rarely with the applicant or inventor themselves. Nevertheless, an agent typically receives instructions from their client – the applicant or inventor – so in this sense the agent represents the patentee collective. In addition, examiners are not blind to the names of the inventors and names may be accessed as part of the examination process.[195] Therefore, while examiners may not speak to the applicant or inventor directly, they may be aware of their names.

We argue that the gender effect seen in Model 3 could arise from either an examiner effect or a patentee effect. In relation to the former, as argued in US studies, Australian patent examiners could carry implicit bias against female inventors. Jensen, Kovács and Sorenson's data and methodology allowed them to conclude that in the US, examiner-side bias was responsible for the majority of the lower probability of female success.[196] However, we cannot attribute gender bias to Australian patent examiners with such granularity due to the limitations of the dataset. We hope to interrogate the issue as more data becomes available. We also caution that excessive focus on examiner side behaviour could disincentivise the need to examine the many complex legal and social structures that diminish the participation and success of women in the patent system at large. We label this: the female patentee effect.

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193 Colleen V Chien, 'Rigorous Policy Pilots the USPTO Could Try' (2019) 104 *Iowa Law Review Online* 1:1–30, 2.

194 Ibid 27.

195 IP Australia, '4.1.3.6 Applicant and/or Inventor Name Searching' (n 171).

196 Jensen, Kovács and Sorenson (n 25) 309.

B Potential Female Patentee Effects

As discussed below, there is some evidence to suggest that gender effects may stem from the female patentee side. For example, it has been found in US studies that female patentees have less funds,[197] less stamina,[198] or less mentoring to deal with objections (or with what they view as unreasonable objections) from the patent office. These factors may make it more likely for female patentees to abandon an application.

In relation to less funds, studies in the US show that financial barriers for female patentees are particularly daunting[199] and men are significantly more likely to secure venture capital or outside investor support.[200] Access to funds is important as patent prosecution can be very costly. In relation to stamina, the Jensen, Kovács and Sorenson study showed that applications with female inventors were less likely to appeal a rejection.[201] This of course, may relate to a lack of funds but it may also reflect a rational decision. Abandoning an application may be rational if the effort invested is rewarded with an unfair result. For example, studies of USPTO data show that female inventors receive a higher number of office actions,[202] rejections[203] and have 'a smaller fraction of their claims allowed'.[204] In other words, female inventors at the USPTO face more scrutiny for less rewards than do male inventors. If female inventors face greater hurdles during prosecution only to be rewarded with less valuable patents, a rational response could be to abandon an application rather than endure expensive negotiation over a set of limited claims.

US studies indicate that mentoring and institutional support to negotiate the patenting process is particularly important for women. For example, these studies show that women in the academic life sciences (in comparison to men) have different attitudes to risk, competition and 'selling' of their own research.[205] Ding, Murray and Stuart found that senior female faculty were less likely to seek advice from broad-reaching networks to initiate patents, felt excluded from industry relationships and relied more on institutional encouragement where available.[206] These studies indicate that female inventors may have less of an appetite or have less support to negotiate a contested patent prosecution.[207] We hope to explore the potential for both examiner and patentee effects in future work.

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197 Paula E Stephan and Asmaa El-Ganainy, 'The Entrepreneurial Puzzle: Explaining the Gender Gap' (2007) 32(5) *Journal of Technology Transfer* 475, 481 <https://doi.org/10.1007/s10961-007-9033-3>; Lori Andrews, 'The Technology Enterprise: Systemic Bias Against Women' (2019) 9(5) *University of California Irvine Law Review* 1035, 1049.

198 Jensen, Kovács and Sorenson (n 25) 307.

199 Jessica Milli et al, *Equity in Innovation: Women Inventors and Patents* (Report, 29 November 2016) 18–19.

200 Stephan and El-Ganainy (n 197) 481; Andrews (n 197) 1049.

201 Jensen, Kovács and Sorenson (n 25) 308.

202 Milli et al (n 199) 12.

203 Jensen, Kovács and Sorenson (n 25) 307.

204 Ibid.

205 See Stephan and El-Ganainy (n 197) summarising the field.

206 Ding, Murray and Stuart (n 113).

207 See, eg, ibid. See also Whittington and Smith-Doerr, 'Gender and Commercial Science' (n 154).

C Our Results and Studies of USPTO Data

Our results are generally consistent with studies of gender and patents at the USPTO. However, more granular comparisons with those studies are not possible due to differences in research methodologies and different contextual factors such as the type of patents that flow through each jurisdiction. The overwhelming majority of patents filed at IP Australia are *PCT* applications. We found that between 2001 and 2015, 76.8% of applications were via the *PCT*. In contrast, only 23.2% were non-*PCT*, that is, filed directly with IP Australia. This has consequences for the quality of patents submitted for examination. The *PCT* tends to be used by both Australian and non-Australian 'firms that operate internationally'.[208] These applicants are likely to be better resourced and more sophisticated participants, and to submit 'better' inventions and 'better' drafted applications. 'Better' in this sense means the applicant believes the invention merits investment and protection in more than one jurisdiction. In support of this contention, we found that *PCT* applications had a higher success rate (75.8%) than non-*PCT* applications (72.1%).[209]

In contrast, at the USPTO, *PCT* applications are the minority of applications. For example, in 2010, *PCT* applications were only 18.5% of annual applications at the USPTO.[210] In addition, USPTO applications are more evenly split between domestic and non-resident applications.[211] For example in 2010, 49.4% of applications received by the USPTO came from US residents.[212] In contrast, in 2010 only 9.7% of IP Australia applications came from Australian residents.[213] This is relevant as large foreign inventors tend to have higher acceptance rates than small US inventors,[214] and these larger firms are more likely apply via the *PCT*. If we assume that *PCT* applicants and non-resident filers have more resources or incentives to file high-quality patents, then given the differences in filing profiles, IP Australia could receive better quality patents than does the USPTO. We propose that this and potential country effects in our large nonresident sample may explain some of the differences between USPTO studies and the present study.

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208 IP Australia, *Report 2021* (n 8) ch 2.

209 Note that, as discussed in Part III(B)(1), we excluded 55,535 patents that lapsed before examination. If we included these, the outcomes would be coded as 'not granted' and would lower the overall success rate.

210 WIPO statistics indicate that, in 2010, only 18.5% of USPTO applications were via the *PCT* (90,931 applications) out of 490,226 applications filed. In contrast, in 2010, 76.5% of IP Australia applications were via the *PCT* (19,041 applications) out of 24,887: see 'Statistical Country Profiles: United States of America', *WIPO* (Web Page, November 2021) <https://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=US>; WIPO, 'Statistical Country Profiles: Australia' (n 23).

211 See WIPO, 'Statistical Country Profiles: USA' (n 210); WIPO, 'Statistical Country Profiles: Australia' (n 23).

212 WIPO, 'Statistical Country Profiles: USA' (n 210).

213 WIPO, 'Statistical Country Profiles: Australia' (n 23).

214 As found in Carley, Hegde and Marco's study of 1996–2013 patents, although they found that '[t]hese numbers should be interpreted with caution. Lower allowance rates for small US applicants could reflect higher propensity for abandonment or differences in the nature of subject matter claimed in the applications. Similarly, large foreign inventors may enjoy higher allowance rates because they seek protection in the United States for only their most important inventions, or because they are more likely to have access to the necessary legal and financial resources': Michael Carley, Deepak Hegde and Alan Marco, 'What Is the Probability of Receiving a US Patent?' (2015) 17 *Yale Journal of Law and Technology* 203, 214–15.

VI CONCLUSION

This study has shown that female participation in the Australian patent system is low, with only 23.6% of standard applications in the dataset (2001–15) listing at least 1 female inventor. We find this figure is driven by female inventors working in mixed gender teams (21.8%) rather than solo female (1.4%) or all female teams (0.4%). Our results in Model 3 (controlling for *PCT*, year of application and technology field) show that adding non-female (eg, male) inventors to a team increased the odds of success but that adding a female inventor did not. We propose that this gender effect could be related to examiner bias, patentee gender effects or a combination of both.

We also confirm the anecdotal belief that female inventors cluster in the life sciences; for example, 61.4% of female inventors were identified in patents across only 4 fields: medical technology, pharmaceuticals, organic fine chemistry and biotechnology. We propose that policies that encourage mixed gender teams of inventors in these life sciences fields may be one way to increase female participation in the patent system.

In relation to the objects clause, we agree with practitioner concerns that a narrow interpretation of 'technological innovation' could affect the life sciences more than archetypal mechanical fields. We also agree with concerns of feminist legal scholars that *TRIPS* concepts of technological innovation (embedded in the objects clause) skew towards male-centric modes of innovation.[215] Our data supports these theoretical concerns by showing that female inventors cluster in four life sciences fields and three of these fields have lower than average acceptance rates. We argue that policies that curb patentability of the life sciences (eg, by imposing a narrow concept of technological via an objects clause) will inevitably have a larger impact on female inventorship levels than on males by virtue of the skewed gender distribution across fields.

It is still unclear how patent examiners and Australian courts will interpret the objects clause in relation to patentability. Nevertheless, we present this data to show that patent applications and outcomes are already gendered and that policies that affect patents will likely have a skewed impact on female inventors today and on the downstream leaky STEM pipeline. We hope to conduct further work to understand the causes of the gender disparity at the patent application and examination stage. More work is needed to better identify 'leaks' and propose concrete solutions particularly given the significant investments made to increase Australia's female STEM participation. We also seek to examine issues specifically related to Australian female inventorship.

As researchers we are acutely aware that empirical research into gender can create a 'double bind' as it may validate prejudices against women rather than illuminate systemic inequities.[216] Our purpose with this article is to draw attention to the gender disparities in the patent system which we see as a product of these

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215 See, eg, Yanisky-Ravid (n 115) 873.

216 Ann Bartow, 'Patent Law, Copyright Law, and the Girl Germs Effect' (2016) 90(3) *St John's Law Review* 579, 591.

systemic inequities. We hope that this research is used to stimulate conversations that leads to meaningful structural and social change.

APPENDIX A[217]

Table A1: Supplementary Data (Jan 2001 – Dec 2015), n = 309,544 standard patent applications

IPC Field of Technology	Percentage total applications	Percentage success	Mean number of female inventors	Mean number of male inventors
Analysis of biological materials	1.77%	66.0%	0.63	2.15
Audio-visual technology	1.53%	76.7%	0.17	1.61
Basic communication processes	0.24%	82.2%	0.13	1.59
Basic materials chemistry	3.90%	77.1%	0.43	2.24
Biotechnology	8.35%	70.8%	0.78	2.24
Chemical engineering	2.90%	79.4%	0.20	2.12
Civil engineering	5.14%	77.2%	0.06	1.77
Computer technology	4.26%	74.3%	0.20	2.23
Control	1.58%	69.7%	0.14	1.94
Digital communication	2.40%	76.3%	0.18	1.79
Electrical machinery, apparatus, energy	2.46%	77.5%	0.10	1.83
Engines, pumps, turbines	1.53%	77.6%	0.07	1.80
Environmental technology	1.40%	78.8%	0.17	1.99
Food chemistry	2.22%	76.5%	0.61	1.97
Furniture, games	3.21%	69.4%	0.14	1.72
Handling	3.02%	77.0%	0.13	1.80

217 Technology Concordance Table (n 174).

IPC Field of Technology	Percentage total applications	Percentage success	Mean number of female inventors	Mean number of male inventors
IT methods for management	1.77%	54.2%	0.29	2.17
Machine tools	1.50%	78.8%	0.09	1.84
Macromolecular chemistry, polymers	1.37%	76.9%	0.40	2.26
Materials, metallurgy	1.82%	83.2%	0.21	2.06
Measurement	3.29%	78.7%	0.16	2.10
Mechanical elements	1.71%	79.5%	0.07	1.73
Medical technology	10.93%	78.3%	0.26	2.35
Micro-structural and nanotechnology	0.07%	71.5%	0.24	2.20
Optics	1.21%	77.7%	0.22	2.21
Organic fine chemistry	8.98%	71.4%	0.73	3.00
Other consumer goods	1.93%	77.4%	0.27	1.75
Other special machines	2.94%	75.9%	0.19	1.89
Pharmaceuticals	8.12%	71.0%	0.60	2.00
Semiconductors	0.46%	66.5%	0.16	1.95
Surface technology, coating	1.23%	78.2%	0.22	2.10
Telecommunications	1.75%	77.5%	0.14	1.73
Textile and paper machines	1.15%	78.9%	0.31	2.05
Thermal processes and apparatus	1.31%	82.0%	0.09	1.71
Transport	2.53%	78.2%	0.06	1.73