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► **To cite this version:**

Yves Meinard, Irene Pluchinotta. C-KE/I: A pragmatic framework for policy innovation. EURO journal on decision processes, 2022, 10, pp.100016. 10.1016/j.ejdp.2022.100016 . hal-03881635

HAL Id: hal-03881635

<https://hal.science/hal-03881635>

Submitted on 9 Dec 2022

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1 C-K^{E/I}: A pragmatic framework for policy innovation

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15

16 Abstract—Improving policy making is key to address numerous contemporary challenges such
17 as the environmental crisis, climate change, global inequality, financial crises, or pandemics.
18 Policy making is a sequence of stages structuring policy problems and choices made to address
19 them. Among these stages, policy design is a crucial phase since it impacts the quality of the
20 policy alternatives being considered. Policy design is, however, largely neglected in the
21 scientific literature, and in practice it is mainly conducted informally. Design theory, and more
22 specifically Concept-Knowledge (C-K) theory, originally aimed at assisting the process of
23 creating marketable objects, offers promises to formalize and rationalize policy design. We
24 critically analyze this theory, showing that, despite its strengths, as it stands it is ill-adapted to
25 support the innovative design of policy alternatives. For that purpose, we propose a refined

26 framework, C-K^{E/I}, appraising innovation based on the explicit or implicit modal statements
27 held by a certain individual or group (“E/I” stands for Explicit vs. Implicit). Through an ex-post
28 analysis of a case study—the search for innovative policy solutions to water management
29 problem in the Apulia Region, Italy—we illustrate the practical applicability and usefulness of
30 our framework.

31

32 Keywords—policy design, C-K theory, policy making, water management, policy analytics.

33

34 Acknowledgements—We thank O. Cailloux, A. Mangos, G. Pigozzi, A. Osorio, A. Richard, J.
35 Rouchier and A. Tsoukias for useful comments and interesting discussions. We also thank the
36 journal’s editor and reviewer for comments that helped us improve the paper.

37

38 1. Introduction

39 Policy making faces numerous problems in many regions of the world, due to the disparity of
40 interests associated with the management of commons, the presence of multiple (and often
41 antagonistic) decision-makers, the role of complex networks of formal and informal
42 interactions, and also bureaucratic protocols, often-inoperative systems of governance, various
43 socio-political events and environmental stressors such as climate change and unexpected
44 pandemics (e.g., Moore, von der Porten, Plummer, Brandes, & Baird, 2014).

45 Studying and eventually improving policy making is accordingly considered a major issue of
46 public concern worldwide. Policy making is a public decision-making process (De Marchi,
47 Lucertini, & Tsoukiàs, 2016) for defining sets of actions taken by a government to control a
48 given system, to help solve problems within it, or to obtain benefits from it (Moran, Rein, &
49 Goodin, 2006). It influences the life of stakeholders (e.g. Cochran 1995, Peters 1999), since it
50 “decides who gets what, when and how” (Lasswell, 1936).

51 Policy making is classically conceptualized as a sequence of stages structuring policy problems
52 and their resolution through choices made by policy makers (Daniell, Morton, & Ríos Insua,
53 2016). Lasswell’s classical presentation (1956) formalizes policy making as an ideal and
54 continuous process, cycling through discrete activities producing policy outputs: issue
55 identification, policy objectives definition, policy design, policy testing, policy refinement,
56 policy implementation, policy monitoring and evaluation, and policy readjustment (this is the
57 so-called “policy cycle”). Different authors used slightly different interpretations of the names,
58 number and order of the stages, but retained the basic staged-feedback-cycle structure (e.g.,
59 Anderson, 1975; Dunn, 1994; Hill, 1997; Howlett et al., 2015; Jann & Wegrich, 2007).

60 For policy improvement purposes, policy design (the third of Lasswell’s phases) represents a
61 crucial phase, since it influences the quality of the policy alternatives subsequently considered
62 (Howlett, 2011). Therefore, policy design or “the invention of policy proposals” (Lasswell,
63 1956) is essential for the development of policy (Bobrow, 2006), and fostering innovation in
64 policy design is a key challenge for policy improvement purposes (for details on the importance
65 of policy design see Ferretti et al., 2019).

66 The role of policy innovation in policy success/ failure has long been debated (Grant, W., 2009;
67 Polsby, 1984). As discussed by Howlett (2014), early studies focused on the cognitive limits of
68 policy-makers and their bounded rationality as a factor which biased decision-making towards
69 consideration of known alternatives (Simon, 1955), or emphasized the complexity of a decision-
70 making process among competing interests (Lindblom, 1959; Simon, 1955). Other studies
71 pointed to more structural factors such as routinization or institutionalization acting as a brake
72 on innovation by restricting or constraining consideration of novel alternatives (Clemens &
73 Cook, 1999). Scholar still discuss whether lack of innovation necessarily leads to overall policy
74 failure, or if such outcome is rather amenable to failed policy innovations (Howlett, 2014;
75 Howlett, Ramesh, & Wu, 2015). These debates show that innovativeness is not sufficient to

76 ensure the quality of policies: some innovative policies can be ill-conceived, and once
77 innovations are at hand, choosing among them is an important challenge on its own. However,
78 all other things held equal, innovation is a positive input to strengthen policy making, since
79 designing a valuable new policy alternative can be worth more than a rehearsal of unsatisfactory
80 “traditional” alternatives (e.g. Enthoven, 1975; Ferretti et al., 2019).

81 Despite the obvious importance of policy design in general, and of innovation in policy design
82 more specifically, their analysis only belatedly became an important theme in contemporary
83 policy research (Pluchinotta et al. 2020). Theorization has lagged, the cumulative impact of
84 empirical studies has not been great and understanding of the phenomena, despite many
85 observations of its significance in policy studies, has not improved significantly (Howlett,
86 Mukherjee, et al., 2015). In line with this lack of theorization, in practice policy design is
87 typically done, rather informally, through the application of available knowledge to the
88 development of actions expected to attain desired goals (Howlett & Lejano, 2013). The
89 knowledge base used in this process is gained from experience and reason, but not formally
90 analyzed through a dedicated scientific apparatus (Alexander, 1982; Bobrow, 2006; Pluchinotta
91 et al., 2019; Taeihagh, 2017). The very question of what should count as “innovative” in policy
92 design matters is not even clarified in the literature.

93 This article aims to bring our contribution to fill this gap by conceptualizing a notion of policy
94 design innovation and by helping rationalize this activity. Our approach to address this question
95 is not a purely empirical protocol that would consist in observations or in asking a panel of
96 respondents what they think is innovative within a policy design intervention. We rather
97 propose a hybrid methodology combining conceptual and empirical analyses, in line with
98 similar studies of other concepts playing a key role in decision-making processes, such as
99 legitimacy (Meinard, 2017), justification (Meinard & Cailloux, 2020) and rationality (Meinard
100 & Tsoukiàs, 2019). This hybrid methodology starts by analyzing relevant sources

101 conceptualizing the notion of interest (innovation, in our case), through the lenses of conceptual
102 analysis (Searle 1997), to propose conceptual refinements and then identify the empirical data
103 and methodology that are relevant to test these findings. Future studies are then called for to
104 develop full-fledged empirical validation, which would be premature at our stage in this
105 exploratory article. This hybrid methodology is relevant for our purposes because, just like the
106 other key notions listed above, innovation is both an ordinary language term and a highly
107 complex notion used in various academic disciplines. In such cases, conceptual investigations
108 are needed to structure associated empirical investigations since, for lack of such conceptual
109 preliminary investigations, misunderstandings between respondents and investigator about the
110 focal concept studied (here, “innovation”) can lead to biased or misleading results.

111 As application of our hybrid methodology, the first step is to identify a relevant corpus of
112 sources conceptualizing innovation. This is a challenge in its own right, since this notion is
113 involved in an immense literature, spanning from late medieval philosophical reflections on
114 political order (Pocock 2003) to contemporary design theory as applied to marketable objects
115 (Le Masson et al., 2017). We do not have the unreasonable ambition to explore the entirety of
116 these possibly relevant sources. We rather focus on one of the most prolific and prominent
117 conceptual approaches to innovation in contemporary design, Concept-Knowledge (C-K)
118 theory. This choice is motivated by the fact that, in addition to its academic prominence and
119 widespread industrial and commercial applications, this theory arguably holds promises in the
120 domain of policy design (Pluchinotta, Giordano, Zikos, Krueger, & Tsoukiàs, 2020; Pluchinotta
121 et al., 2019). Based on this choice, we explore C-K theory at a theoretical level and show that,
122 as it stands, this theory can be improved to make it more relevant and practical to support the
123 innovative design of policy alternatives (section 2). We then introduce a refined framework, C-
124 $K^{E/I}$, appraising innovation based on the explicit or implicit modal statements held by a certain
125 individual or group (“E/I” stands for Explicit vs. Implicit) (section 3). These conceptual

126 findings allow clarifying how empirical data can be collected and analyzed to test the practical
127 relevance of this framework, which we do through an ex-post analysis of a case study, namely
128 water management policy in the Apulia Region (Italy) (section 4). Concluding remarks are
129 reported in Section 5.

130

131 2. C-K theory and its limits for policy innovation purposes

132 The current section will briefly present C-K theory (for more details, an interested reader should
133 refer to Agogué & Kazakçi, 2014; Hatchuel et al., 2015; Hatchuel, Reich, Le Masson, Weil, &
134 Kazakçi, 2013) and highlight some of its limitation for policy innovation purposes. Design
135 theory, originally conceived for assisting practitioners in “designing” marketable objects, has
136 evolved in a more formal version aiming to assist and organize any process of creating
137 “objects”, possibly immaterial and abstract such as a strategy or a policy (Le Masson et al,
138 2017). These “objects” do not exist within our knowledge, but can be designed out of it
139 (Hatchuel & Weil, 2003). In this regard, C-K theory offers a formal framework, which has been
140 used to support the innovative generation of policy alternatives (see Pluchinotta et al., 2019).

141 According to its original definition provided by Hatchuel & Weil (2003), C-K theory is based
142 on the distinction between two expandable spaces: a space of concepts (C-space), and a space
143 of knowledge (K-space). K-space represents all the knowledge available to a designer (or to a
144 group of designers) at a given time and contains all the established propositions (true or false).
145 Whereas the C-space contains concepts, sets of propositions whose truth-value is unknown at
146 the moment of their creation. Concepts are said to be undecidable propositions in K-space about
147 partially unknown objects (Hatchuel & Weil, 2003). A proposition qualifies as “undecidable”
148 relative to the content of a K-space if it is not possible to prove that this proposition is true or
149 false in it. Concepts take the form: “There exists some object X , for which a group of properties
150 p_1, p_2, \dots, p_n are true in K ” (Hendriks & Kazakçi, 2010).

151 The design process is thus defined as the co-evolution of C-space and K-space (Hatchuel &
152 Weil, 2009). In other words, design projects aim to transform undecidable propositions into
153 true propositions in K-space. Hatchuel & Weil (2009) highlight the importance of the
154 expandible K- and C-spaces as a unique way of capturing novelty, including a key feature of
155 innovative design: namely, the revision of the identity of objects and the possibility of C-space
156 partitions. As described in Hatchuel et al., (2017) there are two types of refinements in the C-
157 space, (i) expanding partition when the partition expands the definition of an object with a new
158 property that is not known in K as a possible property of this object; (ii) restricting partition
159 when the partition relies on an existing definition or property of the object in K. According to
160 C-K theory, innovation is thus triggered by one or more expanding partitions and the knowledge
161 used to form these partitions could have been present at the beginning of the process (existing
162 one) or generated during the process (new one) (e.g., Hatchuel et al., 2017, Hatchuel & Weil,
163 2003). Therefore, innovation can also combine old pieces of knowledge, creating an artifact
164 that goes beyond all combinations of the known pieces by “breaking the rules” (Hatchuel et al,
165 2018).

166 C-K theory claims that an innovative design process begins with an initial concept C_0 having
167 properties true in a certain version of the K-space. Afterwards, a novel property is added to C_0
168 to form a new Concept C_1 . The elaboration of concepts can then be continued either by further
169 C-space expansions or restrictions, i.e., by adding/removing properties of the initial Concept
170 C_0 . When elaborating a C-space, a designer might use her/his K-space, either to partition further
171 the concepts, or to attempt a validation of a given concept. This last type of operation is called
172 K-validation and it corresponds to the evaluation of a design description using the K-space. The
173 result of a K-validation is positive, if the designer determines that the proposition “there exist
174 an object X with properties p_1, p_2, \dots, p_n ” is true. The result is negative, if the knowledge
175 available to the designer leads her/him to state that the proposition is false (Hendriks & Kazakçi,

176 2011). In order to validate concepts, new knowledge warranting the existence conditions of
177 such an object should be acquired: this is K-space expansion.

178 C-K theory, in this classical formulation, assumes that the notions of “object” and its
179 “existence” are unproblematic. Based on these assumptions, the K-space is defined as the set
180 of propositions known to be true about an object, and the C-space as the set of currently
181 undecidable propositions concerning the object. This very formulation highlights another
182 assumption, which is that it is always meaningful to ask if the proposition of interest is known
183 to be true or false. Notice the difference between being able to tell if a given proposition is true
184 or false, on the one hand, and being able to make sense of the question whether this proposition
185 is true or false. Hatchuel & Weil (2009) use as an example of a concept the following
186 proposition C_0 : “There is an Mg-CO₂ engine that is more suitable to Mars missions than classic
187 engines”. This illustrates the two assumptions above. It makes sense to ask if this proposition
188 is true or false only if we are able to tell what a Mg-CO₂ engine is, which, in fact, might be
189 unclear when we try to design a Mg-CO₂ engine. (Hatchuel & Weil, 2009) write “there was no
190 proposition within existing K that proved that C_0 was true or false. Thus, C_0 was a suitable
191 concept for further design.” In fact, if what “an Mg-CO₂ engine” refers to too indeterminate,
192 the question whether C_0 is true or false does not even make sense, and the question whether a
193 proposition in K might prove that C_0 is true or false does not make sense either. Because C-K
194 theory implausibly admits that it is always meaningful to ask if the proposition of interest is
195 known to be true or false, it limits the analysis of innovation to a matter of changes in knowledge
196 about objects that are clearly known from the beginning of the design process. In this view,
197 admitting that we unquestionably know what X is, innovation appears when the evolution of
198 knowledge entail changes in propositions that are known to be true or false about X . This vision
199 evacuates what happens when it is unclear what X is, which is however very often the case
200 when one sets out to innovate in designing X .

201 C-K theory says that what happens in the design process is that, at each stage i , a new
202 proposition C_i has been formed: “There exist X with a set of attributes A_i , which can be made
203 with a set of design parameters D_i ”. There are three possibilities for the logical status of C_i in
204 K :

- 205 1. C_i is false in K and the design process has to change some of the A_i s or the D_i s;
- 206 2. C_i is true in K and (D_i, A_i) is one candidate as a “solution” for X ; we call it a
207 “conjunction for X ”;
- 208 3. C_i is neither true nor false in K : hence it is a new concept, and we have to continue the
209 design process.

210 This is ambiguous because it is not possible to know what X means precisely. Take the example
211 of a chair (this is a classical example of C-K theory mentioned by during courses) and assume
212 that A_i is the attribute “being two-legged”. If X is a chair, because the notion of a chair is not
213 completely transparent, it does not even make sense to ask if C_i is true, false or neither. If there
214 were such a thing as an ultimate definition of what it means for an object to be a chair, it would
215 make sense to ask if a two-legged object harboring A_i can be a chair; our answer to this question
216 might then change as knowledge evolves. But, because there is no such a thing as an ultimate
217 definition of what a chair is, thinking about a two-legged chair is a thought experiment that
218 leads us to acknowledge that the idea of a chair is much less clear than one might think at first
219 sight. Hatchuel & Weil (2009) are especially unclear when they talk about “new objects” or
220 changing “identities of objects”: on the one hand, they claim that objects change if the properties
221 recognized to be attached to them change but, on the other hand, they assume that X is defined
222 independently. Indeed, this issue of the definition of objects becomes more important when
223 innovation no longer is about “objects” in the everyday sense of the term, such as chairs or
224 engines, but about policies. What does “ X ” stand for when we talk about a policy?

225 To overcome these limitations of C-K theory, let us elaborate a more satisfactory account of
226 what C-K theory refers to as “objects” and of people’s ability to make statements as to whether
227 propositions concerning “objects” are true or false.

228

229 3. C-K^{E/I}: Refining C-K theory for policy design purposes

230 Although C-K theory assesses innovativeness with respect to the available knowledge at a given
231 moment and in a given situation, it talks about innovation or innovative design in general, as if
232 something could be innovative, absolutely speaking (relative to a given available knowledge).
233 However, some people can find a given item innovative while other people will find it blatantly
234 run-of-the-mill. A first improvement that C-K theory should integrate consists in considering
235 innovativeness as a property that is assigned by an individual or a group to an item. Typically,
236 different people will find different items innovative. Within a group, if there is enough
237 homogeneity among members, they can all agree on what is innovative and what is not. In
238 practice, this kind of homogeneity can be empirically observed among groups of consumers
239 with similar socio-economic characteristics (at least in some cases and for some categories of
240 consumable items whose innovativeness is of interest), or it can be generated by the co-
241 construction of a shared understanding of an issue and a common knowledge background on it.
242 Nevertheless, most of the time people will disagree, at least to some extent, on what is
243 innovative and what is not, and aggregation mechanisms will be needed to decide what, if
244 anything, should be called innovative at the scale of the group. For our purposes in this article,
245 we will leave aside this aggregation issue. We will talk about what is innovative for a focal
246 individual *i*, granting that what we will say will be translatable into what is innovative for a
247 sufficiently homogeneous group *G*, but can raise aggregation issues as soon as the group is
248 heterogeneous enough for people to disagree within the group. It is worth underlining that there
249 is no contradiction between, on the one hand, our claim that, in order to answer the question

250 whether x is innovative for y , we need to focus on a homogeneous y , and, on the other hand, the
251 largely demonstrated fact that diversity fosters innovation (Subrahmanian et al., 2020).

252 A second improvement is that C-K theory should take into account the fact that attributing to
253 an item the property of being innovative is a matter, for the individual attributing the property,
254 of becoming aware of new *possibilities* that the innovative item exemplifies or hints at. The
255 theory account for this basic aspect of the phenomenology of innovation, by theorizing the role
256 of the modal statements that individual i holds. In line with this observation, the key idea that
257 this paper is devoted to formalize, is that innovation is a property that an individual attributes
258 to an item when, as a consequence of her/his encountering this item, this individual becomes
259 aware that something s/he implicitly deemed to be impossible is then possible.

260 To formalize these ideas, let us define X_i as the space of sets x of modal statements held by i .
261 Some of these statements are explicitly endorsed by i , while the others are only implicitly
262 endorsed. Sets of modal statements are used here to replace the problematic notion of “object”
263 used on classical C-K theory. By talking about sets of statements held by i or by people in a
264 group, we usefully avoid having to talk about the truth or falsity of propositions: the point here
265 is not to establish if this or that statement is true or false (How can one be sure that what one
266 thinks true really is true?), but to explore, empirically, the statements that people hold at a given
267 point of time, in given circumstances.

268 We do not have to admit that anyone can be able to extensively identify the set of modal
269 statements corresponding to a member of X_i . And, clearly enough, when asked about it,
270 individuals typically are not able to say more than the list of modal statements that they
271 explicitly endorse. Take for example the “object” chair. Most people explicitly admit that “a
272 chair necessarily is a piece of furniture”, “a chair is possibly made of wood”, “a chair is possibly
273 colorful”, etc., and most people implicitly admit that “a chair is necessarily a solid object”, “a
274 chair is necessarily visible”, etc. This set of explicit and implicit modal statements delineate

275 what is a chair for most individuals. Among the implicit modal statements concerning chairs,
276 one might be “a chair necessarily has four legs”.

277 On this basis, let’s define $K(X_i)$ as the set of knowledge which is relevant for X_i (among the
278 statements that this set contains, one can find statements of facts derived from observations,
279 modal statements derived from scientific laws, probabilistic statements derived from statistical
280 generalizations, and modal statements spelling out regulations and rules).

281 Saying that a statement s in $K(X_i)$ is “relevant” can mean 1) either that s contains a reference to
282 a x in X_i , 2) or that s contains a reference to a category of which x is an instantiation, 3) or that
283 a conjunction of several members of $K(X_i)$ contains a reference to a category of which x is an
284 instantiation. We can start by admitting that there is no statement or conjunction of statements
285 from $K(X_i)$ which contradicts the explicitly endorsed modal statements in X^{expl}_i , because
286 otherwise it would mean that i is deeply confused.

287 Among the relevant statements in $K(X_i)$ one can be: “three-legged objects can be stable”. This
288 statement is liable to undermine the above implicit modal statement (“a chair necessarily has
289 four legs”), because it implies that three-legged chairs can be stable, which undermines a
290 prominent reason why one could implicitly think that chairs should be four-legged. Notice that
291 the X_i space is, by definition, associated with a given individual i , but an object such as “chair”
292 can find a place in many different X_i .

293 Two important questions at this stage are: how can one elicit implicitly and explicitly held
294 statements? How can one distinguish implicitly held statement from explicitly held ones? To
295 answer these questions, we do not have to admit that anyone can have access to the whole set
296 of implicit held statements. Explicit vs. implicit can be distinguished depending on the approach
297 used to query people about these statements. If you ask open questions, such as “what are the
298 features that a chair has in your opinion?” then people will answer by spelling out their explicit
299 knowledge. By contrast, if you want people to express their implicit knowledge, you have to

300 ask closed questions, such “do you think that a chair can have less than four legs?”, in such a
301 case people might reply “well, now that you are saying that, I figure that a three-legged chair
302 might exist, but I would not have thought about that if you had not asked”. In that case, we
303 would conclude that “a chair necessarily has four legs” used to be part of the respondent’s
304 implicit knowledge about chairs.

305 This process of becoming aware of implicitly held statements can also happen spontaneously,
306 as knowledge evolves, or as *i* comes to tackle new problems, which leads them to question some
307 of the assumptions they used to take for granted.

308 In both experimental and spontaneous settings, *i* becomes aware that s/he used to implicitly
309 hold modal statements that were not that crucial after all and should be abandoned while
310 clinging to other related statements s/he holds.

311 Within the C-K^{E/I} framework, an act of creating hence qualifies as an innovation for an
312 individual *i* if and only if its output leads *i* to becoming aware of her/his implicit endorsing
313 modal statements that the output lead her/him to abandon. In other words, when applied to the
314 appraisal of the innovativeness of policy alternatives, our approach claims that the core of the
315 innovation is the identification of alternatives that used to remain unseen due to unwarranted
316 implicitly held modal statements that were discarded.

317 This framework is “pragmatic” in the linguistic sense of the term, i.e., as opposed to “semantic”:
318 it decisively pays attention to the way language is used.

319 If applied to innovation in policy making, the C-K^{E/I} framework will be typically used in pluri-
320 individual settings, in which a group *G* replaces the single individual *i* mentioned so far. In most
321 cases, the relevant group to consider when investigating the innovativeness of policies is the
322 group of stakeholders. Analysts striving to identify innovative policy designs, typically deal
323 with different stakeholders (equipped with different goals, backgrounds, initial problem
324 formulations, etc.) endorsing, both explicitly and implicitly, different statements. Therefore, an

325 important part in any investigation about innovative policy design will be to clarify at the outset
326 the focal group for which we want the policy to be an innovation. In some cases, G might be
327 group of experts who want innovations to emerge because they face a situation where standard
328 solutions are inapplicable, in other cases, G might be a group of concerned local actors, who
329 want the solution to their problem to be heralded as a flagship, and so on. In any case, assessing
330 innovativeness at the scale of G will involve, either using an aggregation mechanism or the
331 collective co-construction of enough homogeneity within G. Both options fall beyond our scope
332 in the present article. Within this context, assuming that groups are sufficiently homogenous to
333 apply the logic delineated above, in the following sections we apply the proposed C-K^{E/I}
334 framework to the case of the Apulia Region water protection policy to highlight that the core
335 of innovation is the identification of alternatives that used to remain unseen due to unwarranted
336 implicitly held modal statements.

337

338 4. Application of the framework to innovative policy design to manage water resources in 339 the Apulia Region

340 In this section, we propose to use the above-described framework to analyze ex-post a policy
341 design process. We provide a detailed presentation of the process and show how our framework
342 allows to understand why the various people involved considered some policies to be
343 innovative. Our ultimate aim is to identify how such a process could be piloted from the start
344 to produce as much innovation as possible.

345 Our case study is an experimental work designed to help a group of stakeholders identifying
346 solutions to the water management problem in the Apulia Region (for details on the case study
347 see Pluchinotta et al., 2019). Briefly, the main objective of the case study was to generate policy
348 alternatives, in order to reduce the ground water (GW) and surface water (SW) dependence of
349 the agricultural sector of the area, ensuring a suitable water (W) volume for the agriculture. The

350 experiment brought together stakeholders, experts, institutional and non-institutional actors
351 aiding them to find new ways of working together efficiently, generating novel possible
352 alternatives, and encouraging longer-term thinking. It facilitated the transfer of knowledge,
353 enabling participants to embed learning back into their organizations. The main stakeholders
354 and participants of the C-K theory-based policy design process were: Farmers (F), the Irrigation
355 Consortium (IC) managing the SW, and the Regional Authority (RA).

356 The C- and K- spaces of generating the policies of the case study are described in Pluchinotta
357 et al., 2019. For the purposes of this paper, here we propose to analyze three policy proposals
358 that were considered innovative by at least some of the actors involved. We show that, in each
359 case, when people deem that a given alternative is innovative, we can identify a modal statement
360 relevant to this alternative, which is such that those people used to hold this statement implicitly,
361 but figured, thanks to the collective discussion process, that this statement should be discarded.
362 We thereby illustrate how our framework accounts for people's apprehension of innovativeness.

363 The information reported in the following tables the information were gathered from
364 meetings/workshops notes and ex-post discussions between the authors.

365 The first alternative is the development of a shared management of GW aquifers. All the
366 stakeholders, i.e., F, IC and RA, considered this alternative to be innovative. As illustrated in
367 Table 1, IC and RA used to implicitly admit that IC was the only possible manager for GW too.
368 This idea underlined all their discourses during the discussions because IC was considered the
369 only suitable authority managing all the water resources (SW and GW). However, this idea was
370 immediately discarded when the new knowledge on the shared management of the GW aquifers
371 was introduced (K-space expansion). The alternative of shared management therefore appeared
372 innovative to the stakeholders. Similarly, F used to admit that they could not be involved in
373 GW management, presumably because (i) the authority of IC for this activity is traditionally
374 accepted and (ii) the knowledge of a shared management of a common pool resource was not

375 held before the experiment. This assumption was shared by F but not explicitly expressed or
376 endorsed. This assumption was discarded when the idea of a shared management emerged, and
377 the latter management option was hence seen as innovative by F.

378 Insert table 1 about here

379 The second alternative (Table 2) that was considered to be innovative by F and IC was the
380 setting up of a drought early warning system, thanks to an expert who showed examples of how
381 such systems work. In this case, the key propositions implicitly accepted by F and IC were that
382 drought cannot be forecast and, relatedly, that the information on the yearly water availability
383 cannot be shared before the beginning of the agricultural irrigation season. As soon as
384 references to forecasting and information sharing tools started to surface in the discussions, they
385 progressively figured that numerous tools, among which several they already knew about, could
386 perfectly work to foresee droughts in a relevant and sufficiently early way. The early warning
387 system was hence seen as innovative by F and IC because it led them to discard the implicitly
388 held assumption that droughts cannot be forecast and information on water availability cannot
389 be efficiently shared.

390 Insert table 2 about here

391 The third alternative (Table 3) considered was the transport of water from other regions. The
392 Apulia Region does not hold SW sources, and GW is difficult to reach in several parts of the
393 region bringing several issues related to its quality and quantity. For this reason, the region
394 already imports fresh water from the regions nearby. It has one of the longest aqueducts in
395 Europe and a system of dams, built in the 1900s. Based on these facts, F implicitly assumed
396 that it is not possible to increase the volume already transported. By contrast, other actors such
397 as IC knew of existing, technically feasible means to transport water from other regions and
398 thereby provide a solution to the problem facing F. As discussions unfolded and started to

399 mention these technical possibilities, F figured that their above-mentioned implicit assumption
400 was not warranted, which led them to this this alternative as innovative.

401 Insert table 3 about here

402

403 5. Conclusions

404 Innovating in designing policy alternatives is an urgent and major challenge for policy makers,
405 the general public and scientists concerned to contribute to address current problems of global
406 concern, such as environmental crises or widespread socio-economic inequalities. While the
407 literature in political science is almost silent on this key issue, design theory has developed
408 tools, most prominently C-K theory, which proved very fruitful in their application to the design
409 of marketable objects, but have barely been applied to policy issues. We have shown here that
410 this gap can be explained by conceptual weaknesses of the original C-K theory framework, and
411 we have explained how these weaknesses can be overcome by introducing a new, refined
412 framework, C-K^{E/I}. This work intended to contribute to rationalizing policy design by clarifying
413 a conceptual framework (C-K^{E/I}) demonstrably empirically relevant. Full-fledge large-scale
414 empirical validation in randomized experimental design fall beyond our scope. Our pilot
415 application to water management in Apulia Region illustrated the relevance and operability
416 of this proposed framework. Further empirical applications are needed to confirm its usefulness.
417 Future studies should also explore other design theories (beyond C-K theory) to assess their
418 promises, in an approach paralleling what we have done here. Similarly, because innovation in
419 policy design is only one aspect of the policy cycle, analyzing the other aspects of the cycle
420 through the lenses of our approach can also be promising to improve policies.

421 At a conceptual and formal level, future work should strengthen formalization by building on
422 relevant insights from the literature in philosophy and theoretical computer science.
423 Philosophers have extensively studied different mental attitudes (beliefs, intentions,

424 acceptance, etc.) and explored their relations (Bratman 1992, Cohen 1992, Tuomela 2000,
425 2002). The interplay between individual and collective attitudes (like common belief and
426 common knowledge) has also been investigated in artificial intelligence (Fagin et al. 1995, van
427 Ditmarsch et al. 2007, Herzig et al. 2009), based on modal logic with a standard possible world
428 semantics. These various approaches could open avenues for further developments or our
429 framework.

430

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537 Apulia Region case study – Ex-post analysis about generated policy alternatives, implicit and
 538 explicit modal statements (from Pluchinotta et al. 2019)

539 Table 1. Explicit and implicit modal statements relative to the alternative “shared management of the GW aquifer”

Alternative: Shared management of GW aquifer [considered to be innovative by F and IC]		
Explicit/Implicit propositions	Stakeholder	Propositions
Explicit	RA	GW use cannot be ruled but with a tariff
Explicit	IC	GW use cannot be ruled but with monitoring systems
Explicit	RA Epm	GW use must be drastically reduced due to the bad state of the aquifers
Explicit	IC RA Epm	In case of drought, GW cannot be used
Explicit	IC RA E	Seawater intrusion is the consequence of GW over pumping
Explicit	IC RA	F use only SW managed by IC
Explicit	F	F use GW
Explicit	RA	The territory is wide, monitoring directly GW use is expensive
Explicit	Eae	GW has a distributed distribution system, SW has a centralized distribution system

Implicit	IC	<p>W can be managed only by IC</p> <p>→ the idea of shared management discards this proposition implicitly held by IC => innovative for IC</p>
Implicit	IC	<p>GW distribution system can be managed too</p> <p>→ becoming aware thanks to an intervention of an expert in agricultural economy and Ostrom's principles of governance of the commons explaining the specificities of a shared GW management led IC to discard this implicitly held proposition. In details, while SW is generally characterized by a centralized distribution system, GW aquifers are highly distributed on the territory, this was considered a constraint rendering its management by a centralized authority impossible. However, the shared management of a GW aquifer would be possible if we move from a command and control approach to the reward/responsibility principles => the idea of shared management discards this proposition implicitly held by IC => innovative for IC</p>
Implicit	<p>IC</p> <p>RA</p> <p>F</p>	<p>GW cannot be managed by F</p>

		→ the examples and idea of a shared GW management led F to discard this implicitly held proposition => innovative for them
Implicit	F	It is not possible to know the evolution of the quality state of the aquifers → the information shared by the experts on the water analysis, led F to discard this implicitly held proposition => innovative for F
Implicit	F	The well are in my private property and I obtained the license, I can use GW without constraints → the information shared by the experts on the difference between formal ownership and the right of use of the resource, led F to discard this implicitly held proposition => innovative for F

540

541 Table 2. Explicit and implicit modal statements relative to the alternative “Drought early warning system”

Alternative: Drought early warning system [considered to be innovative by F and IC]		
Explicit/Implicit propositions	Stakeholder	Propositions
Explicit	IC RA	In case of drought, GW cannot be used, due to the reduced quality and quantity
Explicit	IC RA	F need to adapt their crop plan to the IC rainfall forecast

Explicit	F IC RA	F choose profitable and water-demanding crops over rain-fed crops
Explicit	F	It is difficult to change drastically from water-demanding crops to other crops due to the automatic harvesting process (via crop harvesting tools)
Explicit	F	It is expensive to invest in other crop harvesting tools
Explicit	IC RA	F use only SW managed by IC
Explicit	F	F use GW
Explicit	F	The crop plan cannot be modified in a short time frame, due to the contracts, advance capital, work schedule, etc.
Implicit	F IC	It is not possible to forecast drought events in advance → the information shared by the experts on the drought watch systems, led F and IC to discard this implicitly held proposition => innovative for F and IC
Implicit	F IC	The information on the yearly water availability cannot be shared before the beginning of the agricultural irrigation season → the awareness on technologies for the earlier information, led F and IC to discard this implicitly held proposition => innovative for F and IC

542

543

544 Table 3. Explicit and implicit modal statements relative to the alternative “Water transport from other regions”

Alternative: Water transport from other regions [considered to be innovative by F]		
Explicit/Implicit propositions	Stakeholder	Propositions
Explicit	IC RA	In case of drought, GW cannot be used
Explicit	IC RA	F need to adapt their crop plan to the IC rainfall forecast in a short timeframe
Explicit	IC RA	F use only SW managed by IC
Explicit	F	F use GW
Explicit	IC F	It is expensive to transport more water from other regions
Implicit	IC	We already transport water from other regions, it is not possible to increase the volume already transported

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