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# A sub-national Economic Complexity analysis of Australia's states and territories

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## Abstract

This paper applies Economic Complexity analysis to the Australian sub-national economy (9 regions with 506 exported goods and services). Using a 2009 Australian multi-regional Input-Output table for base data, we determine the number of export goods or services in which each state and territory has a revealed comparative advantage, and visualise the complexity of Australia's interstate and international exports. We find that small differences in industrial capability and knowledge are crucial to relative complexity. The majority of states (especially Western Australia) export primarily resource intensive goods, yet interstate trade has many complex products that are not currently internationally exported.

**Keywords:** economic complexity, implied comparative advantage, Australia; input-output; sub-national; regional

**JEL classifications:** H70, O41, O47, O56

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20

## 21 1. Introduction

22 The long-term prosperity of Australia's states and territories depends on their success in  
23 (re)building their economic competitiveness in a post-global financial crisis, and post-  
24 Australian mining boom, globally-linked economy. The upcoming closure of the Victorian and  
25 South Australian concentrated automotive industry (Davis, Dowling, & Norrie, 2008; Taylor,  
26 2013), and the 2015 closure of the Tasmanian heavy mining vehicle industry(Cook, Silici, &  
27 Adolph, 2015) is further weakening these states' manufacturing capabilities with the ensuing  
28 reduction in economic complexity negatively impacting on state and national prosperity. The  
29 correct identification of future industry sectors that will be beneficial to transition into, and  
30 invest in, is therefore vital for future prosperity.

31

32 An impediment to identifying beneficial sectors is the current inability to identify — at the  
33 sub-national level — competitive and comparative advantages; how best to achieve these  
34 advantages, and how to monitor progress. Hausmann and Hidalgo (Hausmann & Hidalgo,  
35 2013; Hausmann, Hidalgo, Bustos, et al., 2014; Hidalgo & Hausmann, 2009) have developed  
36 *Economic Complexity* (EC) analysis as a method to identify current export capability as well as  
37 predict future economic growth. EC analysis has been used at a global level (Felipe, Kumar,  
38 Abdon, & Bacate, 2012; Hausmann, Hidalgo, Bustos, et al., 2014), the national level  
39 (Hausmann & Hidalgo, 2013), and at the city level (Nepelski & De Prato, 2015). However, the  
40 scarcity of detailed interstate trade data has so far proven to be a challenge in adapting EC to  
41 the sub national level.

42

43 In this paper we propose a novel source of trade data to allow a further proliferation of EC  
44 analysis: high resolution Multi-Regional Input-Output (MRIO) tables. IO tables contain  
45 matrices describing the supply, use, import, and margins of goods and services by industry  
46 sectors in economies, with data expressed in monetary terms (UN, 1999). Traditionally, IO  
47 tables have been confined to a limited number of aggregated macroeconomic sectors or  
48 commodities due to computational power limits and data availability. However, recently  
49 global and regional MRIO databases that have a high resolution of specific commodities have  
50 been produced (Lenzen, Moran, Kanemoto, & Geschke, 2013; Lenzen et al., 2014). IO tables  
51 have been previously used to examine national EC (Szyrmer, 1985a, 1985b), with Wood and  
52 Lenzen (2009) providing an analysis of Australia's internal EC from 1975 to 1999 at a 344  
53 intermediate industry sector resolution. Wood and Lenzen revealed that Australia has  
54 transformed since 1975, with decreasing primary and manufacturing sectors and increasing  
55 tertiary and service sectors. Wood and Lenzen did not consider sub-national or international  
56 linkages and trade in their analysis, instead investigated the developments of economic  
57 structure solely at the national level.

58

59 This paper applies Hausmann and Hidalgo's EC analysis method to examine the complexity  
60 of the Australian sub-national (interstate) economy. We determine the number of export  
61 goods or services that each state and territory has a revealed comparative advantage (RCA)  
62 in, and visualise the relative complexity of Australia's interstate and international exports.  
63 The application of the EC methodology to sub-national level economies is considered a  
64 novelty in this paper. Likewise, our use of a subregional Multi-Regional Input-Output (MRIO)  
65 table for trade and export data, and the inclusion of service based sectors, are other  
66 innovations specific to this paper. Our paper differs from the work of Wood and Lenzen by

67 focusing on using the export and import data of MRIO tables rather than the internal  
68 production and consumption data.

69

70 Section two provides a theoretical background to EC analysis. Section three lists the data  
71 sources used for the EC analysis. Section four presents the results of EC analysis. Section five  
72 discusses the results, and section six concludes. Appendixes are provided in the online  
73 accompanying data. These provide detailed results of all analysis.

74

## 75 **2. Theoretical background**

76 This section summarises the theory behind Hausmann and Hidalgo's (Hausmann & Hidalgo,  
77 2013; Hausmann, Hidalgo, Bustos, et al., 2014; Hidalgo & Hausmann, 2009) EC analysis with  
78 specific attention given to its use in measuring sub-national trade.

79

80 The core concept of EC is that specific products are produced when a combination of  
81 knowledge, natural resources and monetary capital, comes together in a specific way – with  
82 each economy having its own combination of the three factors. EC theory proposes that  
83 since natural resources and monetary capital are scarce, that it is by increasing the amount  
84 of knowledge in an economy that more products can be made available for production,  
85 specifically for export. In the case of sub-national states, this export of goods could be to  
86 other sub national entities, or international export. Likewise, it is the differentiation of  
87 knowledge capital between sub national states – in addition to natural resources and  
88 monetary capital – that will help shape each state's unique EC measures.

89

90 Each economy's EC is also influenced by both 'relationship' capital – cultural collaboration  
91 propensity; network economic effects due to economic agent density – and 'organisational'  
92 capital – policy landscape, rules, regulations, systems, processes etc. These two additional  
93 forms of capital are difficult to quantify, and are not captured in current EC modelling. This  
94 means that EC modelling has limits to the amount of economic transformation it can explain  
95 – typically 70% of the change.

96

97 Hausmann and Hidalgo propose that the amount of knowledge capital that an economy has  
98 can be expressed in two complementary measures: Diversity, how many different products  
99 are exported by a given economy  $x$ ; and Ubiquity, how many economies export product  $y$ . The  
100 ubiquity of a product reveals information about the volume of knowledge that is required for  
101 its production, with products that demand large volumes of knowledge only becoming  
102 feasible in places where all the requisite knowledge is available. Likewise, the diversity of  
103 products can indicate the relative level of knowledge in an economy when compared to other  
104 economies.

105

106 In EC modelling, diversity is used to correct the information carried by ubiquity, and ubiquity  
107 corrects the information carried by diversity, this operation is processed a finite number of  
108 times until a convergence is achieved, this is also known as Method of Reflection (Hidalgo &  
109 Hausmann, 2009). Hausmann and Hidalgo note this relationship as a mathematical formula,  
110 which provides as output the Economic Complexity Index (ECI), a ranking of economies by  
111 their complexity; and Product Complexity Index (PCI), a ranking of products by their  
112 complexity. The greater the amount of data in the model (number of products, and number  
113 of economies) the greater the intricacy, and the truer the representation of the system. This

114 means that models with smaller numbers of aggregated products, or fewer economies, may  
115 not present reliable depictions of ECI or PCI and associated other measures.

116

117 Using the PCI, EC analysis creates a holistic measure: *opportunity value*<sup>1</sup> — the value to be  
118 gained by an economy from shifting production to unexploited prospects (more complex  
119 products). This value is relative to the level of technology already present in that economy.  
120 Each product also has a relative *opportunity gain*<sup>2</sup> — the ‘spillover’ benefit to an economy  
121 from producing new products in terms of providing capacity for producing even more  
122 complex products. The opportunity value score is higher for economies that are already  
123 closer<sup>3</sup> to more products and products that are more complex. This implies that economies  
124 with a low level of knowledge have fewer opportunities for expansion available and that the  
125 expansion is harder to achieve. Economies with high levels of complexity typically have few  
126 remaining products left to manufacture in their chosen manufacturing field<sup>4</sup> Economies with  
127 intermediate complexity can differ in their opportunity value scores depending on the  
128 complexity of the products (i.e. the PCI value) that they currently produce.

129

130 EC modeling suggests two ways in which economies can grow. First, if the economy is  
131 currently underperforming given the level of complexity it has. Second, Hausmann et al  
132 derive a measure of the ‘proximity’ of each product category to other product categories. In

---

<sup>1</sup> In later publications, Hausmann & Hidalgo use the term *complexity outlook* instead of *opportunity value*.

<sup>2</sup> In later publications, Hausmann & Hidalgo use the term *complexity outlook gain* instead of *opportunity gain*.

<sup>3</sup> That is, closer in *Product Space*, in which products are organised such that Product a is close to Product b if a high number of countries co-export both products. The implication of high co-export numbers is that the two products are very likely to require similar types of expertise.

<sup>4</sup>Unless new knowledge is made available through research, as this can form the basis for new innovations. Note that this also implies that research has a higher importance for economies the higher their economic complexity – which seems to be supported by plotting Business Expenditure on R&D (BERD) as a share of GDP vs Economic complexity for all countries..



133 'product space', those close to one another are co-exported by a large number of countries,  
134 leading to the conclusion that they require similar capabilities for their production. If a  
135 country exports a product with a high Revealed Comparative Advantage (RCA), it is inferred  
136 that the country has an Implied Comparative Advantage (ICA) in those products that are  
137 'close' (in Product Space) to this exported high RCA product and could, therefore, develop  
138 production capacity in those products. It should also expect to be able to develop the  
139 capability to export them with respectable RCA.

140

141 It should be noted that the ECI is not a measure of trade openness, or a report on the level  
142 of export diversification. Nor is the ECI related to an economy's size, population size or the  
143 population's education level. There is, however, some relation between ECI, on the one  
144 hand, and population density (linked to the agglomeration economic benefits of having  
145 mutually beneficial economic agent interaction within relatively close geographical  
146 proximity) on the other. Hausmann and Hidalgo articulates this as denser populations  
147 having closer networks and greater knowledge exchange (Hausmann & Hidalgo, 2013;  
148 Hausmann, Hidalgo, Bustos, et al., 2014; Hidalgo & Hausmann, 2009). We would, as a  
149 consequence, expect propensity to collaborate to affect ECI positively in economies that  
150 have similar size and population density. The ECI is a more generalised measure of potential  
151 growth related to how knowledge is translated into the capability to produce products in  
152 each specific economy.

153

154 Export data is used, rather than total production data, because trade data is more readily  
155 available, and because it is a better indicator of international competitiveness in a product,  
156 that is, it offers a 'value proposition' that appeals to a significant number of 'non-captive'

157 buyers. In addition, for export products to be of importance in EC modelling an economy must  
 158 export a significant quantity – as indicated by the economy possessing a Revealed  
 159 Comparative Advantage (RCA) in that product. EC modelling uses Balassa’s (Balassa, 1965)  
 160 definition of RCA. Specifically, an economy has an RCA in a product if it exports ‘more than its  
 161 “fair” share — that is, more than the share of total world trade that the product represents’.  
 162 As formal definition, if  $X_{cp}$  represents the exports of country  $c$  in product  $p$ , then the Revealed  
 163 Comparative Advantage that country  $c$  has in product  $p$  can be written as

164 
$$RCA_{cp} = \frac{X_{cp}}{\sum_c X_{cp}} / \frac{\sum_p X_{cp}}{\sum_{cp} X_{cp}}$$

165 Of course, in the context of sub-regional EC modelling, the subscript  $c$  would represent the  
 166 State (or sub-region) instead of country.<sup>5</sup>

167 A state or territory has a significant export presence in a good or service within the sub-  
 168 regional economy if its revealed comparative advantage (RCA) is greater than 1 – and thus  
 169 produces more than its “fair share” when compared to total Australian production.  
 170 Accordingly, Revealed Comparative Advantage (RCA) can then be used to construct a matrix  
 171 ( $M_{cp}$  matrix) that connects each state to the products that it makes. The entries in  $M_{cp}$  matrix  
 172 are 1 if state  $c$  exports product  $p$  with Revealed Comparative Advantage larger than 1, and  
 173 zero otherwise.

174 Once the  $M_{cp}$  matrix is constructed, diversity  $k_{c,0}$ , and ubiquity  $k_{p,0}$  can be calculated  
 175 simply by summing over the columns and rows of  $M_{cp}$ , respectively. Formally,  $k_{p,0} =$   
 176  $\sum_c M_{cp}$ .

177

---

<sup>5</sup> We have chosen to use consistent terminology so that the accustomed formulae remain the same and intact.

178 To generate a more accurate measure of the number of capabilities available in a state, or  
 179 number of capabilities required by a product, the information that diversity and ubiquity  
 180 carry is to be corrected by using each one to correct the other. For states, this requires  
 181 calculation of the average ubiquity of the products that each state exports, the average  
 182 diversity of the states that make those products and so forth. For products, on the other  
 183 hand, this requires calculation of the average diversity of the states that make them and the  
 184 average ubiquity of the other products that these states make. This can be expressed by the  
 185 recursion:

$$186 \quad k_{c,N} = \frac{1}{k_{c,0}} \sum_p M_{cp} \cdot k_{p,N-1}$$

187

$$188 \quad k_{p,N} = \frac{1}{k_{p,0}} \sum_c M_{cp} \cdot k_{c,N-1}$$

189

190  $k_{c,N}$  can be rewritten as

$$191 \quad k_{c,N} = \sum_{c'} \widetilde{M}_{cc'} k_{c',N-2}$$

192 where

$$193 \quad \widetilde{M}_{cc'} = \sum_p \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}}$$

194 We then calculate  $\vec{K}$ , the eigenvector that corresponds to the second largest eigenvalue of  
 195 the matrix  $\widetilde{M}_{cc'}$  (because this is the eigenvector that captures most of the variance in the  
 196 system). The Economic Complexity Index (ECI) is defined as

$$197 \quad \overrightarrow{ECI} = \frac{\vec{K} - \langle \vec{K} \rangle}{stdev(\vec{K})}$$

198 where  $\langle \rangle$  denotes the average, *stdev* stands for the standard deviation and  $\vec{K}$  is the  
 199 eigenvector of  $\widetilde{M}_{cc'}$  associated with the second largest eigenvalue.

200

201 Product Complexity Index (PCI) can be defined analogously. Due to the symmetry of the  
 202 problem this can be done simply by swapping the indices  $c$  and  $p$  in the definitions above.

203 Hence, we define PCI as

$$204 \quad \overrightarrow{PCI} = \frac{\vec{Q} - \langle \vec{Q} \rangle}{stdev(\vec{Q})}$$

205 where  $\vec{Q}$  is the eigenvector of  $\widetilde{M}_{pp'}$  associated with the second largest eigenvalue.

206

207 The objective of EC modelling is to provide the ECI and PCI to establish the RCA of each  
 208 economy, and allow identification of potential products that the state might have  
 209 opportunities in. This is where the concept of opportunity value (OV) is useful. Before we see  
 210 a formal definition of OV, it is important to understand the notion of proximity between the  
 211 products, and also the notion of distance between state  $c$  and the product  $p$ . Formally, for a  
 212 pair of products  $p$  and  $p'$  proximity is defined as:

$$213 \quad \Phi_{pp'} = \frac{\sum_c M_{cp} M_{cp'}}{\max(k_{p,0}, k_{p',0})}$$

214 where  $M_{cp} = 1$  if state  $c$  exports product  $p$  with  $RCA_{cp} > 1$  and 0 otherwise, and  $k_{p,0}$  is the  
 215 ubiquity of the product  $p$ . Measure of proximity is based on the conditional probability that a  
 216 state that exports product  $p$  will also export product  $p'$ .

217

218 The concept of distance gives us an idea of how 'far away' each product is given a state's  
 219 current mix of exports. The distance between state  $c$  and the product  $p$  is defined as the

220 weighted proportion of products connected to product  $p$  that state  $c$  is not exporting. The  
 221 weights are given by proximities. Formally,

$$222 \quad d_{cp} = \frac{\sum_{p'} (1 - M_{cp'}) \phi_{pp'}}{\sum_{p'} \phi_{pp'}}$$

223

224 Opportunity Value of a state  $c$  can then be defined as

$$225 \quad OV_c = \sum_{p'} (1 - d_{cp'}) (1 - M_{cp'}) PCI_{p'}$$

226 where  $PCI_p$  stands for PCI of a product  $p$  while  $d_{cp}$  denotes distance between state  $c$  and the  
 227 product  $p$ . The term  $1 - M_{cp'}$  makes sure that we count only the products that the state  $c$  is  
 228 not currently exporting (with  $RCA > 1$ ). Higher OV indicates that a state (and the products it  
 229 produces) are in the vicinity of more products and/or of products that are more complex.

230 OV can be used to calculate the potential benefit to a state if it were to move to a particular  
 231 new product. This is called the “opportunity gain” (OG) that state  $c$  would obtain from making  
 232 (and exporting) product  $p$ . This is calculated as the change in opportunity value that would  
 233 come as a consequence of developing product  $p$ . OG quantifies the contribution of a new  
 234 product in terms of opening up the doors to products of greater complexity. OG of a state  $c$   
 235 is formally expressed as:

$$236 \quad OG_c = \sum_{p'} \frac{\phi_{pp'}}{\sum_{p''} \phi_{p''p'}} (1 - M_{cp'}) PCI_{p'} - (1 - d_{cp}) PCI_p$$

237

### 238 3. Data

239 To measure economic complexity at a sub-national level, sub-national trade data was  
240 sourced from a sub-regional multi-regional Input-Output table (MRIO). This MRIO table was  
241 based on the supply-use structure (Eurostat, 2008), and was obtained from the Australian  
242 Industrial Ecology Virtual Laboratory (IELab) (Lenzen et al., 2014; Lenzen, Wiedmann, et al.,  
243 2013).

244

245 The IELab is a unique cloud-environment for the compilation of high resolution sub-national  
246 IO tables for Australia, it aggregates and harmonises many sources of economic information  
247 into one customised super table (Lenzen et al., 2014; Lenzen, Wiedmann, et al., 2013). The  
248 IELab consists of highly detailed Australian data for 1284 industry sectors (Australian Bureau  
249 of Statistics, 2012a, 2012b) and 2214 regions (Australian Bureau of Statistics, 2010), with the  
250 ability to augment this with additional Rest of the World (ROW) import/export vectors.

251 Using this root classification, users construct customised MRIO tables. In this instance, our  
252 custom MRIO table featured 9 sub-regions of Australia (New South Wales, Victoria,  
253 Queensland, South Australia, Western Australia, Tasmania, Australian Capital Territory,  
254 Northern Territory, and Other territories (comprising Jervis Bay Territory, Christmas Island  
255 and the Cocos (Keeling) Islands), and 506 industry (intermediate) sectors that corresponded  
256 to the ANZSIC06 industry sector classification (Australian Bureau of Statistics, 2006).

257 International trade import/export vectors were added from the EORA world MRIO database  
258 (EconSearch, 2015; Lenzen, Geschke, Kanemoto, & Moran, 2011; Lenzen, Kanemoto, Moran,  
259 & Geschke, 2012; Lenzen, Moran, et al., 2013). Data sources used to create, harmonise, and  
260 concord the MRIO table included the core IELab dataset, the ABS 5206 national IO tables,

261 ABS5220 state accounts (Australian Bureau of Statistics, 2008, 2014, 2015) , state and sub-  
 262 state economic information from EconSearch (EconSearch, 2015), and balancing constraints.  
 263 Results for monetary transactions were given in AUD millions (1,000,000). The time period  
 264 considered was 2009, as this matches the latest time period used in *The Atlas of Economic*  
 265 *Complexity*.

266

267 The technical layout of a supply-use input-output table is as follows:

	Industry	Product	Int. Export	Final Demand	Total
Industry		$\mathbf{V}$			
Product	$\mathbf{U}$		$\vec{E}$	$\mathbf{f}$	$\vec{g}$
Int. Import	$M$				$\vec{q}$

268

269 where  $\mathbf{U}$  is a product-by-industry use matrix,  $\mathbf{V}$  is an industry-by-product supply matrix,  $\vec{E}$  is  
 270 a vector of international exports,  $M$  is a series of vectors of international imports,  $\mathbf{f}$  is final  
 271 demand of products,  $\vec{q} = \mathbf{U}\mathbf{1}^i + \vec{E} + \mathbf{f}_p\mathbf{1}^f$  is total use by product,  $\vec{g} = \mathbf{V}\mathbf{1}^p$  is total use by  
 272 industry, and  $\mathbf{1}^i$ ,  $\mathbf{1}^f$ , and  $\mathbf{1}^p$  are summation operators  $\{1,1,\dots,1\}^T$  for industries, final demand  
 273 categories, and products, respectively.

274

275 Within  $\mathbf{U}$

$$\begin{array}{c}
 \text{State}_1 \quad \text{State} \dots \quad \text{State}_9 \\
 \left. \begin{array}{l} \text{State}_1 \\ \text{State} \dots \\ \text{State}_9 \end{array} \right\} \left[ \begin{array}{ccc} \overbrace{U_{1,1} \quad U_{1,\dots} \quad U_{1,9}} \\ U_{\dots,1} \quad U_{\dots,\dots} \quad U_{\dots,9} \\ U_{9,1} \quad U_{9,\dots} \quad U_{9,9} \end{array} \right]
 \end{array}$$

276

277  $U_{1,1}$  are the internal transactions of State 1, while  $\sum U_{1,2} \dots U_{1,9}$  represents the interstate  
 278 exports of State 1 to the other states. For our EC analysis we used the interstate and  
 279 international export data, with direct interstate consumption to households excluded.

280

281 It should be noted that the ANZSIC06 industry sector classification includes goods and  
282 services industries. This is a distinction from the Standard International Trade Classification  
283 Revision 2 at the 4-digit level (SITC4) dataset used in *The Atlas of Economic Complexity* and  
284 other prior EC research, as the SITC4 only includes tradable goods. The addition of services  
285 export activities provides a more representative description of each state's economic  
286 complexity, as exported service industries have the potential to be complex exports.

287

288 Due to the nature of MRIO data, exports are given as Port of Exit, rather than State of  
289 Origin. However, as total exports (interstate + international) are used for this EC analysis  
290 rather than interstate this difference is academic: products created in one State and  
291 exported from an interstate port appear as both interstate and international trade, so the  
292 total exports from each State are correct. The use of Port of Exit trade data, rather than  
293 State of Origin could possibly incorrectly inflate the ECI of states, if large quantities were  
294 exclusively shipped to one specific state for export.

295

296 However, our EC analysis of only interstate trade, shows similar findings due to high  
297 correlations between interstate and International exports. Please refer to Appendix 4 in the  
298 online accompanying data for further detail on the correlations between interstate trade  
299 data and interstate and Rest of World trade data. Furthermore, if analysis was to focus upon  
300 State of Origin rather than Port of Exit, one could use the Leontief inverse (Leontief, 1936)  
301 to back calculate the State of Origin of all sectors.

302



#### 303 4. Australian economic complexity at national and sub-national levels

304 In *The Atlas of Economic Complexity*, Australia was ranked 79<sup>th</sup> out of 128 countries in 2009,  
305 with an Economic complexity score of -0.321 (Hausmann, Hidalgo, Bustos, et al., 2014). This  
306 analysis implied that the majority of Australia's export products are resource intensive,  
307 while being knowledge and skill deficient.

308

309 However, our results reveal that interstate trade is more nuanced than international trade,  
310 with the sub-national EC of Australia being much more varied. At the interstate level,  
311 Australia exports many objects, goods and services that would never be internationally  
312 exported due to fragility, perishability, or lack of productive capacity (volume). In addition,  
313 Australia's states have no import barriers between them, and somewhat similar levels of  
314 technological capacity, thus there is much generalised trade occurring between states.  
315 Our EC analysis highlights that the small differences in industrial capability and knowledge  
316 are crucial to relative complexity (and thus the future prosperity) of Australia's states and  
317 territories.

318

319

320 <

321 Table 1 The contribution of interstate and international export monetary transactions for

322 each state and territory. Monetary values listed in \$1,000,000 AU

323 >

324 Table 1 indicates the contribution of interstate and international export for each state, with

325 roughly half of each state's export generated from interstate sub-national trade. The

326 exceptions to this export split are Western Australia (WA), the Australian Capital territory

327 (ACT), and the Northern Territory (NT), that have 15%, 89% and 77% of their total trade as

328 interstate. This indicates the differing product bundles exported by WA, ACT and the NT

329 compared to the rest of the Australian States.

330 Table 2 highlights the differences between interstate and Rest of the World (ROW), that is,

331 international export. Due to the aforementioned split between interstate and international

332 export in most states, the proportional share of exports is matched to the economic size of

333 the state. However, the export specialisation of WA, ACT and NT has led to a

334 disproportionately large share of interstate or international export coming from these states

335 and territories.

336

337 <  
338 [Table 2 The percentage differences between interstate and international \(ROW\) exports](#)

339 >

340 The exported product mixes of each state also differ. Further information on these are  
341 provided in Appendix 4 of the online accompanying data, along with the differences of  
342 interstate export data versus interstate and Rest of World export data.

343

344 Diversity and Ubiquity

345 Diversity and Ubiquity are the core measurements of EC modelling. The average diversity  
346 score indicates the number of products in which each state or territory has a Revealed  
347 Comparative Advantage, while a high average ubiquity score indicates a network of  
348 exported goods that are commonly exported together. More specifically, this state or  
349 territory is specialised in export goods that are also specialised in by other states and  
350 territories. In the Australian context a high ubiquity score means that there is dominance of  
351 unsophisticated products exported from that state. Graphically, the juxtaposition of these  
352 two values indicates the production capability of each state and territory relative to the  
353 other states and territories. Figure 1 and Table 3 plot the relative average diversity ( $k_{c,0}$ )  
354 and ubiquity ( $k_{c,1}$ ) for Australia's states and territories.

355 Not shown in Figure 1 is Other Territories (OT) region, as its diversity ( $k_{c,0}$ ) was 30, much  
356 lower than the rest of Australia's state and territories. However, OT had the highest ubiquity  
357 ( $k_{c,1}=4.1$ ). This combined score indicates that though OT exported a small unique bundle of  
358 goods and services, it had very limited export specialisation. Due to its unique position OT  
359 will not be discussed for the rest of this paper.

360 New South Wales (NSW) has the next highest ubiquity score ( $k_{c,1}=3.83$ ), followed by  
361 Victoria (Vic,  $k_{c,1}=3.73$ ), and Queensland (Qld,  $k_{c,1}=3.64$ ). The Northern Territory has the

362 lowest ubiquity score ( $k_{c,1}=3.17$ ). However, the Northern Territory (NT) had the highest  
363 diversity score ( $k_{c,0}=249$ ), followed by Qld ( $k_{c,0}=238$ ), and Vic ( $k_{c,0}=219$ ).  
364 South Australia (SA) had the lowest diversity score besides OT ( $k_{c,0}=138$ ), with a low to  
365 moderate ubiquity score of  $k_{c,0}=3.45$ . It is worth noting that SA had similar ubiquity scores  
366 to Western Australia (WA,  $k_{c,0}=3.47$ ) and Tasmania (Tas,  $k_{c,0}=3.46$ ), with their relative levels  
367 of diversity distinguishing them.  
368

369 <

370 [Table 3 Diversity and Ubiquity scores for Australia's states and territories.](#)

371 >

372 <

373

374 Figure 1 Comparing diversity and ubiquity measures for each state and territory with internal+ ROW export. Other  
375 Territories (OT) is not shown as its kc0, Diversity=30

376 >

377 The high ubiquity from international exporters confirms the situation discussed in Tables 1  
378 and 2, and Figure 2: a large percentage of international export is from a small number of  
379 non-complex products - in this case resources and agricultural products. The central  
380 hypothesis of economic complexity modelling is to build upon the export of these non-  
381 complex products, and move into the export of more complex, knowledge intensive  
382 products – this is what has happened over time in Sweden and many other innovation-rich  
383 countries. (Schön, 2012; Sjöo, 2014; Taalbi & Ljungberg, 2015; Taalbi, 2014; Tamrakar, 2014)

384

385 The Economic Complexity Index (ECI)

386 Table 4 provides the ECI for each state and territory, the higher the EC score the more  
387 relatively complex the state's economy is compared to the rest of Australia. New South  
388 Wales has the highest ECI, while the Northern Territory has the lowest ECI. South Australia  
389 (SA) is positively placed in Figure 2, and placed close to the middle of Figure 3. This indicates  
390 that SA has much room for growth and improvement (opportunity) in expanding its goods  
391 and services. However, the OV of 8.46 and ECI of 0.19 indicates this expansion may come at  
392 a greater cost (i.e. with greater obstacles to overcome) than for states with a higher ECI and  
393 OV.

394

395 <

396 **Table 4 The Economic Complexity Index and Opportunity value for each state and territory, along with the GSP per**  
397 **capita in current price, Source: 5220.02013-14 ABS (Australian Bureau of Statistics, 2014)**

398 >

399 Figures 2 and 3 complement Table 4, as a pictorial comparison of the ECI of each state and  
400 territory to its relative OV (Figure 2), or log GSP per capita (Figure 3). Together these  
401 illustrate how complex each economy is and the relative gains from increasing complexity.  
402 The positive location of NSW, Vic, WA, QLD and SA, on the OV axis indicates that these  
403 states have more to gain from moving into more complex products than the states and  
404 territories with negative locations.

405

406 From Figures 2 and 3, it is apparent that QLD and VIC have higher OV than NSW, even  
407 though NSW has the highest ECI. The reason for this positioning is that NSW is exporting  
408 different types and quantities of commodities to the ROW, than QLD and VIC, this in turn has  
409 impacts on the overall ECI and OV of NSW. NSW is a more complex economy, but has less  
410 to gain (opportunity) to expand its exports into new goods or services.

411

412 <

413 **Figure 2 The ECI and Opportunity Value for each state and territory. OT is omitted.**

414 >

415 <

416 **Figure 3 Opportunity value as a function of GSP per capita (log value). OT omitted.**

417 >

418 The Product Complexity Index (PCI)

419 Figure 4 shows the relative product complexity of the 506 goods and services produced in  
420 Australia according to the ANZSIC06 classification. It can be seen that there is fluctuation of  
421 product complexity within product groups with the notable exceptions of the 3 blocks of  
422 product numbers #227-#244, #246-#284, and #285-#320. The appearance of these blocks of  
423 equal PCI are due to these being common products across all states, though this  
424 commonality is also likely to be attributable to the aggregation and disaggregation method  
425 of the IELab. The higher the PCI score on the horizontal axis of Figure 4, the more complex  
426 the good or service is to produce.

427 <

428 [Figure 4 The Product Complexity Index for the 506 goods and services \(ANZSIC 06 classification\)](#)

429 >

430 Appendix 5 in the online accompanying data lists the lowest national PCI for the goods and  
431 services (the least complex products) for comparison.

432

## 433 5. Discussion

434 The upcoming and ongoing exit of the automotive and heavy vehicle manufacturing  
435 industries from Victoria, South Australia and Tasmania will have major impacts on the  
436 economic structure and prosperity of these states. Our EC analysis has found that among  
437 these three states, Victoria is the best situated to shift into other complex industries.

438 Likewise, South Australia, with a positive OV has the immediate ability to shift into other  
439 complex export products but has to overcome larger barriers (i.e. incur higher costs) and  
440 this industry shift will likely take a longer time. Tasmania is the least well positioned state to  
441 respond to this economic restructure due to its negative opportunity value.



442

443 Our analysis extends the economic picture painted by Wood and Lenzen (2009) into the  
444 year 2009. In the 25 year time period of Wood and Lenzen (2009), the Australian economy  
445 had evolved increased efficiency of resource use and employment, smaller primary and  
446 manufacturing sectors and larger and better linked tertiary and service sectors. Our EC  
447 analysis confirms that this trend toward linked tertiary and service sectors has continued.  
448 Our results also show that there has been greater development in specialised trade  
449 occurring within the sub-national Australia (and thus Australia as a national entity).  
450 Comparing this papers EC results for each state and territory against the results of Wood  
451 and Lenzen's (2009) 1975-1999 national model, provides the insight that all states and  
452 territories have developed and are at different stages of complexity and structure, with both  
453 local and global developments in the intermittent decade having had impacts.

454

455 Our EC analysis also confirms Hausmann and Hidalgo's national EC analysis, finding that the  
456 majority of states (especially Western Australia) export primarily resource-intensive goods.  
457 However, our analysis also shows that interstate trade has many complex industries and  
458 products that are not internationally exported. Expansion into international export of these  
459 products will strengthen both national and sub national EC.

460

461 The results and analysis in the paper must be taken with a caution, as the small number of  
462 states and (much economically smaller) territories, with only 506 industry ANZSIC06 sector's  
463 may not provide a big enough model for the EC calculation process to work correctly. This  
464 means that our model may have produced uncertain values for Diversity and Ubiquity,  
465 which in turn will affect the ECI and PCI values given in this paper. Future research should

466 align the subnational EC analysis presented here to with global results. This would also allow  
467 placement of Australia's regional complexity at a global scale, and produce more robust  
468 values for Diversity, Ubiquity, ECI and PCI.

469  
470 In addition, a limitation of EC theory, is that there is no theoretical integration of the  
471 importance of historic relationships, population density bias and geographic proximity when  
472 trade occurs (R Boschma & Frenken, 2010, 2011; Furman, Porter, & Stern, 2002). These  
473 factors act as additional drivers of innovation and collaboration for economic actors, but are  
474 absent from EC theory. Future studies could use network analysis to examine these impacts  
475 within a longitudinal EC framework. These are especially important when discussing the  
476 sub-national case of Australia, as the complexity analysis is showing bias towards the  
477 eastern states, away from the more geographically distant WA, NT, and SA. Future research  
478 could use the data found in the **U** matrices of MRIO tables and the EC analysis  
479 methodologies of Wood and Lenzen (2009) (i.e. measures of multipliers and transactions,  
480 and calculating forward and backward linkages) to take account of these relationships.  
481 However, this analysis would be very data and processing intensive. Currently, no MRIO  
482 time series database is available at a high enough resolution of data. This could probably be  
483 a reason why Hausmann and Hidalgo's EC analysis is focused only on trade data.

484

485 A further limitation is that the importance of relationship capital is omitted in the EC  
486 theory. Relationship capital<sup>6</sup> impacts cultural collaboration propensity – where Australia  
487 ranks 24<sup>th</sup> (29<sup>th</sup>) out of 31 OECD countries for collaboration between SME's (large firms) and  
488 Researchers (Office of the Chief Economist, 2015). In fact, the likelihood of having any form

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<sup>6</sup> For definition and discussion about relationship capital see (Roos, Pike, & Fernstrom, 2012) and (Roos, 2014)

489 of collaborative arrangement in place peaks at 9%, which is for a firm aged between one and  
490 four years (Office of the Chief Economist, 2015).

491 In addition to this there are national organisational capital aspects that impact national  
492 prosperity e.g. policy landscape, rules, regulations, systems, processes etc. This can be  
493 exemplified with the negative impact of a rapidly shifting policy landscape, like in Australia,  
494 where uncertainty will originate from the inability to predict the performance of new  
495 institutions, the actions of other players, or what will be gained or lost if present behaviour  
496 is changed (Culpepper, 2008).

497

498 A final limitation of EC theory predictive accuracy is the role of economic uncertainty. This  
499 type of uncertainty is contributing to limiting national prosperity growth since capital  
500 investment and workforce hiring decisions have long term consequences – often 10- to 20-  
501 year or more – and consequently policy uncertainty over longer time periods makes it  
502 almost impossible to formulate business and investment strategies with sufficient  
503 confidence which reduces the ability to commit to stakeholders and hence postpones  
504 prosperity driving investments. Together these limitations contribute to understanding why,  
505 as articulated in the correlation analysis underpinning the EC theory, change in economic  
506 complexity explains (in correlation terms) 70% and not a greater amount of national  
507 prosperity.

508

## 509 6. Conclusion

510 In this paper we have performed a sub-national EC analysis on the states and territories of  
511 Australia. We have calculated the ECI, RCA, PCI, OG and OV relating to 9 sub-national  
512 economies and 506 exported goods and services. To our knowledge this is the first

513 application of EC analysis to sub national dataset, and the first use of an MRIO database as  
514 base data for EC analysis, and the first to include services sectors in EC analysis.  
515 Future application of EC analysis at the sub national level could include calculation of the  
516 implied comparative advantage for each sector (Hausmann, Hidalgo, Stock, & Yildirim,  
517 2014), and thus identification of the best sectors (*the low hanging fruit* (Hausmann, Hidalgo,  
518 Bustos, et al., 2014)) for investment and expansion into; further scenario modelling of the  
519 impact of industries exiting or entering sub national markets; and integration of this sub  
520 national model into Hausmann and Hidalgo's previous international model (STIC). This  
521 would allow the use of the base MRIO table to perform structural decomposition analysis to  
522 enable the tracing of the supply chains of complex products to quantify relationships  
523 between sub-national and global economies.

524

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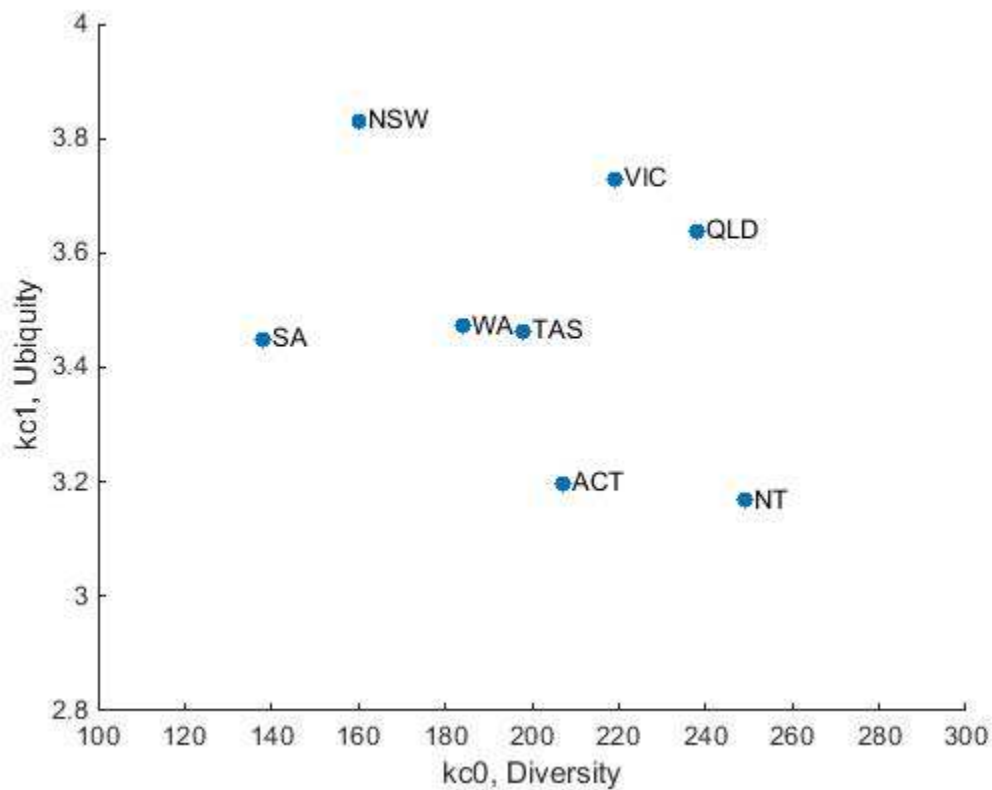
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Opportunity value

Economic Complexity Index

100  
80  
60  
40  
20  
0  
-20  
-40  
-60  
-80

1.5 -1 -0.5 0 0.5 1 1.5

NT

ACT

TAS

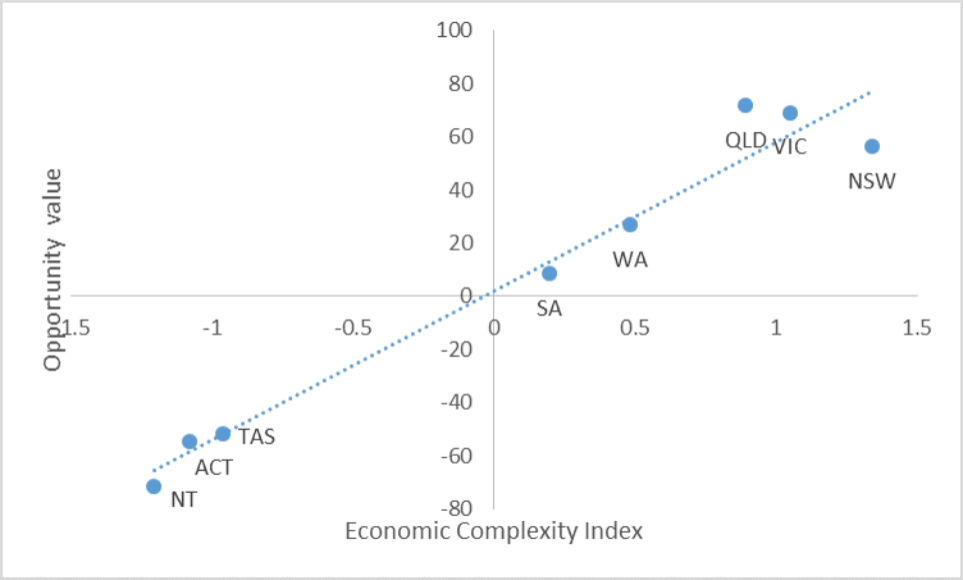
SA

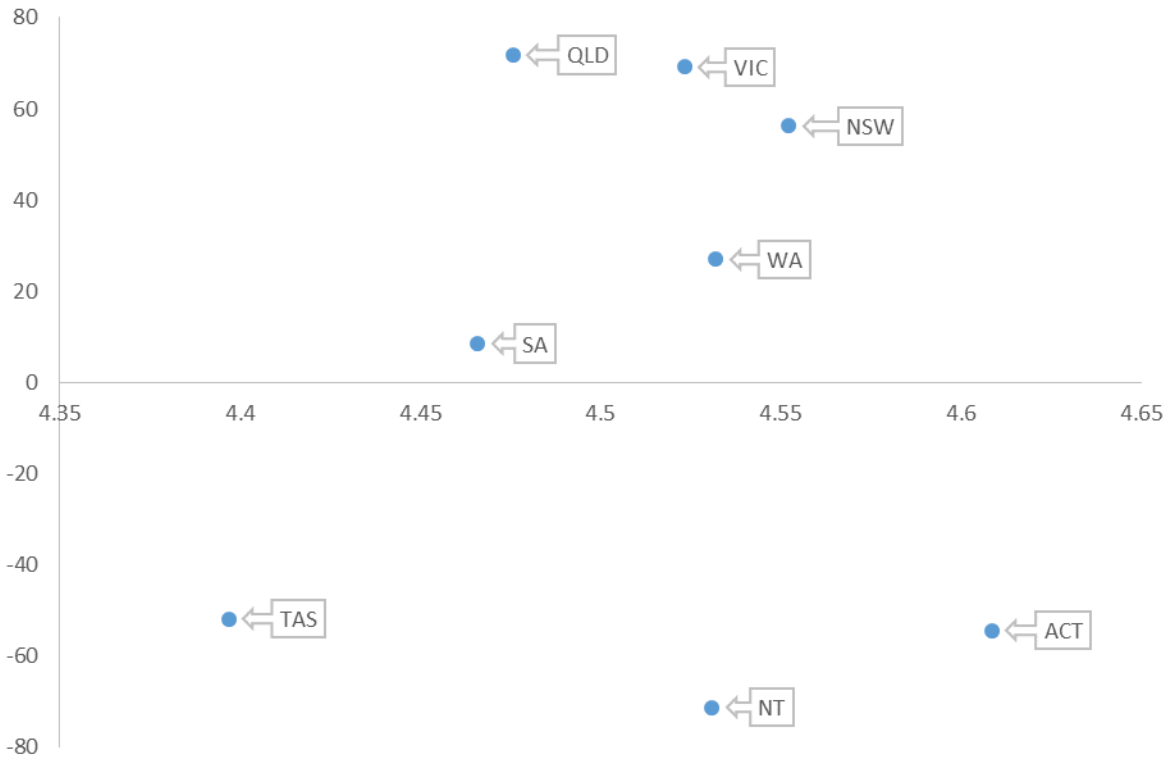
WA

QLD

VIC

NSW





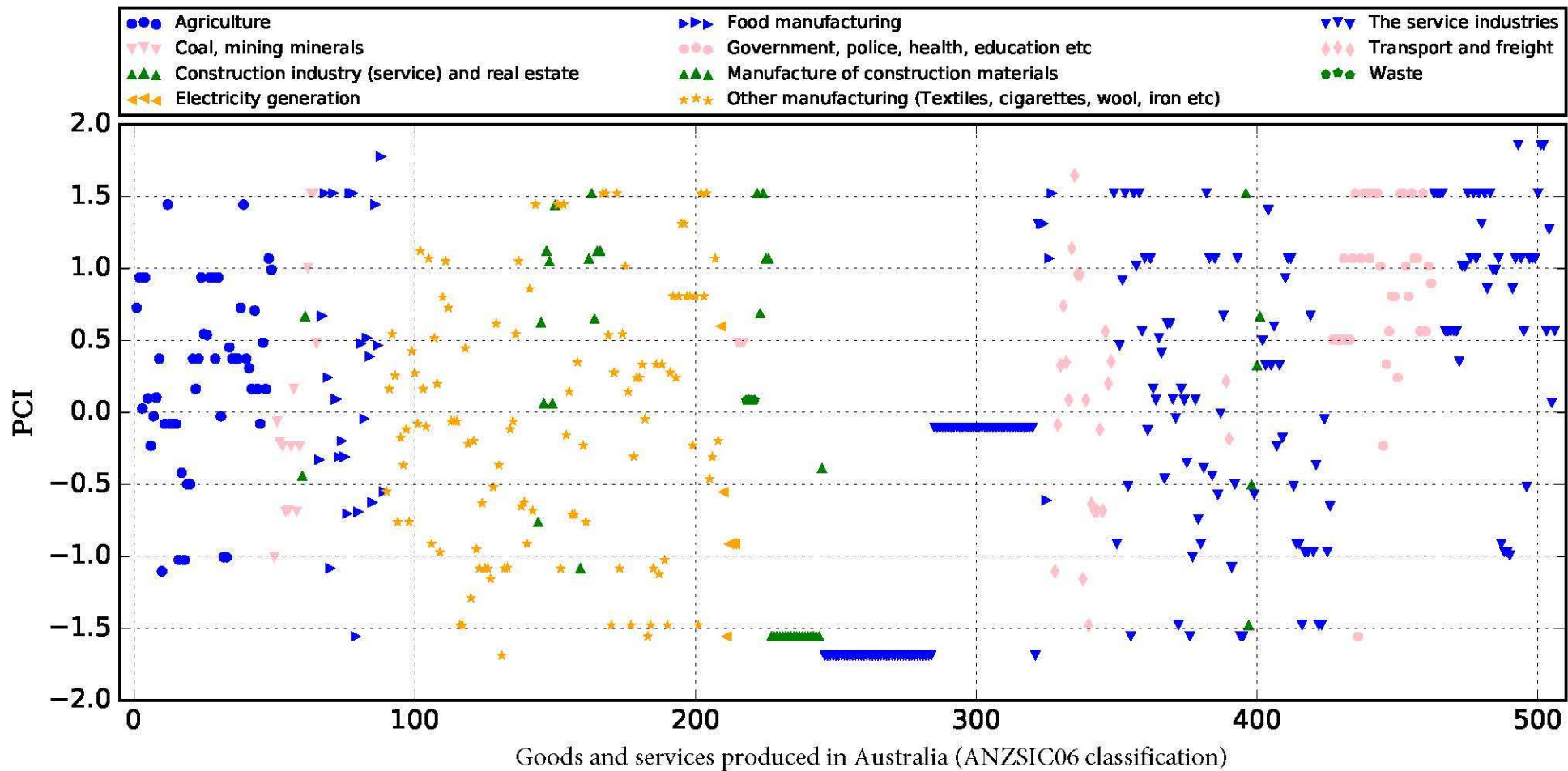


Table 1 The contribution of interstate and international export monetary transactions for each state and territory.  
 Monetary values listed in \$1,000,000 AU

	INTERSTATE	INTERSATE AS % OF TOTAL EXPORTS	ROW	ROW AS % OF TOTAL EXPORTS	ROW+INTERSTATE
<b>NEW SOUTH WALES</b>	45411	56	35283	44	80694
<b>VICTORIA</b>	29585	50	29261	50	58846
<b>QUEENSLAND</b>	22317	48	24201	52	46518
<b>SOUTH AUSTRALIA</b>	12916	46	15139	54	28055
<b>WESTERN AUSTRALIA</b>	16826	15	91771	85	108597
<b>TASMANIA</b>	9800	44	12266	56	22067
<b>AUSTRALIAN CAPITAL TERRITORY</b>	63194	89	8038	11	71232
<b>NORTHERN TERRITORY</b>	69015	77	20102	23	89117
<b>OTHER TERRITORIES</b>	163	3	4718	97	4882
<b>TOTAL</b>	269227	53	240779	47	510006

Table 2 The percentage differences between interstate and international (ROW) exports

	<b>% OF ROW</b>	<b>% OF INTERSTATE</b>	<b>% OF TRADE</b>
<b>NEW SOUTH WALES</b>	15	17	16
<b>VICTORIA</b>	12	11	12
<b>QUEENSLAND</b>	10	8	9
<b>SOUTH AUSTRALIA</b>	6	5	6
<b>WESTERN AUSTRALIA</b>	38	6	21
<b>TASMANIA</b>	5	4	4
<b>AUSTRALIAN CAPITAL TERRITORY</b>	3	23	14
<b>NORTHERN TERRITORY</b>	8	26	17
<b>OTHER TERRITORIES</b>	2	0	1
<b>TOTAL</b>	100	100	100

Table 3 Diversity and Ubiquity scores for Australia's states and territories.

<b>kc0 Diversity</b>		<b>kc1 Ubiquity</b>	
<b>NORTHERN TERRITORY</b>	249	<b>OTHER TERRITORIES</b>	4.10
<b>QUEENSLAND</b>	238	<b>NEW SOUTH WALES</b>	3.83
<b>VICTORIA</b>	219	<b>VICTORIA</b>	3.73
<b>AUSTRALIAN CAPITAL TERRITORY</b>	207	<b>QUEENSLAND</b>	3.64
<b>TASMANIA</b>	198	<b>WESTERN AUSTRALIA</b>	3.47
<b>WESTERN AUSTRALIA</b>	184	<b>TASMANIA</b>	3.46
<b>NEW SOUTH WALES</b>	160	<b>SOUTH AUSTRALIA</b>	3.45
<b>SOUTH AUSTRALIA</b>	138	<b>AUSTRALIAN CAPITAL TERRITORY</b>	3.20
<b>OTHER TERRITORIES</b>	30	<b>NORTHERN TERRITORY</b>	3.17

Table 1 The Economic Complexity Index and Opportunity value for each state and territory, along with the GSP per capita in current price, Source: 5220.02013-14 ABS (Australian Bureau of Statistics 2014)

	GSP per capita, current price (\$), 2009	log10(GSP)	ECI	Opportunity value
<b>NEW SOUTH WALES</b>	35,668	4.55	1.34	56.27
<b>VICTORIA</b>	33,371	4.52	1.05	69.20
<b>QUEENSLAND</b>	29,903	4.48	0.89	71.86
<b>SOUTH AUSTRALIA</b>	29,233	4.47	0.19	8.48
<b>WESTERN AUSTRALIA</b>	34,045	4.53	0.48	26.91
<b>TASMANIA</b>	24,938	4.40	-0.96	-51.94
<b>AUSTRALIAN CAPITAL TERRITORY</b>	40,602	4.61	-1.08	-54.46
<b>NORTHERN TERRITORY</b>	33,959	4.53	-1.21	-71.37
<b>OTHER TERRITORIES</b>	-	-	-0.71	-7.95