FORECASTING USING INTERNAL MARKETS, DELPHI, AND OTHER APPROACHES: THE KNOWLEDGE DISTRIBUTION GRID

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ABSTRACT

Much forecasting is done by experts, who either make the forecasts themselves or who do opinion research to gather such forecasts. This is consistent with previous knowledge management research that typically has focused on directly soliciting knowledge from those with greater recognized expertise.

However, recent research has found that in some cases, electronic markets, whose participants are not necessarily individual experts, often have been found to be more effective aggregated forecasters. This suggests that knowledge management take a similar tact and expand the perspective to include internal markets. As a result, this chapter extends the use of internal markets to be included in knowledge management, thus expanding the base of knowledge to gathering from nonexperts.

In particular, in this paper I examine the use of human expertise and opinion as a basis to forecast a range of different events. This chapter uses a "knowledge distribution grid" as a basis for understanding which kind of forecasting tool is appropriate for particular forecasting situations. In particular, we examine a number of potential sources of forecast

Advances in Business and Management Forecasting, Volume 6, 157–172

ISSN: 1477-4070/doi:10.1108/S1477-4070(2009)0000006010

information, including knowledge acquisition, Delphi techniques, and internal markets. Each is seen as providing forecasting information for unique settings.

1. INTRODUCTION

Some forecasting questions, such as "who will be elected President?" or "Who will win the Olympic Medal in Water Polo?" can use expert opinion, general opinion polls, or electronic markets as a basis of forecasting. Recent results have found that although expert opinion and opinion polls might receive the most publicity in the media, electronic markets are likely to provide a more accurate forecast of what will happen.

The same approaches might be used to address similar enterprise or corporate forecasting problems. As a result, it is probably not surprising that recent results have found that corporate internal markets provide insight that often is better than expert opinion.

However, having nonexperts, use internal virtual dollars to help develop forecasts, to assist corporations is a break from the classic approach, based on having experts forecast events.

1.1. Knowledge Management and Forecasting

Knowledge management systems generally gather knowledge from experts. For example, as seen in O'Leary (2008a, 2008b), the classic notion of expert systems and even new artifacts, such as Wikis, are based on the notion that some people know more than others and the knowledge management systems let them share that knowledge.

Further, historically, knowledge management has been backward looking, accumulating knowledge about what has occurred. For example, for consultants, knowledge management systems may gather proposals of previous engagements or summaries of actual engagements as key summaries of knowledge. Furthermore, other documents, such as news articles are likely to be accessible in such systems. Accordingly, virtually all the so-called knowledge management resources are backward looking. Knowledge is summarized for expert decision makers and they use that historical information to anticipate future events. The systems rarely provide forward-looking information, such as forecasts. Instead, experts use the knowledge in the systems to generate forward-looking views and forecasts.

1.2. Internal Prediction Markets

However, recently enterprises and other organizations have begun to use internal markets to anticipate and forecast future events. For example (Wolfers & Zitzewitz, 2004), the Department of Defense was interested in knowing questions such as "Will the U.S. Military withdraw from country A in two years or less?"

Hewlett-Packard was one of the first companies to use such internal prediction markets (e.g., Totty, 2006). In 1996, they were concerned with how well such markets could forecast monthly printer sales. Approximately 15–20 people from various parts of the company were chosen to be a part of the market. Participants were given some cash and securities that were constructed to represent various monthly printer sales forecasts. In their market, only the winning sales number paid off to the participants. Using this internal market approach, the markets beat the experts 6 out of 8 times.

1.3. Expert vs. Nonexpert and Historic vs. Future

Accordingly, internal markets provide an approach that allows us to change the focus of knowledge management from just gathering knowledge from experts to a broader base of users (nonexpert). In addition, internal markets allow us to change our focus from a historical one to a view aimed at forecasting the future, rather than a historical view, summarizing the past. These results are summarized in Fig. 1.

1.4. Purpose of this Chapter

As a result, we need to understand those conditions under which to use alternative knowledge management approaches, particularly in forecasting of future events. Thus, this chapter is concerned with analyzing different approaches to gather human opinion and information as to the possible occurrence of future events.

Forecasting the answers to difficult problems often depends on asking the right person or group of people the right question. However, knowing which

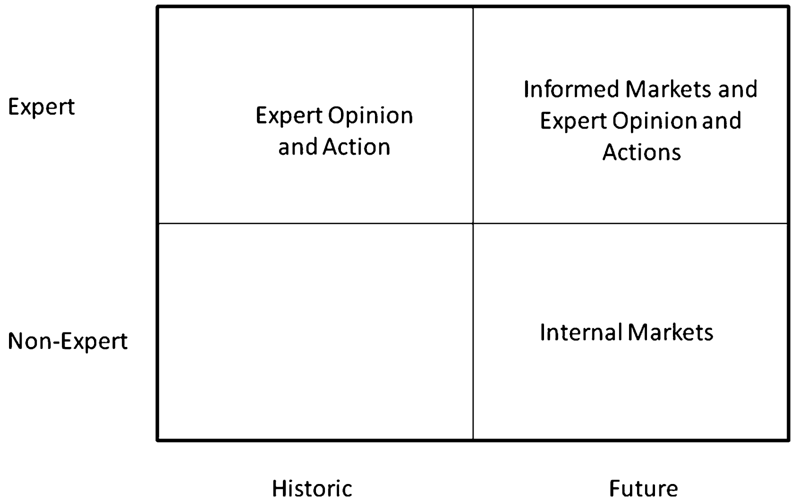

Fig. 1. Knowledge Management and Internal Markets.

approach to use is not always clear. Thus, the remaining purpose of this chapter is to outline two "knowledge distribution grids" that can be used to help determine which approach to forecasting is appropriate for particular situations, based on different characteristics of knowledge.

1.5. Outline of this Chapter

Section 2 examines notions of shallow knowledge vs. deep knowledge, whereas Section 3 examines distributed knowledge vs. concentrated knowledge. Section 4 examines a number of approaches used to gather knowledge in the different settings. Section 5 brings together Sections 2–4, and generates a knowledge distribution grid that allows us to better understand which approaches are useful for different forecasting opportunities in the cases of shallow and deep knowledge and distributed knowledge and concentrated knowledge. Section 6 extends the knowledge characteristics to dynamic and stable, and deterministic and probabilistic. Section 7 reviews some limitations of forecasting approaches, whereas Section 8 provides a brief summary of the chapter, and examines some contributions of the chapter and analyzes some potential extensions.

2. SHALLOW KNOWLEDGE VS. DEEP KNOWLEDGE

Different people may have knowledge about an area based on a range of factors, including ability, education, or experience. Further, knowledge may be distributed to a broad range or a small group of users. Thus, that knowledge may be distributed in varying depths to a range of users. The purpose of this section is to briefly discuss the first dichotomy, shallow and deep knowledge, and then examine some of the implications of that dichotomy.

2.1. Shallow Knowledge

In many cases, individuals have only shallow knowledge about particular issues. At the extreme, as noted by Hayek (1945, pp. 521–522)

> there is beyond question a body of very important but unorganized knowledge which cannot possibly be called scientific in the sense of knowledge of general rules: the knowledge of the particular circumstances of time and place ... (and that individuals have) ... special knowledge of circumstances of the fleeting moment, not known to others.

According to this description, there is asymmetric knowledge, particularly, in the case of knowledge that appears to describe events or contemporary activity. In particular, the knowledge is not general scientific knowledge. Further, that knowledge is distributed to a number of people, and the knowledge that people have may be relatively shallow.

In particular, knowledge is considered to be shallow if it is not connected to other ideas or if it is only loosely connected to other knowledge. Another view is that knowledge is shallow if it is more data than knowledge, or if that knowledge is or can be "compiled." For example, Chandrasekaran and Mittal (1999) suggested that if the knowledge can be put in a table (i.e., a classic table lookup) then that knowledge can be compiled and the corresponding knowledge is not particularly deep.

2.2. Deep Knowledge

Knowledge is regarded as "deep" if central or key issues in a discipline need to be understood to understand the issues at hand. Further, generally, knowledge has greater depth if it is connected to other ideas.

Deep knowledge also has been thought to be based on "first principles" (e.g., Reiter, 1987; Chandrasekaran & Mittal, 1999), rather than just based on causal knowledge. First principles provide a basis to reason from or about a set of issues. As an example, in the case of diagnostic systems, first principles ultimately employ a description of some system and observations of the behavior of the system and then reasons as to why the system may have failed.

Organizations are aware of and encourage cultivation of deep knowledge. For example, professional service firms have consulting "experts" in particular areas. A review of most consultants' resumes will rapidly tell you their areas of expertise. Universities are famous for having faculties that have deep knowledge in what can sometimes be very narrow areas. Oftentimes professional certifications can be issued to indicate that a level of depth and breadth in knowledge has been attained by an individual, for example, "certified public accountant" (CPA).

2.3. Shallow Knowledge vs. Deep Knowledge

One view of knowledge is that it comes in "chunks" (Anderson & Lebiere, 1998). Deep knowledge takes more "chunks" to be captured or described. Further, if there are numerous links between the chunks, rather than fewer, then that is another indication of deep knowledge. Thus, number of "chunks" provides one measure of the depth.

Research and other activities might change the classification by generating additional links or influencing the chunks. Potentially shallow knowledge may be made deeper if fragmented notions are connected or linked to other possibly related ideas. Alternatively, deep knowledge may be made shallower if it can be decomposed into relatively unconnected chunks.

2.4. Implications of Shallow vs. Deep Knowledge

One of the key tenets to system sciences (Ashby, 1956; Weick, 1969, p. 44) is that "it takes variety to destroy variety," or "it takes equivocality to remove equivocality." Thus, to paraphrase, "it takes shallow knowledge to capture shallow knowledge and deep knowledge to capture deep knowledge." If the knowledge of concern is shallow, rather than deep, then representation of the knowledge is likely to be easier. In addition, if the knowledge is shallow, then the basic approach used to capture shallow knowledge is likely to be more straightforward. Further, capturing deep knowledge is likely to be more time consuming, and require greater resources.

2.5. Deep Knowledge and Internal Prediction Markets

In some settings deep knowledge is necessary to be able to attain an appropriate level of insight to a problem, even when using internal prediction markets. For example, if we are trying to forecast a flu epidemic AU :2 this fall then knowledge of current viruses in circulation and the diffusion of those over time would be helpful at understanding the issue; otherwise, responses are likely to be little more than a random guess. Shallow knowledge of a problem, even if it is aggregated with knowledge of others is not likely to facilitate forecasting.

3. DISTRIBUTED KNOWLEDGE VS. CONCENTRATED KNOWLEDGE

In general, knowledge about forecasting events of interest can be what we call "distributed" among members of a population, such as an enterprise, or it can be concentrated in the hands of a relative few. The extent to which knowledge is distributed or concentrated can influence which approach is used to gather that knowledge.

3.1. Distributed Knowledge

Hayek (1945, p. 519) argues that much knowledge (in particular, knowledge of circumstances) is not "concentrated," but instead is what we will call "distributed,"

> The peculiar character of the problem of a rational economic order is determined precisely by the fact that the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as dispersed bits of incomplete and frequently contradictory knowledge which all of the separate individuals possess.

With some members knowing some things that others do not, this results in "information asymmetry." Thus, with distributed knowledge, as noted by Hayek (1945, p. 520) "knowledge (is) not given to anyone in its totality."

3.2. Concentrated Knowledge

Hayek (1945) was specifically concerned with settings where a central group made decisions and set prices for the overall economy, rather than letting market forces determine prices. However, the concern generalizes to enterprises where, a central group of managers makes many decisions, rather than letting a broad range of users in the enterprise determine what should be done. Although some knowledge is concentrated in a few experts, much knowledge is distributed to a broad range of people in the enterprise. As a result, a critical characteristic of knowledge is whether knowledge is distributed in many different people or if knowledge is concentrated in a few specialists, and ultimately how the enterprise addresses this issue.

Concentrated knowledge refers to situations where expertise in a particular area is accomplished. There are numerous measures of concentration in different professional fields. For example, in accounting, there are numerous certifications, such as a CPA or certified management accountant (CMA). In education, various degree levels, for example, Ph.D., also denote concentration of knowledge.

In some economic systems, concentrated knowledge is assumed of central planners. In sporting events, odds makers (e.g., those from Las Vegas) are considered a concentrated source of knowledge. Other such assumed concentrated settings include planning departments or strategic planners.

3.3. Implications of Distributed or Concentrated Knowledge

In either case if we wish to manage the knowledge and make good decisions we need to determine the extent to which knowledge is either concentrated or distributed. The extent to which knowledge is concentrated or distributed influences the approaches that we will use to gather that knowledge. Thus, there are implications if the knowledge is distributed or concentrated.

If the knowledge is concentrated, then approaches to gather the knowledge would focus only on the small group with the resident knowledge. If we wish to be unobtrusive, then we could gather knowledge or implied knowledge from what people do. As a result, in the case of consultants, we could gather documents that consultants have generated and make those documents available to others, for example, engagement proposals and summaries. If the knowledge is concentrated into only a small group, then using an internal market to gather knowledge is not likely to be effective for various reasons discussed in the following text.

With distributed knowledge one must use approaches that tap into the asymmetric knowledge available to the many knowledgeable participants. If the knowledge is distributed, then gathering knowledge must take a different tact that tries to assemble the knowledge into an aggregated totality of sorts. In the case of forecasts, one such approach is internal markets, where we try to generate a solution that incorporates all of the disparate knowledge, through the choice of one alternative over another or an index representative of the choice concern.

3.4. Knowledge Diffusion

Knowledge is more likely to diffuse if there are so-called "network effects" that are dependent on communication and distributed knowledge. Thus, distributed knowledge seems more likely to diffuse, and more likely to diffuse more rapidly, than concentrated knowledge.

4. KNOWLEDGE GATHERING FOR FORECASTING

One of Hayek's (1945, p. 520) key concerns was with investigating "what is the best way of utilizing knowledge initially dispersed among all the people (as) is at least one of the main problems of economic policy – or of designing an efficient economic system." This chapter is basically concerned with the same issue. In particular, there are a number of ways to gather knowledge that could be used for forecasting, including the following.

4.1. "Man on the Street" Interview (One Person or More)

A well-known approach to gathering knowledge is to interview the random "man on the street," in an attempt to gather opinion or general knowledge of the populace. Such opinions could provide interviewers with an insight into a number of issues, such as would a particular product sell or who might win the presidential elections. Unfortunately, such interviews may or may not be successful at gathering the opinions desired, in part based on the limited sample, and the particular opinion.

The next step to generalization of "man on the street" interviews is to expand the sample size and gather opinion from a broader base of participants, and then aggregate their responses. Unfortunately, aggregation is not an easy and noncontroversial issue. Given a base of opinions, how do we aggregate?

In general, opinion polls do not seek out those with any particularly deep expertise, but instead, seek a reasonable sample of some particular population. For example on college campuses, not surprisingly, frequently, the concern is with the opinion of the student population.

4.2. Knowledge Acquisition (1–10 People)

The development of the so-called "expert systems" and "knowledge-based systems" led to the analysis of what became known as knowledge acquisition, generally from a single expert (e.g., Rose, 1988). Enterprises generated a number of clever approaches to capture knowledge, such as videotaping events or the transfer of information between human actors (e.g., Kneale, 1987; Shiplberg et al., 1987) and those interested in being able AU :3 to capture the knowledge.

However, over time there has been an interest in acquiring knowledge from multiple experts, rather than just a single expert. In the case of knowledge acquisition, "multiple" typically meant 2, 3, or 4, and rarely more than 10 (e.g., O'Leary, 1993; O'Leary, 1997). With multiple experts in such small samples, comes concerns as to whether the experts are from the same paradigm and whether the combination of expertise from different paradigms is sensible, and if it is sensible, how those multiple judgments should be combined.

4.3. Delphi Technique (5–30 People)

The Delphi technique (Dalkey, 1969; Green, Armstrong, & Graefe, 2007) is used to generate opinion, typically from expert. Using a three-step approach of gathering anonymous responses, controlling information feedback in a number of iterations, and aggregating opinions, the technique has been primarily used to generate consensus among a set of experts. The initial investigations used between 11 and 30 members in the group, but other investigations have used as few as 5. As a result, generally, this approach is used when the available expertise is distributed to a sufficiently large number of agents. In addition, this approach is used when there are time and resources to iteratively go back and forth with the experts to gradually elicit group consensus.

4.4. Enterprise or Internal Prediction Markets (20 or More People)

Enterprise markets, also known as "internal prediction markets" can be used to gather knowledge for forecasting a wide range of issues. Although internal prediction markets are not known as a knowledge management tool, in some cases they likely offer the best opportunity for gathering knowledge.

For example, recently internal prediction markets have been used to examine such issues as "Will our store in Shanghai open on time?" Such markets are "enterprise markets" since they are used by enterprise to forecast the future.

Internal prediction markets can be "informed markets" where the participants are those with more experience or knowledge about a particular area. Informed markets are necessary when the topic requires deep knowledge. For example, a market aimed at forecasting flu virus mutation likely necessarily would be an expert group.

5. A KNOWLEDGE DISTRIBUTION GRID

Our discussion about shallow knowledge vs. deep knowledge and distributed knowledge vs. concentrated knowledge, and knowledge gathering for forecasting is summarized in Fig. 2. Each axis has one of the two characteristics on it, yielding four different settings. It is referred to as a knowledge distribution grid because it provides view as to where knowledge is distributed and tools for gathering knowledge in different settings.

5.1. Gathering vs. Communicating

To this point, we have focused on gathering knowledge – whether dispersed or concentrated. However, in addition, the approaches provide differential communication devises between the sources of the knowledge and ultimately structuring the knowledge in a usable forecast form.

For example, when compared to markets, some authors think that Delphi may be easier to maintain confidentiality (e.g., Green et al., 2007) and that Delphi is more difficult to manipulate. Further, because Delphi is grounded in feedback, the approach is a bit more efficient than markets because other participants directly benefit from research of other participants that surface as feedback. This is in contrast with markets where participants each need to do their own research.

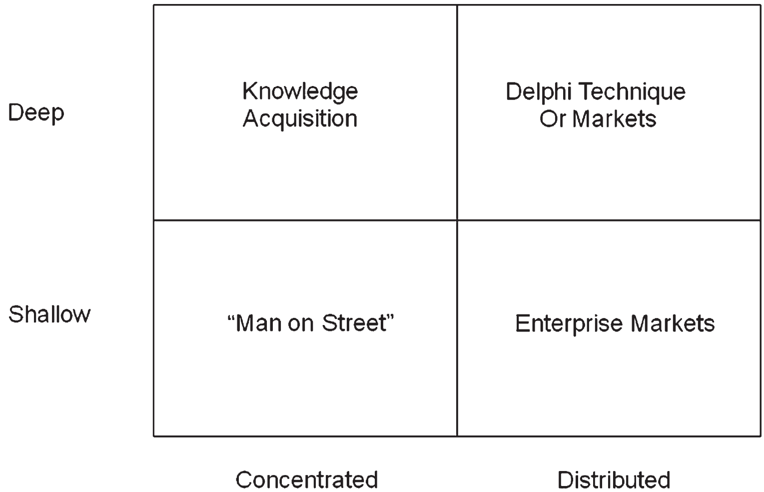

Fig. 2. Knowledge Distribution Grid.

6. EXTENSION TO DETERMINISTIC VS. PROBABILISTIC KNOWLEDGE AND STABLE VS. DYNAMIC KNOWLEDGE

Another set of characteristics that can be investigated include whether the knowledge is "stable vs. dynamic" or "deterministic vs. probabilistic." Knowledge may be stable over time or it may be dynamic, and change substantially as events unfold. However, knowledge may be deterministic or probabilistic. In some settings, conditions and events appear deterministically related. For example, many events in electrical or plumbing systems are often characterized as deterministic. In those settings, given a set of conditions, deterministic forecasts about what will happen can be made. Alternatively, in other systems events are more probabilistic. These dimensions are summarized in Fig. 3.

If we suppose that dynamic is more complex than stable and probabilistic is more complex than deterministic, then dynamic and probabilistic systems are the most complex of all four conditions. As a result, in general, as we move out of the lower left quadrant, and into the upper right quadrant, events become more complex.

How knowledge fits in these categories can impact which approach can be used to forecasts events. In quadrant #1, where there are relatively stable and

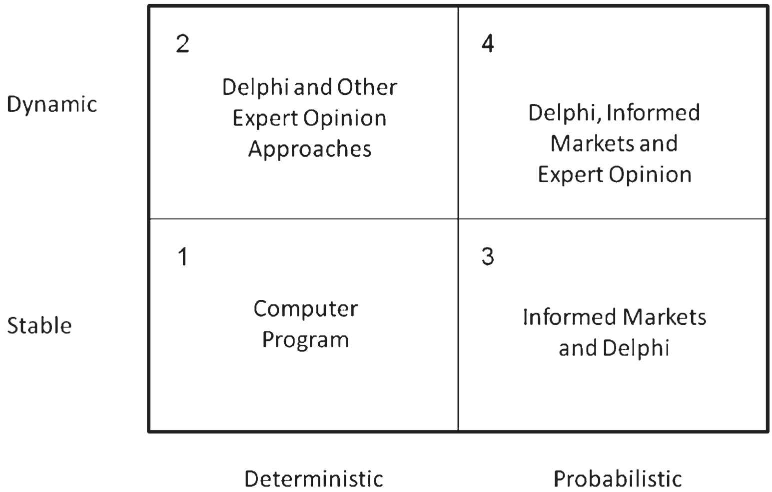

Fig. 3. Dynamic vs. Stable and Deterministic vs. Probabilistic.

deterministic problems there often are sets of rules that forecast an outcome, for example, credit determination. In this setting, a computer program can be AU :4 used that embodies those rules probably to provide a consistent and cost-effective approach to forecast when knowledge characteristics fit here.

In quadrant #2, where the world is dynamic and fast changing, it takes a unique set of experts to keep up with the events to forecast the future. As a result, expert opinion is likely to be particularly helpful in this setting.

In quadrant #3, the knowledge is stable, but probabilistic. In this setting, a market can be executed and a probabilistic estimate gathered. Knowledge is stable enough to allow a market to evolve.

Quadrant #4 is the most difficult because knowledge is dynamic and probabilistic. If the knowledge changes too rapidly, then before a market of informed participants can be successfully generated, the solution may have changed. However, if it is too dynamic, then perhaps expert opinion is the answer. As a result, Delphi, done in a time manner, could provide appropriate insights. In this quadrant, there is no one solution approach.

7. CONCERNS

There are some potential sample concerns, no matter which approach is used to gather potential forecasts. First, the size of the sample from which the knowledge and forecasts is gathered is critical to generating an appropriate view of the future. With internal markets, this issue is referred to under the notion of "thin markets" where there are too few traders to guarantee an effective and efficient market. Probably not unexpectedly, when using internal markets, in general, larger markets are better. However, if the sample size gets too large, then Delphi can bog down.

Second, sample bias from the population investigated has been considered by researchers in most of these disciplines. In general, the smaller the population is being drawn from, the bigger is the potential problem of bias. However, in some of the approaches discussed earlier, for example, in the case of knowledge acquisition, the problem has been largely ignored.

Third, there is the potential for conflicts between points of view. In the arena of knowledge acquisition, O'Leary (1993, 1997) has investigated this issue. As part of the concern of knowledge acquisition from multiple experts, there has been concern with the so-called "paradigm myopia." In that setting, with few experts as the basis of the knowledge used, any bias is likely to be reflected in the forecast that is made. Similarly, when using Delphi, a diverse opinion set can drive the group to generate unique solutions or deadlock them.

8. SUMMARY, CONTRIBUTIONS, AND EXTENSIONS

This chapter has differentiated characteristics of knowledge along a number of dimensions and investigated those dichotomous characteristics, including

- expert vs. non-expert and historic vs. future,
- deep vs. shallow and concentrated vs. distributed,
- dynamic vs. stable and deterministic vs. probabilistic.

Using those characteristic pairs, we analyzed settings where different approaches were more appropriate than others. In particular, we generated the knowledge distribution grid, and used the grid to differentiate between different approaches that might be used for forecasting future events. Four different basic approaches were discussed: "man-on-the-street," "knowledge acquisition," Delphi technique, and internal prediction markets. Markets were labeled as "informed" for those involving experts, and "enterprise" for those internally conducted by enterprises to address issues of direct concern to the enterprise.

8.1. Contributions

This chapter has extended knowledge management to be forward looking and to include internal markets as a means of gathering knowledge from a broad base of users. Virtually all previous knowledge management has focused on knowledge management as a medium to capture historical information. Further, internal markets have been ignored as a knowledge management tool. In addition, comparison of internal markets to approaches such as Delphi, have received little attention.

This chapter provides three distinct sets of grids featuring different knowledge characteristics. Each of those grids provides the ability to investigate knowledge characteristics, and how those knowledge characteristics influence different approaches to gathering information for forecasting future events.

8.2. Extensions

This research can be extended in a number of directions. First, we could expand the number of methods examined in Section 4. For example, other approaches, such as using surveys to gather knowledge and opinions could be generated. Second, the discussion in this chapter has suggested that the time and resources available also influence the choice of an approach to forecast the future. Compiled expertise would be a rapid approach, but running an internal market while investigating time constrained issues is not likely to provide timely returns. Third, in some cases there appear to be multiple feasible approaches to problems. For example, Delphi and internal markets both seem feasible with approximately 20 or more people and an expert environment. However, it is not clear which approaches provide the "best results." As a result, the two approaches could be compared for which works best under which conditions, and the strengths and weaknesses of each could be more fully fleshed out.

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