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Different Roles and Viewpoints of Scientific Experts in Advising on Environmental Health Risks

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Environmental health risks are often complex, largescale, and uncertain. The uncertainties inherent in these problems permit differences among experts in the appraisal of risks. This raises the question of whether different expert roles exist and, if so, how this affects the policy advice that is given. Here, we present a pilot study of the different roles and viewpoints that can be discerned among scientific experts in the Netherlands. Q methodology was used to empirically explore existing theoretical treatises on different expert roles. In total, 26 electromag-netic field (EMF) experts and 21 particulate matter (PM) experts participated. The responses were analyzed separately for EMF and PM respondents using Q factor analysis. In both the EMF and PM domain, three different expert roles were identified. This suggests that particular expert roles depend on the specific environmental health risk. The results indicate that different expert roles exist among scientists who provide policy advice on environmental health risks. This empirical study adds new data and insights to the literature on expert roles. The results of this study are relevant for the selection and composition of expert committees and the interpretation of expert advice.

KEY WORDS: Electromagnetic fields; environmental health risks; expert roles; particulate matter; Q methodology; scientific policy advice

1. INTRODUCTION

The advisory role of scientific experts in the field of environmental health is subject to scientific and public debate.(1,2) Public doubt concerning the role of scientific experts is regularly expressed, as occurred recently during the IPCC "Climategate" incident and the Mexican flu outbreak, for example. Scientifically, this debate has been ongoing for decades.(3,4) Several scholars have discussed the various potential roles of experts in the interplay between science and policy. Wildavsky's(5) famous phrase "speaking truth to power" suggests a clear division of tasks between science and politics. According to Wildavsky, scientific experts should communicate objective and true knowledge to politicians. Jasanoff,(6) however, states that "the notion that scientific advisors can or do limit themselves to addressing purely scientific issues seems fundamentally misconceived" because the idea of the completely value-free scientist is outdated and the relationship between science and policy is intricate. These competing positions point to the dilemmas that scientists often face in their interactions with policymakers, as well as to the tension between science and policy making in general.(7)

Discussions about the position of scientific experts in the policy process are especially likely to occur when knowledge is incomplete, the research

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subject is highly uncertain, and ambiguity of values exists. These properties characterize many modern environmental health risks, which are complex problems embedded in wider environmental, social, economic, and political systems.[8–14] The WHO defines environmental health risks as "all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviors. It encompasses the assessment and control of those environmental factors that can potentially affect health."[15]

In many cases, policymakers are required to make decisions even when the available data are scarce, uncertain, and contradictory because the effects of environmental health hazards may turn out to be irreversible before conclusive scientific evidence becomes available.[16,17] Hence, pressure exists on scientific experts to give advice, even when substantial scientific uncertainties and ambiguity of values remain. Our interest lies in the roles of scientific experts and the tension that results from the combination of uncertain knowledge with a societal demand for clear policy advice. In this article, we examine the ways in which scientific experts cope with this tension, with an empirical focus on the topics of electromagnetic fields (EMFs) and particulate matter (PM).

EMFs are produced by a variety of natural and man-made sources. EMFs are characterized by their frequencies and associated wavelengths. Important anthropogenic EMFs are the static fields and extremely low frequency fields (typically 50 or 60 Hz) associated with electricity production, transport, and use in appliances and radio frequency fields (ranging from 300 Hz to 300 GHz and used in applications such as mobile communication, WiFi, DECT phones, radio and television transmission, and radar). Many EMF sources have proliferated rapidly over the past few decades (e.g., DECT and cell phones and associated base stations, WiFi, radiographic baby phones, and remote controls). The health effects of EMFs at high exposures are well documented, but at exposure levels that are currently typical for the general population, there is insufficient scientific evidence of adverse health effects. Effects reported at lower exposures in some studies (but not in others) differ in nature from effects observed at higher levels. Currently, the scientific community is highly divided on whether EMFs represent a health risk.[18]

The second domain considered in this study, PM, consists of a complex mixture of airborne particles of various diameters, chemical compositions, and physical properties. PM may be natural (e.g., suspended sea salt, soil dust, pollen) or may result from human activity (e.g., industry, energy production, transport). There is ample scientific evidence for adverse health effects of PM at exposure levels that are currently typical among the general population.[19]

The health effects of both EMFs and PM are subject to public and scientific debate. The debate concerning EMFs focuses on whether a causal relationship exists between exposure and possible adverse health effects at exposure levels that are experienced by the general population. The debate about PM mainly concerns the health impacts of different particle types, the underlying causal mechanisms, and the nature of the exposure-response relationship for various health endpoints. Linked to these debates is the question of whether (precautionary) policy measures can be taken and, if so, what these measures are.

Multiple scholars, including Pielke and Weiss,[20–24] have discussed whether all experts give advice in the same way or whether different experts assume different roles. Pielke and Weiss have each described in a theoretical manner the different ways in which experts might cope with complex environmental health risks. Central to their descriptions is the idea that scientists assume different expert roles in different situations. Pielke described the different roles that experts can fill when interacting with policymakers in highly uncertain and politicized contexts, presenting his ideas by means of a typology (see Fig. 1a). Some scientific experts believe that their role is primarily to conduct research and not to engage in intensive contact with policymakers. These experts are likely to present their research questions and results differently than do scientists who believe policy-relevant knowledge, that is, science that answers specific policy questions, to be most important. Pielke distinguishes four roles: the pure scientist, the science arbiter, the issue advocate, and the honest broker of policy alternatives. The *pure scientist* seeks to focus only on facts and has no interaction with the decisionmaker. The *science arbiter* answers specific factual questions posed by the decisionmaker. The issue *advocate* seeks to reduce the range of choices available to the decisionmaker by promoting one specific solution, and finally, the *honest broker* of policy alternatives seeks to expand, or at least clarify, the range of choices available to the decisionmaker.

Weiss proposed a typology based on five positions that a scientist can take in dealing with uncertainty. Each position represents an attitude that is the result of a given level of uncertainty in

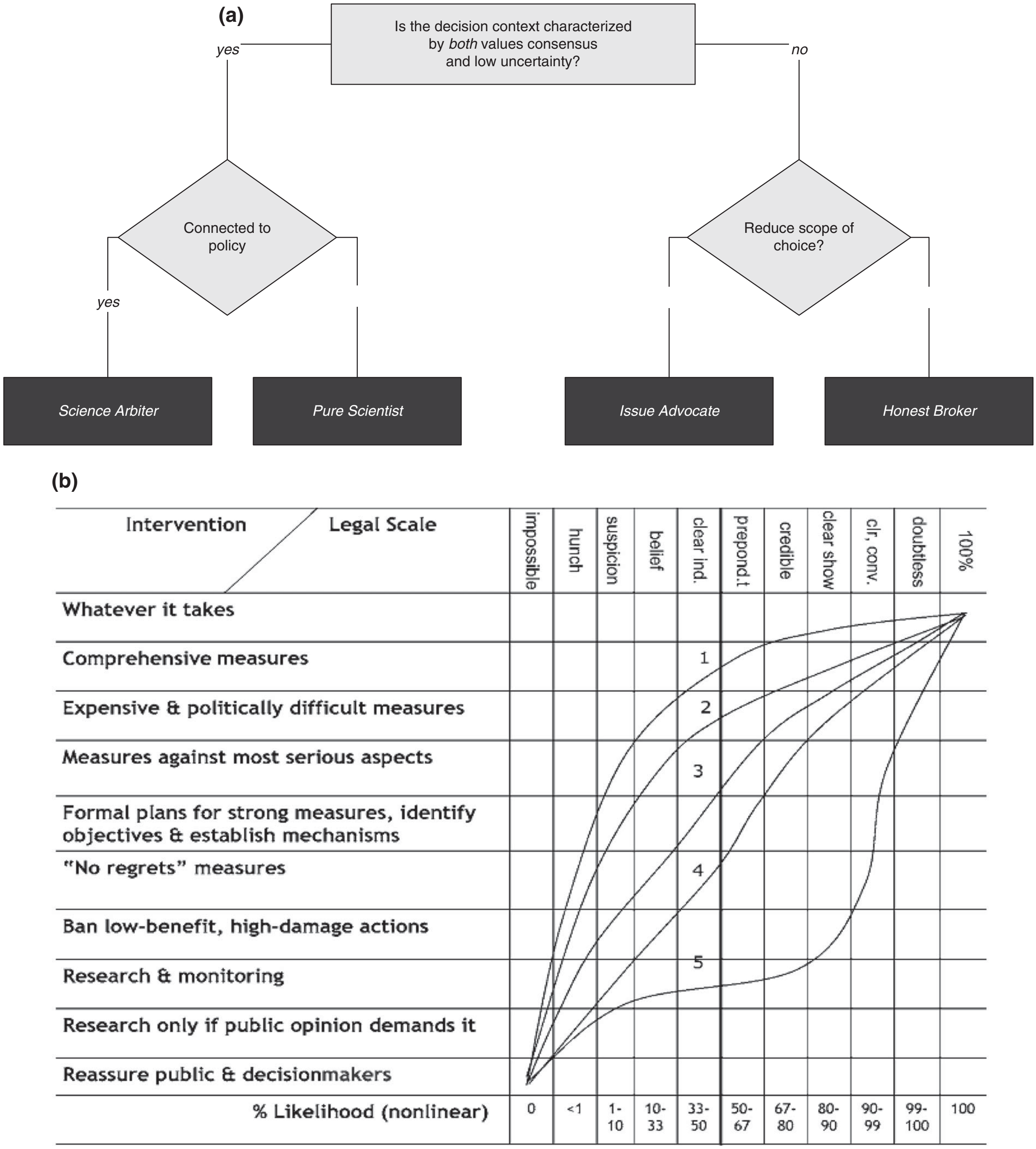

Fig. 1. (a) The criteria proposed by Roger A. Pielke, Jr. for the different roles of scientists in policy and politics.[22]
(b) The typology proposed by Weiss.[35] The expected international action to address the shared danger of severe and irreversible harm is plotted as a function of the degree of scientific certainty and the degree of risk aversion. The probability scale is nonlinear and asymmetrical. Curves corresponding to different levels of risk aversion are represented as follows: 1. Environmental absolutist; 2. Cautious environmentalist; 3. Environmental centrist; 4. Technological optimist; 5. Scientific absolutist.

combination with differences in the perceived necessity to take measures and the willingness to do so, given the associated (societal) costs (see Fig. 1b). Some experts might assert that any suggestion of an increase in risk is unacceptable and that the widespread use of new technologies should therefore be permitted only after thorough research has shown that there is no adverse health effect. Weiss termed these experts *environmental absolutists*. Other experts see risk as an inextricable part of innovation and accept the possibility of negative (side-) effects in the name of progress. Weiss used the term *scientific absolutists* to denote these experts. In between these two extremes, Weiss positioned the *cautious environmentalist*, the *environmental centrist*, and the *technological optimist.*

Thus far, there has been little empirical evidence to support the proposed typologies. By empirically exploring the existence of different expert roles, this study extends the existing knowledge about expert advice and policy making. Our overall aim is to empirically explore the existence of different roles and viewpoints among experts in the EMF and PM domains and to do so against the background of scientific and public debates on environmental health risks. The following questions have guided us throughout our research:

(1) Do different experts have different roles when interacting with policymakers about environmental health risks?
(2) Do EMF and PM experts differ in how they interpret evidence and advice concerning environmental health risks?
(3) To what extent do these different roles correspond with the elements of Pielke's and/or Weiss's typologies?

2. METHODS

2.1. Q Methodology

Q methodology was used to explore the presence of different expert roles in the field of environmental health (for an extensive description of the history, function, and reliability of Q methodology, see Refs. 25–28). Q methodology was developed in the 1930s as a technique for studying human subjectivity.[29] This technique involves asking participants to sort a number of statements based on their personal level of (dis)agreement with the statements. The resulting Q sorts, which represent the viewpoints of individuals, are used to identify clusters of shared ways of thinking that exist among groups of people.[30] These clusters are identified statistically using Q factor analysis. An important assumption in Q methodology is that a limited number of distinct clusters exist for any particular topic.[25] The methodology has only recently become more frequently used by researchers,[31] particularly in the domain of environmental studies.[32]

Table I. Background Information on Participants

	EMF	PM
Age (average)	47 (*SD* 10)	47 (*SD* 8.5)
Number of years in field (average)	1.8 (*SD* 0.4)	8.4 (*SD* 8.8)
Scientific background	Natural and social sciences	Natural sciences
Gender (m/f)	20/6	17/4

2.2. Q Sample

The 39 statements included in the Q sample (see the Appendix) were compiled by the authors based on the published literature (including the work of Pielke and Weiss) and input provided by colleagues working in the respective scientific domains. The statements were numbered randomly. Thirty-four of these statements were exactly the same for both of the domains, with the abbreviations EMF and PM interchanged. The other five statements were related to concrete policy measures and were therefore domain specific. The balance, clarity, and simplicity of the Q sample were pretested with the help of three respondents who did not take part in the final study.

2.3. Participants and Data Collection

Dutch experts were selected based on their knowledge of the scientific discourse and professional activity on either one of the two specific research domains (EMFs and PM). Their expertise is evident from research activities (the majority holds a Ph.D.), scientific publications, and/or scientific advisory activities. The recruitment process consisted of contacting the members of Dutch national committees, researchers at Dutch universities and other scientific institutes, and additional experts identified through the network of the Dutch National Institute for Public Health and the Environment (RIVM). We approached 38 EMF experts and 49 PM experts by mail. After a week, nonrespondents received one reminder. In total, 26 EMF experts and 21 PM experts participated (response rates: EMF = 68.4% and PM = 42.9%). Table I shows selected background information on the participants, including scientific background (i.e., physics, chemistry, medicine,

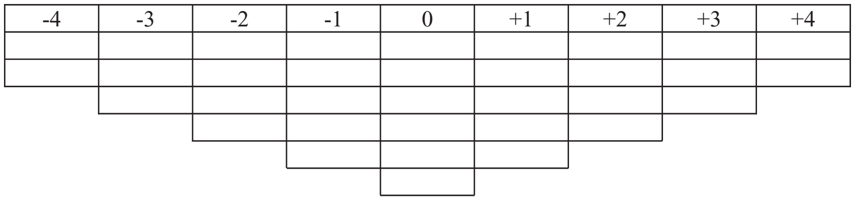

Fig. 2. Example of score sheet for the Q sort (quasi-normal distribution).

epidemiology, biology, environmental sciences, and psychology) and number of years in the field.

Data collection was conducted in May 2010 using the web-based program FlashQ. For the sorting exercise, participants were asked to read the statements and score them according to a forced quasi-normal distribution ranging from –4 (most strongly disagree) to +4 (most strongly agree), with a middle column representing "neutral" or "do not know" (see Fig. 2). Additional open questions about the motivation behind the scoring of the statements gave us further insight into the reasoning and motivations of the participants.

2.4. Statistical Analysis

PQMethod software (version 2.11) was used to analyze the correlation and factoring of the Q sorts. A Q sort consists of the complete rank ordering of the statements as scored by one participant. First, a statistical correlation summarizes the similarities in views among participants. Q factor analysis then identifies clusters of similar viewpoints. Subsequently, a characteristic Q sort distribution is calculated for each factor based on the standardized factor scores. This distribution reveals the statements that are scored similarly in each cluster and therefore gives an idea of the common viewpoint represented by each factor. The 26 EMF sorts and the 21 PM sorts were analyzed separately but in an identical manner. The sorts and the statements were correlated in an n-by-n matrix. Centroid factor analysis was conducted on each matrix using PQMethod.[26] Three factors were distinguished for each domain based on the following three criteria conventional in Q methodology: (1) factors with eigenvalues above 1 were considered significant,[25,33] (2) each group contained at least three experts, and therefore only factors with three or more significant loadings were considered (note that with Q, persons rather than statements load on each factor), and (3) an explained variance of over 4% was considered acceptable. The analysis sensitivity was tested by changing the eigenvalue, shifting the percentage explained variance boundary, increasing/decreasing the minimum number of sorts, and analyzing both data sets together. Varimax rotation[34] was used to obtain a clear pattern (simple structure) of factor loadings such that factors were clearly characterized by a small number of high loadings for some variables and a large number of zero or small loadings for others. The vast majority of sorts loaded on one factor, but we also found sorts that were not significantly associated with just one factor. Two EMF sorts and one PM sort loaded on several factors; these can be seen as hybrids of the derived factors. As is common with the Q method, these sorts were set aside during the interpretation phase, although we are aware of theirexistence.

We interpreted the factors based on both the computed composite factor scores and the so-called distinguishing statements. Given three factors X, Y, and Z, a distinguishing statement for factor X is a statement that received a score in factor X that is significantly different from the corresponding score in factors Y and Z. An example of a distinguishing statement is EMF statement 15 (see Table A1), which states that an expert has a choice in the way he or she presents scientific knowledge to a policymaker. Of the three factors that we found among EMF experts, the experts in factor 2 hold a very different point of view regarding statement 15 compared to the experts in factor 3, as is shown by the average scores for this statement of +3 (strongly agree) in factor 2 and −3 (strongly disagree) in factor 3.

3. RESULTS

In each of the two domains, three distinct factors were distinguished. The extracted factors yield total explained variances of 57% in the EMF domain and 51% in the PM domain. The full list of statements with associated factor scores is presented in Table A1. Although the number of extracted factors is the same for both domains, the factor loadings and thus the meanings of the factors differ between the two domains. Each of the two groups of three factors

Table II. Statistics Related to Roles in the Electromagnetic Field Subdomain

	Role A: The Autonomous Scientist	Role B: The Pragmatist	Role C: The Action-oriented Expert (*C*1: *Overseer* and *C*2: *Proactive Expert*)
N	9	12	3
Explained variance (%)	25	23	9
Statements most strongly agreed with (+3 and +4)	16, 21, 28, 29, 30	1, 11, 12, 15, 24	1, 12, 14, 24,37
Statements least strongly agreed with (−3 and −4)	5, 6, 26, 33, 36	6, 9, 26, 33, 38	15, 26, 31, 33, 36

will be discussed separately in relation to the typologies of Pielke and Weiss. In line with these typologies, the factors are here referred to as "roles."

3.1. Electromagnetic Field Experts

Although the level of agreement with most of the statements in the Q sample varied among experts, there was consensus on a few of the statements. For example, all of the experts disagreed with the statement that EMFs are a danger to public health (statement 26). Not a single expert agreed that exposure to EMFs from cell phones causes brain tumors (statement 33) or that we should drastically reduce the overall exposure of the population to EMFs (statement 36). All of the EMF experts strongly agreed with the statement that risks to public health and the environment have always existed and will always remain (statement 24). Finally, most of the experts did not agree that EMFs represent an uncertain risk (statement 7). From the pattern of responses, three clusters of viewpoints emerged. We interpreted these as representing Role A: the *autonomous scientist*, Role B: the *pragmatist expert*, and Role C: the *action-oriented expert*.

3.1.1. Role A: The Autonomous Scientist

The *autonomous scientist* role was shared by nine participants and explained 25% of the total variance. This role is characterized by a belief in the strict separation of science and policy. This role emphasizes that scientists are sources of pure scientific knowledge (statements 4, 8, 21, 28, 29, and 30; see Table II) and highlights the opinion that science should contribute to the solution of social problems (statement 12). Put differently, this role reflects the belief that science must contribute to society but that it should do so without intense deliberation between scientists and policymakers (statements 1 and 13). Scientific findings should incite action or new policies (statement 13), but at the same time, the interaction between scientist and policymaker should be unidirectional (namely, from the scientist to the policymaker).

The *autonomous scientist* role expresses the belief that EMFs do not pose a real threat to public health and the environment (statement 26). The perception of the participants is that we do not need to bring down the overall exposure of the general public to EMFs (statements 36, 38, and 39). In line with this, precautionary policies are not considered necessary (statement 19). More concretely, the government should not dissuade children from using cell phones (statement 31), and according to the experts in this role, EMFs do not increase the risk of developing a brain tumor (statement 33). Additionally, these experts believe that disagreement exists among their peers about the definition of the problem and how to tackle it (statements 5 and 6). The nine participants who scored high on the role of the *autonomous scientist* do not think that there are certainly health risks of EMFs, but they do agree that there is a lot of certainty in our current knowledge about EMFs. In line with this, the *autonomous scientist* believes that there is no need for more research. (S)he thinks that it is adequate to monitor current and future developments in this domain. In the *autonomous scientist*, elements of Pielke's *science arbiter* and *pure scientist* types (both of which support a low level of science-policy interaction) are found. In addition, Weiss's *scientific absolutist* type (take no action until EMFs are proven to be damaging) is found in this role. Taking all of this into account, we have termed this role the *autonomous scientist* because the participants strongly value a strict separation between science and policy and thus support the autonomy of scientists.

3.1.2. Role B: The Pragmatist

The *pragmatist* role was shared by 12 participants and explained 23% of the total variance. This role is characterized by participants who do not seek a strict separation between science and policy (statements 9, 4, and 8). This is in contrast to the role of the *autonomous scientist* (as is also shown by a Pearson's correlation of –0.61 between the factor scores for Roles A and B). The *pragmatist* emphasizes that scientific information is often used as a strategic resource in ideological debates (statement 11) and highlights the opinion that a scientific expert can choose how to present scientific knowledge to policymakers (statement 15).

The *pragmatist* participants disagreed with statements 5 and 6, indicating that they believe that disagreement exists among EMF experts about the definition of the problem and how to tackle it, although this opinion was not as strong in this role as it was in the *autonomous scientist* role.

The *pragmatist* role is found to be directly opposite to elements of Pielke's *pure scientist* and *issue advocate* types (both of which support the minimization of the range of choices available to the policymaker), as the *pragmatist* believes that experts should not reduce the range of choices available to policymakers. None of Weiss's types are convincingly found in the *pragmatist* role, but this role points in the direction of the *environmental centrist* type (statement 18).

We have termed this role the *pragmatist* because the participants who scored high on this role appear to support a turn toward concreteness and adequacy. These participants are aware of the different ways in which knowledge can be used (e.g., strategically, informatively, or deliberatively) and believe that it is the expert who chooses between these options. The *pragmatist* believes that interaction between science and policy is inevitable and necessary.

3.1.3. Role C: Action-Oriented Expert

The *action-oriented* role was shared by three participants and explained 9% of the total variance. Important to note is that within the role of the *action-oriented expert*, two participants sorted the statements in one order and one participant sorted them in the reverse order. For example, a statement about dissuading cell phone use by children was given a factor score of +3 by the first two participants and a factor score of −3 by the third participant. Hence, this role is a "bi-polar role" with two opposing viewpoints on the same axis, which makes it necessary to distinguish two subroles (Role C1: the *overseer* and Role C2: the *proactive expert*). The common denominator for all three action-oriented experts is a position on the continuum of action perspectives, though these experts differ in which action they consider to be the most appropriate.

*C*1: The *overseer* perceives the monitoring of concentrations and possible health effects as an appropriate policy approach in the EMF domain, as the factor score for statement 37 illustrates. This role expresses the beliefs that consensus exists among experts about the extent of the problem (statement 6) and that experts agree on the most suitable measures to take (statement 5). In line with this, the *overseer* role is characterized by the belief that there is little uncertainty regarding the risks of EMFs to public health. This role emphasizes that there is no need for more research in this domain (statement 32) and highlights the opinion that the government should not take active measures (e.g., advise children to minimize the use of cell phones [statement 31]). We have termed this role the *overseer* because these participants appear to believe that the EMF domain must be monitored but that, at the moment, this domain is under control and intervention is unnecessary.

*C*2: The *proactive expert* is on the same axis as the *overseer* but at the other end, which means that these two roles hold opposite views. Whereas the *overseer* believes that the monitoring of developments is an appropriate policy approach, the *proactive expert* thinks that precautionary action is necessary and that all options should be presented to policymakers. Furthermore, the proactive expert beliefs that there is no consensus among experts about the extent of the problem or on the most suitable measures to take.

3.2. Particulate Matter Experts

All of the PM experts strongly disagreed with statements 22 and 23, which state that measures should be taken to protect public health only when irrefutable scientific evidence is available. All of these experts shared the belief that the development of new sources of PM should be impeded (statement 22). The experts agreed that the current Dutch standards for PM are debatable and that PM levels under the current standards do not necessarily mean that there are no health effects (statement 34). Finally, there was strong agreement among the experts that research should contribute to solving societal problems (statement 12).

Table III. Statistics Related to Roles in the Particulate Matter Subdomain

	Role 1: The Engaged Expert	Role 2: The Instrumental Expert	Role 3: The Deliberator
N	7	6	7
Explained variance (%)	20	16	15
Statements most strongly agreed with (+3 and +4)	12, 18, 20, 33, 39	12, 14, 16, 30,37	1, 12, 14, 16, 28
Statements least strongly agreed with (–3 and –4)	9, 22, 23, 27, 34	8, 10, 22, 23, 34	9, 22, 23, 34, 37

Based on the pattern in the responses of these experts, we distilled three roles within the PM expert group. These will be described as Role 1: the *engaged expert*, Role 2: the *instrumental expert*, and Role 3: the *deliberator*.

3.2.1. Role 1: The Engaged Expert

The *engaged expert* role was shared by seven participants and explained 20% of the total variance. This role is characterized by the idea that the government should take precautions to reduce PM emissions (statements 39 and 18; see Table III) and that merely monitoring developments is not a sufficient approach (statement 37). Furthermore, the role emphasizes that we should not act on natural sources of PM such as windblown dust, sea spray, and wildfires (statement 33) and highlights the opinion that there is agreement among scientific experts on the nature and extent of the problem (statement 6). The *engaged expert* participants disagreed with the statement that finding truth is the only objective of science (statement 8) and agreed with the idea that scientific experts have a choice in how they present scientific knowledge to policymakers (statement 15).

The *engaged expert* role is found to be opposite to Pielke's *pure scientist* and *science arbiter* types. Elements of Weiss's *environmental absolutist* type are found in the *engaged expert*, as these participants expressed agreement that precautionary measures are the most appropriate policy approach. We have termed this role the *engaged expert* because the participants who scored high in this role appear to be strongly convinced that PM is an important issue that deserves attention from science and policy.

3.2.2. Role 2: The Instrumental Expert

The *instrumental expert* role was shared by six participants and explained 16% of the total variance. This role is characterized by the belief that scientists should maximize the range of choices available to policymakers. Correspondingly, these participants strongly disagreed with the idea that a scientist should select any particular type of knowledge to present to a policymaker (statement 10). The *instrumental expert* role highlights the opinion that PM is an uncertain risk (statement 7) but that despite the uncertainty, the government should not follow the "standstill principle" (statement 38). Indeed, monitoring developments is the most appropriate approach (statement 37) according to this group. This is opposite to the viewpoints of the *engaged expert* and the *deliberator* (as is also evident from a Pearson's correlation of –0.49 between the factor scores for Roles 1 and 2).

Typical of the *instrumental expert* is the belief that science should not be separated from policymaking (statement 8). This role is found to be opposite to Pielke's *pure scientist* and *issue advocate* types. Indeed, *instrumental expert* participants agreed with the idea that a scientific expert should expand the range of choices available to a policymaker. This point of view corresponds to that of Pielke's *honest broker of policy alternatives*.

We have termed this role the *instrumental expert* because these experts consider monitoring to be an appropriate policy approach even though they believe that PM represents an uncertain risk. This points toward the support of instrumental action, that is, the implementation of measures when necessary but not the direct implementation of every possible solution.

3.2.3. Role 3: The Deliberator

The *deliberator* role was shared by seven participants and explained 15% of the total variance. This role is characterized by the belief that monitoring current and future developments is not sufficient (statement 37). Instead, the role emphasizes that scientific experts should deliberate with policymakers about different policy options (statement 1). According to this role, the deliberation, that is, dialogue, itself is important. The *deliberator* does not support the precautionary principle *per se* (statements 19, 24, and 18) and does not strongly agree with the idea that commotion or anxiety amongst civilians is a good motivation for action (statement 3). According to this role, the scientist is the one who presents the facts, and politicians must decide how these facts should be used to guide policy (statement 29). Contrary to the *engaged expert* and the *instrumental expert*, who have relatively neutral positions, the *deliberator* considers knowledge presented by laymen to be less valuable to policymakers than knowledge presented by scientific experts (statement 28).

The *deliberator* is a clear example of the type that Pielke called the *honest broker of policy alternatives*. The emphasis of this role is on a broad dialogue, and because of this, we have termed this role the *deliberator*.

3.3. Comparison Between Electromagnetic Fields and Particulate Matter

The three roles distinguished among the EMF experts are different from the three roles found among the PM experts. Overall, we see a divide in the interpretation of the knowledge bases of the two domains: EMF is interpreted as a certain risk problem (i.e., EMFs are believed to present no health risk to the general population), and PM is interpreted as an uncertain risk problem (i.e., PM is believed to present a health risk to the general population). We recognized elements of Pielke's *pure scientist* and *science arbiter* primarily among the EMF experts and elements of the *issue advocate* and the *honest broker* primarily among the PM experts. Weiss's typology can be seen as a continuum ranging from the *scientific absolutist* to the *environmental absolutist*. Both extremes were observed in this study. The *scientific absolutist* was found among the EMF experts and the *environmental absolutist* was found among the PM experts. None of the middle positions on Weiss's continuum were clearly identified among the respondents in this study. Nonetheless, the *pragmatist* (Role B) in the EMF domain indicates that some experts do assume a more intermediate role.

4. DISCUSSION

In this study, Q methodology was used to identify and describe the different roles that environmental health experts can assume in their interactions with policymakers. The aim of this study was to empirically explore the existence of different roles among experts in the EMF and PM domains, with reference to the typologies of Pielke[22] and Weiss.[24,35]

We found three distinct roles in each expert group that met the selection criteria applied in the factor analysis. In the EMF domain, the roles of the *autonomous scientist*, the *pragmatist*, and the *action-oriented expert* were recognized. In the PM domain, we distinguished the roles of the *engaged expert*, the *instrumental expert*, and the *deliberator*. These six roles are considered to represent hybrids of the expert roles proposed by Pielke and Weiss.

Due to the exploratory nature of this study, the results presented here have some limitations. First, in the development of the Q sample, we referred most heavily to the typologies of Pielke and Weiss because those typologies are well elaborated. As a consequence of the ideal-typical nature of the roles postulated by Pielke and Weiss and due to the fact that we combined statements relating to both of those typologies in one Q sample, it may not be surprising that we found combinations of Pielke's and Weiss's roles. However, other theoretical treatises on expert roles exist: for example, see Hisschemöller and Hoppe[20,36] and Funtowicz and Ravetz.[37] In addition, we cannot rule out the possibility of some differences in interpretation between our statements and the original theories. Future research might tease out explicit differences between the theoretical concepts of Pielke and those of Weiss or merge them into an overarching model.

A second limitation of the present results is that additional elements may affect the role that an expert takes in a certain debate, such as the costs of interventions, equity, and the impact on social unrest. Experts may also take the effect on future funding opportunities into account as well as their previous experience with giving policy advice and their relationships with other committee members. These elements would require extensive further assessment, which was outside the scope of this study.

Third, the methodological choices in our study regarding the number of respondents, the selected eigenvalue cutoff of 1, the 4% explained variance criterion, and the minimum number of sorts loading on a factor are conventional in Q methodology but somewhat arbitrary. Different choices might have led to some differences in the results, which is why we cannot claim that we found definitive invariable factors. We have tested the sensitivity of our analysis in a number of ways: changing the eigenvalue, shifting the percentage explained variance boundary, increasing/decreasing the minimum number of sorts (i.e., number of experts sharing a common view), and analyzing both data sets together (results not shown here). Increasing the minimum number of sorts to four would eliminate one factor, Role C. A minimum of three sorts per factor is the common cut-off point in Q methodology studies[38] and increasing that number would mean loss of information (Role C). All other methodological changes that we have analyzed did not affect the results. The sensitivity analysis indicated that the results are rather robust. We have not performed a follow-up of nonresponders in our study and thus do not know their motives. After one reminder, the response rate for PM was 43%. Potentially, experts with views other than mainstream may have been under- or overrepresented. Though there is no indication of bias concerning the final set of respondents, in future applications the use of a more formal expert nomination and selection procedure such as the one proposed in the expert elicitation model by Knol *et al.*[39] could structure the selection process and improve its transparency. There was a difference in the number of years that EMF and PM experts work in their field, reflecting the different histories in environmental health research. PM has a long research history in the Netherlands (going back to the 1960s), while Dutch EMF research is of a more recent date. Therefore, EMF experts on average work fewer years in their field.

Finally, in this study, not all of the sorts (i.e., experts) loaded significantly on one factor; some sorts loaded on multiple factors. Our interpretation is that not all experts fit one particular (theoretical) role and that, instead, some experts adopt parts of different roles. The presence of these hybrids makes us aware that any theoretical distinction may leave some people and positions unaddressed. Collins and Evans[40] argue that all categorizations of expertise will be flawed because such categorizations involve "ideal types," when in reality, cases will exist in which one kind of expertise shades into another. Despite this, our study provides a structured reflection on expert roles at a time when the position of experts is publicly contested. We empirically observe elements of previously proposed expert role typologies, although it appears that the typologies are not fully empirically corroborated. This may also be due to the way this exploratory study has been set up. Nevertheless, we consider it valuable to use the existing typologies to inform discussions about expert roles.

Further empirical work can eventually improve our understanding of expert roles, with potential implications for the way expert advice is organized. For example, the processes of selecting individual advisory experts and assembling advisory panels and committees may be reexamined once the existence of different expert roles is confirmed. The selection of experts in advisory bodies often varies due to the historical contexts in which they were established.[2] Experts are generally selected based on a set of criteria such as their individual knowledge base (discipline), their status as authorities within their discipline, and their willingness to put their knowledge at society's disposal in a disinterested way.[41] This article adds as possible criteria the different roles held among experts. Eventually, teams of experts, with members holding roles that are sufficiently representative of the divergent roles in the expert community, could provide more balanced advice and input for policy assessment and policy making. While consensus advice is desirable where possible, it is generally believed that dissenting views should be made explicit to fully acknowledge pertinent uncertainties. Whether such reporting is possible is, however, dependent on, for example, the type of advice that a committee has been asked to give.

To our knowledge, this is the first empirical study on the advisory roles of scientific experts in the field of environmental health. The overall result is that some elements of the ideal-typical roles distinguished theoretically by Pielke and Weiss are indeed supported by our empirical data. However, the roles found empirically in this study do not completely correspond to those ideal-typical definitions. Moreover, we found some differences in roles between the experts in the EMF domain and those in the PM domain. These may reflect genuine differences, but this must be confirmed in further research. We observed that none of the roles described here were identical in both of the domains, but some overlap exists between the roles in the two domains. Within this study, we cannot rule out an effect of statistical variation stemming from the sampling of experts from two different domains. Overall, we conclude that the existence of different expert roles is evident from the empirical data presented here. However, given the exploratory nature of our study, our findings must be replicated on a larger scale before conclusions can be drawn about the observed differences between the roles identified in each of the two domains and between these and the roles previously described in the literature. Moreover, additional empirical work is needed to determine the cultural elements, context-specificity, and variation over time of expert roles. Following this idea, we note that research in the domains of EMF and PM is dynamic in nature and, consequently, the responses to our statements provide a snapshot that could change when new scientific insights arise.

In conclusion, this pilot study on expert roles is the first of its kind and reveals significant differences in roles among experts, particularly regarding agreement about the necessity and utility of different action perspectives on policy intervention.

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APPENDIX

Table A1. Factor Arrays and Factor Q Sort Values for Each Statement

	EMF Experts			PM Experts		
Statements (with EMF and PM Interchanged)	Role A: The Autonomous Scientist	Role B: The Pragmatist	Role C: The Action-Oriented Expert (*C*1: *Overseer*, *C*2: *Proactive Expert*)	Role 1: The Engaged Expert	Role 2: The Instrumental Expert	Role 3: The Deliberator
1. As an expert, I see it as my job to initiate deliberation with policymakers (and *vice versa*)	–1	3	3	1	0	3
2. As an EMF/PM expert, I see it as my duty to recommend specific policy actions	0	0	2	1	0	1
3. Anxiety reduction in civilians is a good motivation to take action in the case of scientific uncertainty	–1	–1	–1	–2	–1	1
4. Science should only be about the systematic collection of knowledge	2	–2	0	–2	–1	–2
5. EMF/PM experts agree on the measures to be taken to reduce the health risks of EMF/PM	–3	–2	1	0	–2	–2
6. There is complete consensus among EMF/PM experts on the nature and extent of the problem	–4	–3	2	2	–1	–2
7. Uncertainty about the risks of EMF/PM is high	1	0	–1	–1	1	–1
8. Truth is the only purpose of science; policy purposes are irrelevant for science	2	–1	0	–2	–3	1
9. As an expert, I seek strict separation between science and policy. Therefore, I have minimal contact with policymakers	0	–3	1	–3	–2	–4
10. Scientists should present their own selection of knowledge to policymakers	–1	–1	–2	–1	–4	0
11. Science is often used as a strategic resource in ideological debates	0	3	2	–1	1	–1
12. I think it is important for scientific research to contribute to solving societal problems	2	4	3	3	3	3
13. Science should incite action, such as taking concrete policy measures	1	0	1	1	1	0
14. As an expert, it is my responsibility to fully inform decision makers about the available policy alternatives	1	2	4	0	4	4
15. As an expert, I have a choice in how I present my knowledge or assessment to policymakers	0	3	–3	1	–1	–1
16. It is up to politics to decide whether the costs associated with a particular measure are reasonable	3	2	0	1	3	4
17. I think it's better to be safe than sorry	0	0	0	1	0	1
18. When the public health and environmental consequences of a project are uncertain, the benefit of the doubt must be given to people and to the planet	1	1	–1	3	–2	0
19. Even though the effects of EMF/PM are highly uncertain, the government should advise individuals and businesses to take precautionary action	–2	–1	0	0	0	–1
20. Technological innovation will reduce the adverse health effects of EMF/PM	0	1	0	3	2	0
21. New EMF/PM policies should be based only on scientific evidence or at least on the best available knowledge	4	2	2	0	–1	1
22. Given the lack of solid scientific evidence, there is no reason to impede the development of specific EMF/PM sources	0	1	1	–4	–4	–3
23. Measures should be taken only if conclusive evidence that EMF/PM is harmful to public health becomes available	–1	–1	–1	–4	–3	–4
24. Environmental health risks have always existed and will always remain	2	4	3	2	2	–1

(*Continued*)

Table A1. (Continued)

Statements (with EMF and PM Interchanged)	EMF Experts			PM Experts		
	Role A: The Auto-nomous Scientist	Role B: The Prag-matist	Role C: The Action-Oriented Expert (*C*1: *Overseer*, *C*2: *Proactive Expert*)	Role 1: The Engaged Expert	Role 2: The Instru-mental Expert	Role 3: The De-liberator
26. EMF/PM poses a major threat to public health	–4	–4	–4	2	1	0
27. Lack of clarity about appropriate EMF/PM policies is caused primarily by disagreement among experts	–2	–1	–1	–3	–2	–2
28. All things considered, the knowledge of lay people is less valuable for politicians and policymakers than the knowledge of scientists	3	–2	1	–1	–1	3
29. Scientists deal with the facts, and politicians deal with the policy implications of these facts	4	0	1	–1	0	2
30. When there is insufficient knowledge, politicians should decide how to deal with uncertainty	3	2	–2	–2	4	2
32. I think that investing in more research is a sensible policy approach with proportional costs, given the risks and uncertainties about the effects of EMF/PM at current levels	1	1	–2	0	2	2
36. Given the high uncertainty about the effects of EMF/PM at current levels, I think that drastic exposure reduction is a sensible policy approach with proportional costs	–3	–2	–3	0	0	0
37. Given the high uncertainty about the effects of EMF/PM at current levels, I think that monitoring of developments is an effective policy approach with proportional costs	1	1	4	–2	3	–3
38. Given the high uncertainty about the effects of EMF/PM at current levels, a powerful "standstill principle" should be applied	–2	–4	–2	0	–2	0
39. The government should take precautionary measures to reduce exposure	–1	0	–2	4	1	2
Specific EMF statements						
25. People who do not want to be exposed to EMF should just move	–1	–2	0			
31. I think we should implement a measure to discourage children from using cell phones	–2	0	–3			
33. Cell phones probably cause brain tumors	–3	–3	–4			
34. It is necessary to set standards that protect employees from frequent EMF exposure	2	2	2			
35. It is hypocritical to take precautionary measures for new pylons while old ones may simply persist	–2	1	–1			
Specific PM statements						
25. I think we should introduce a compulsory particle trap for diesel engines				2	1	2
31. I think there should be a regulatory standard for particles smaller than PM10, say a PM2.5 standard				2	2	–1
33. PM originating from sea salt is a natural phenomenon that we should not seek to reduce				4	2	1
34. PM concentrations under the current policy standard imply a healthy environment				–3	–3	–3
35. Lowering the speed limit for road traffic has a positive effect on public health; therefore, it is a desirable policy measure				–1	0	–2

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