Part III.

Knowledge Trading

Although economists claim to study the working of the market, in modern economic theory the market itself has an even more shadowy role than the firm. [...] In the modern textbook, the analysis deals with the determination of market prices, but discussion of the market itself has entirely disappeared

Ronald H. Coase [44]

5. Model for Knowledge Trading

The trading of knowledge assets can be considered as a kind of incentive system for knowledge exchange. Knowledge markets have the appealing characteristics of being applicable not only inside an organization, but also between organizations and individuals or in a virtual company, because no subsidy is necessary, cf. [135, 136, 139, 140].

A market is defined as the *economic* place for the exchange of products and services, in which a market price is derived through the interaction of demand and supply. An electronic market uses information systems to support at least some of the different transaction phases (see Section 5.2) electronically. An electronic market in the strict sense exists if all phases are supported electronically, and if market mechanisms are utilized [125, p. 10].

In this chapter, we elaborate on knowledge markets as an alternative to an open knowledge repository. Firstly, in Section 5.1 we show an extension of the prisoner's dilemma model of Section 3.1.1 by introducing the possibility of setting a price for the knowledge transfer. In Section 5.2, we present the different transaction phases in a market and discuss the transaction costs that occur during the phases. One objective of an electronic market is to reduce these transaction costs by automating tasks. In Section 5.3, we present a model for knowledge trading which may help a market engineer to analyze and to design an electronic knowledge market. The different elements of the model are then described in the following sections.

5.1. Game-Theoretical Model of Knowledge Trading

In Section 3.1.1, we presented knowledge sharing as a prisoner's dilemma. There, mutual knowledge hoarding was the equilibrium even though mutual knowledge sharing would benefit both players. Introducing knowledge trading in this situation could solve the prisoner's dilemma. A price p, that the players pay for a specific knowledge asset may change the equilibrium to mutual knowledge sharing. (see Table 5.1).

Each player only sells his knowledge asset if the price compensates him for the benefit of hoarding (see Equation 5.1). This benefit consists of the value of being

Player A \ Player B	Knowledge Hoarding h	Knowledge Sharing s
Knowledge Hoarding h	hh / hh	sh+**p** / hs-**p**
Knowledge Sharing s	hs-**p** / sh+**p**	ss / ss

Table 5.1.: Payoff Matrix for a Two-Person Knowledge-Sharing Game given a Price p

the only one that has this knowledge asset and the saved time and cost of sharing the knowledge asset.

Selling Condition:

$$\text{Benefit of Hoarding} = hh - sh < p \tag{5.1}$$

On the other hand each player only buys the other's knowledge asset if the price is lower than the benefit of the knowledge asset (see Equation 5.2).

Buying Condition:

$$p < hs - hh = \text{Benefit of Knowledge Asset} \tag{5.2}$$

To ensure a Pareto improvement for every change from knowledge hoarding to knowledge trading, the price must be $hh - sh < p < hs - hh$, which means the price p must be between the base value and the additional monopolistic value. With such a price p the new dominant strategy for each player is to share his knowledge and the new equilibrium is given by mutual sharing.

5.2. Transaction Phases and Transaction Costs

The interaction process of a market can be divided into several transaction phases (see for example [174]). We distinguish between the information phase, the agreement phase, the execution phase and the after-sales phase. In each phase different transaction costs occur (see Figure 5.1).

By examining the different transaction phases, it is possible to analyze the transaction costs for the participants that arise when entering the market. The analysis of the transaction costs indicates if any transaction within the market is actually beneficial for the participants [177].

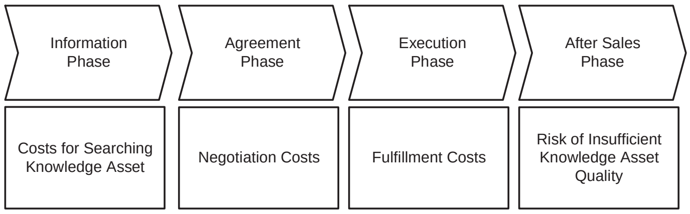

Figure 5.1.: Different Transaction Phases and their Transaction Costs

5.2.1. Information Phase

In the information phase, providers and advice seekers attempt to get information about market participants (e.g. reliability, expertise) and about commodities being traded (such as quality).

In electronic marketplaces sellers can tender their products or services, so that buyers can search for the right offerer. On the other hand potential buyers can publish their needs, so that sellers can search for requests.

High transaction costs occur during the information phase because of the search for the right expert or documented knowledge. Matching services as described in Section 5.8 can lower these costs.

5.2.2. Agreement Phase

In the agreement phase the buyers and sellers negotiate the conditions of the transaction. This phase ends with a legally-binding contract. The method for negotiation is defined through the market mechanism. Electronic market mechanisms can lower the transaction costs of the agreement phase (see Section 5.7).

5.2.3. Execution Phase

In the execution phase, the contract is fulfilled and the goods and services are exchanged. In an electronic knowledge market in this phase the knowledge asset is transferred. Digitally documented knowledge would be transferred as a file or a set of files. Online expert advice is created *during the execution phase* in interaction with the advice seeker. Also, the advice seeker needs time for the internalization of the acquired knowledge. This effort can also be subsumed into the transaction costs of this phase. Fulfillment services are intended to lower these transaction cost (see Section 5.9).

5.2.4. After Sales Phase

During the after sales phase all activities after the execution phase happen, like payment or the claim of guarantees. In electronic knowledge markets with a reputation system, the advice seeker rates the expert in this phase. Also, the usage of the knowledge assets happens in this phase. There is a risk that the knowledge assets do not have sufficient quality. Quality assurance services can reduce this risk (see Section 5.10).

5.3. A Model for Electronic Knowledge Markets

In this section, we present a framework for electronic markets for knowledge assets. The generic market frameworks of Smith [181] and Weinhardt et al. [199] have partially inspired this model.

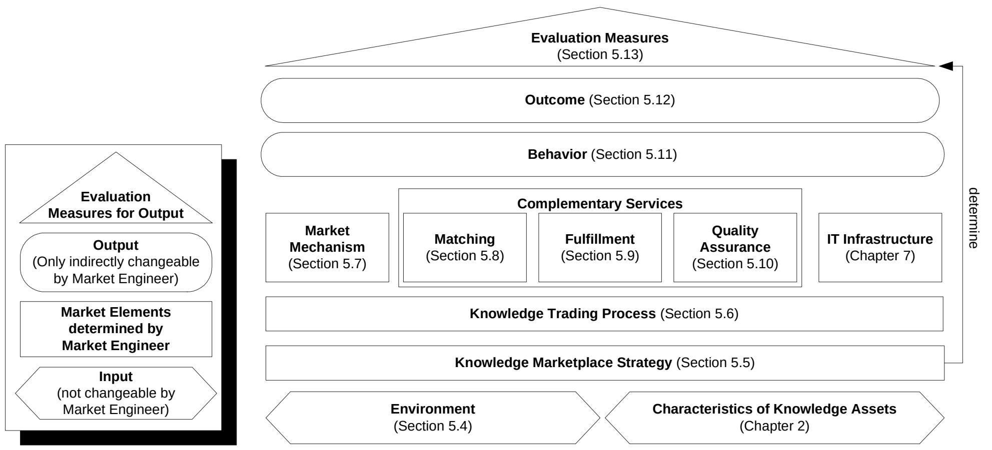

Figure 5.2.: A Framework for Electronic Knowledge Markets

Figure 5.2 shows an overview of the market framework. The basis for an analysis of an electronic market is the economic, social and cultural *environment*, which is described in Section 5.4. Also important are the *characteristics of the knowledge assets* that we have analyzed in Chapter 2. These two layers cannot be changed by the market engineer—visualized as hexagons in Figure 5.2—and are the input factors for the next elements. The *knowledge marketplace strategy* (see Section 5.5) takes into account the environment and the knowledge asset characteristics and is the foundation for all elements that are under direct control of the market engineer—visualized as rectangles in Figure 5.2. The *knowledge trading process* (see Section 5.6) defines the sequential order of the tasks and activities of the marketplace.

On top of these layers are three elements:

- The *market mechanism* (see Section 5.7),
- the *IT infrastructure* (see Chapter 7) and
- the *complementary services*.

These complementary services in knowledge asset markets are *matching* advice seekers with appropriate experts or documents (see Section 5.8), the *fulfillment* of the knowledge transfer (see Section 5.9) and the *quality assurance* of the knowledge assets (see Section 5.10).

The market engineering decisions influence the *behavior* of the market participants, that means the participation decision and the bidding behavior (see Section 5.11). The behavior is not under the direct control of the market engineer but can only be influenced indirectly—visualized as ovals in Figure 5.2. The behavior then determines the overall market *outcome*, that means the revenue, prices, and allocation (see Section 5.12). We did several experiments with different market mechanisms in Chapter 6, where we analyzed the behavior and outcome in these markets. The outcome can be evaluated by different measures, dependent on the goal of the marketplace owner or regulator (see Section 5.13).

5.4. Environment

The environment comprises all the external factors that are not in control of the marketplace engineer (cf. [182, p.4] and [94, p.5]). The environment consists of the following factors:

Preferences. The preference structure of the participants defines who and what knowledge assets are valued. The preferences is a factor that determine the demand for the different knowledge assets.

Costs. The cost functions defines the effort for producing different knowledge assets. The costs co-determine the supply side of the knowledge market.

Legal Regime. The legal regimes are the laws and the possibilities to execute these laws in a society in order to enforce contracts and copyright restrictions.

Recourses. The distribution of the resource like knowledge and monetary income influences the supply and demand side.

Culture. As we saw in Section 3.5, the cultural context of the participants may also be an important factor that influences user behavior.

The environmental factors determine the demand and supply for the knowledge assets and influence the behavior of the market participants (see [182] and [94, p.4]).

5.5. Marketplace Strategy

The marketplace strategy defines the business model for the market [199]. This model element describes, among other aspects, *target groups* for the marketplace, the *knowledge asset selection*, and the *financial model* in which the market operator is intending to recoup expenses. Furthermore, strategies to ensure a *critical mass* of participants and trades are necessary. The marketplace operator also has to make the *market engineering decisions* for the other elements of the market framework. The business model must satisfy both the knowledge provider and the knowledge seeker and provide enough revenue to run the market.

5.5.1. Target Group

This design dimension describes the envisioned target group and the degree of cooperation between the market participants.

A distinction may be made between open knowledge markets, virtual communities, markets within a closed group of companies and knowledge markets within a company.

Knowledge markets within a company include knowledge management solutions with incentive systems. The company also has the option of operating a compensation model that need not necessarily cover the costs. A sponsored model such as this may be beneficial for a company, if it can make a profit as a result of improved knowledge exchange. Alternatively, incentives for knowledge providers may be carried by the knowledge users.

In public knowledge markets between independent individuals and companies or in virtual communities, it is not possible to realize a sponsored model. Virtual communities are groups of users with similar interests and requirements that meet online with the aim of exchanging ideas and forming a community [109].

A knowledge market may also be open only for a restricted group of participants. A condition for participation might be, for example, membership in a company network or a virtual company. Virtual companies are networks of independent companies, which have specialized in their key competencies and come together on a temporary basis for the sake of projects.

An open as well as a closed knowledge market can define an envisioned target group. This can reduce the marketing costs to reach potential participants. It can also accelerate the achievement of a critical mass of participants.

5.5.2. Knowledge Asset Selection

Another marketplace-strategy decision is the selection of the traded commodities, i.e. knowledge assets (see Chapter 2). The market engineer has to choose if online expert advice or digitally documented knowledge or both are traded. Furthermore, the specific definition of the traded knowledge asset may be necessary. For example, the traded knowledge asset could be a single answer to a question, a time slot in the expert's schedule, the non-exclusive or exclusive right to use a document or even the right to use and resell a document. Also a topic selection is possible. For example, a knowledge market may be specialized in online expert advice in the legal domain.

5.5.3. Financial model

This aspect deals with the question of how the market covers its costs and yields a profit. There are different revenue opportunities for the marketplace [102]:

Participation Fees. A participation fee may be charged for access to the market.

Transaction Fees. These are fees that may be charged per transaction. The fee could be a fixed amount per transaction or it could be a fraction of the sales value or a combination of both.

Advertising. Another revenue possibility for the marketplace operator is advertising. This can be done in a context aware manner, where the advertising is related to the knowledge assets, that the bidder is interested in.

Other Services. Additional Revenue can be generated by selling other goods and services. This can be enhanced fulfillment or matching services.

5.5.4. Critical Mass

A potential seller profits from a market with a higher number of potential buyers. Vice versa also a potential buyer is interested in as many potential sellers as possible. Therefore, network effects [59] exist for an electronic knowledge market: The utility of the market for the participants is a function of the number of the participants. However, the decision to participate in a market is determined by the utility of the market and therefore there may exist a critical mass of participants that has to be reached to have a sustainable situation. When several knowledge markets compete, a significant factor for the success of the markets is the number of participants.

5.5.5. Market Engineering Decisions

Based on the business model the market operator has to decide on the other market framework elements. These are discussed in the corresponding sections.

- The choice of the appropriate market mechanism (see Section 5.7).
- How the market operator can ensure additional value to the market participants by
  - matching the right expert to the advice seeker (see Section 5.8),
  - providing services for the fulfillment of the knowledge transfer (see Section 5.9), and
  - ensuring the right quality of the knowledge assets (see Section 5.10).
- The development of the appropriate IT infrastructure (see Chapter 7).

5.6. Knowledge Trading Process

The knowledge trading process describes the sequentially connected activities in a marketplace. The knowledge trading process is different for online expert advice and for digitally documented knowledge.

5.6.1. Knowledge Trading Process in a Market for Expert Advice

The knowledge trading process in an electronic knowledge market for expert advice may be as follows: The expert begins by formulating his knowledge based on the knowledge taxonomy of the marketplace and by making an offer (a). Next, the advice seeker defines his or her request (problem, question) in order to find appropriate

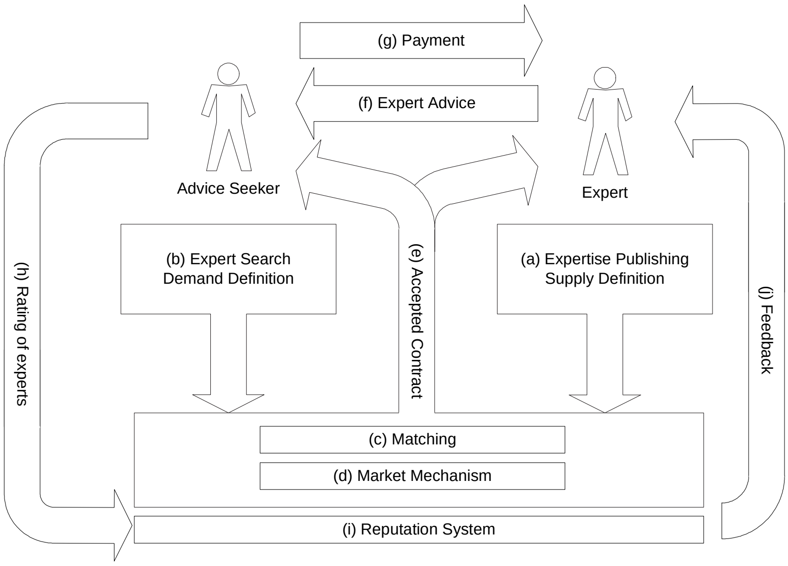

Figure 5.3.: Knowledge Trading Process of an electronic Market for Expert Advice

experts (b). Once this has been done, the matching engine (c) finds suitable experts. The market mechanism (d) results in an accepted contract (e) between the advice seeker and the expert. Once the contract is arranged the fulfillment of the expert advice (f) takes place. After the consultation has taken place, payment of the agreed fee follows (g). Finally, the advice seeker evaluates the expert (h), on the basis of the quality of the expert's knowledge received, the rating is stored in the reputation system (i) and a feedback is given to the expert (j).

5.6.2. Knowledge Trading Process in a Market for Documented Knowledge

The knowledge trading process in an electronic knowledge market for documented knowledge can be described in the following way: In a market for documented knowledge (see Figure 5.4), the expert must at first codify the knowledge he wants to provide (a). Afterwards he can offer and classify the documents on the marketplace by means of a knowledge taxonomy (b). The advice seeker is looking or asking for a specific document (c). The matching engine (d) results in a list of appropriate hits (e), on which the advice seeker can place a bid (g). The expert can also bid on advice seekers' requests (f). The market mechanism (h) determines who receives a

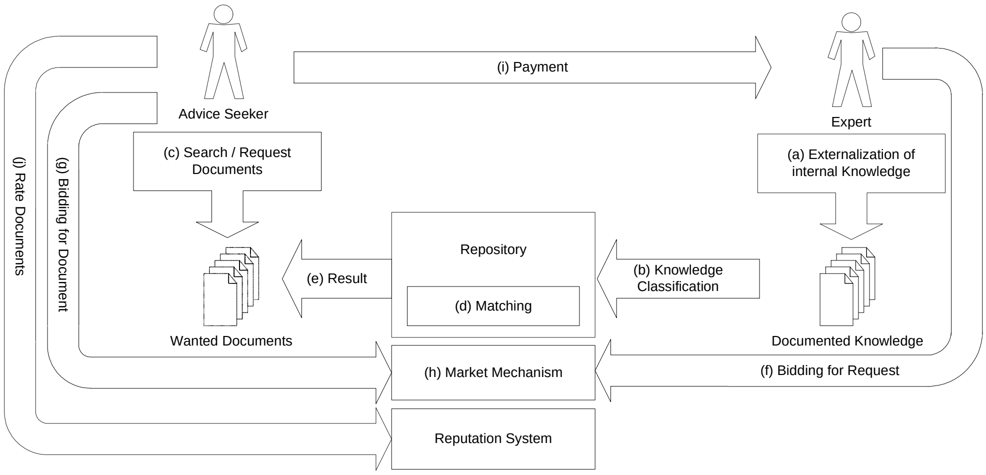

Figure 5.4.: Knowledge Trading Process of an electronic Market for Documented Knowledge

copy of the document and under what conditions. Subsequently the documents are transferred to the successful buyers. The advice seeker then pays the expert (i) and rates the expert as well as the value of the document, if necessary (j).

5.7. Market Mechanisms

A market mechanism can be seen as a function which has the bids of the players as the input and the decision who gets the items and what price they have to pay as the output [129]. Therefore, a market mechanism determines who gets access to which assets for which price. How can we formally describe a market mechanism? We not only want to be able to describe the classic market and auction mechanism but also variants of classical auctions and complex market mechanisms. We need a more detailed possibility to describe market mechanisms.

5.7.1. Parametric Description of Market Mechanisms

Market mechanisms can be described in a state transition diagram (see Figure 5.5) with two states:

- **Bidding.** During the bidding, the market accepts bids from sellers or buyers and verifies the accuracy of the bids.

- **Clearing.** The market determines the winning bids and sets the price or the prices for the winning bids.

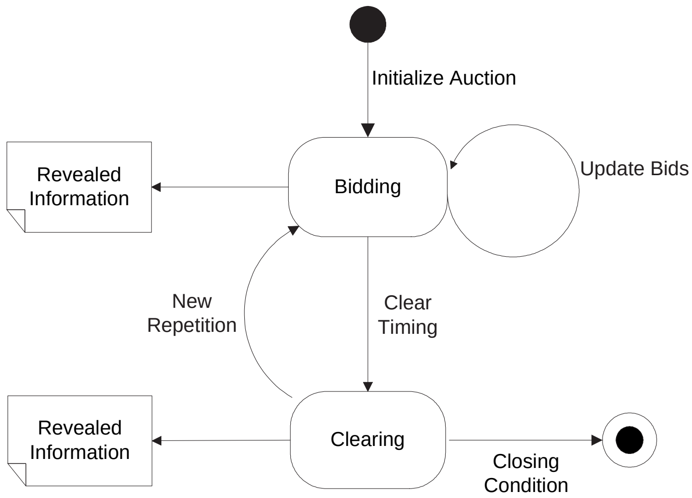

Figure 5.5.: State Diagram for Bidding Processes

During the bidding or after clearing, the market reveals intermediate status information, called quotes.

According to Wurman et al. [207] a market can be described by defining the bidding, the clearing, and the information revelation policies together with their parameters. With these formal descriptions we can define all standard auctions and numerous non-standard market mechanisms.

Bidding policy

The bidding policy defines a legitimate bid. We can distinguish between various parameters of a bidding policy (cf. [207]):

- **Buyers-Sellers Cardinality.** The cardinality between sellers and buyers ({one buyer : many sellers}, {many buyers : one seller}, {many buyers :many sellers})

- **Bid Expressiveness.** What is the structure of a bid? (price bid, combinatorial bid, etc.)

- **Dominance.** Does an update of a bid have to fulfill certain constraints compared to the former bids? (decreasing, increasing, etc.)
- **Beat-the-quote.** Does an update for a bid or a new bid have to fulfill certain constraints related to the bids of other bidders? (decreasing, increasing, etc.)
- **Withdraw.** Is it possible to withdraw a bid?
- **Expiration.** Does a bid expire and when does this happen?
- **Activity.** Are there any rules that require bidder's activity?

Clearing policy

The clearing policy determines which buyer and which seller will trade under which conditions.

- **Allocation Function.** The allocation function determines which buyers and sellers are going to trade.
- **Pricing Function.** The pricing function determines the terms of each exchange.
- **Clear Timing.** When will the market be cleared? (scheduled, random, bidder activity, bidder inactivity)
- **Closing Conditions/Repetition.** When will the market be closed? (fixed number, seller's *ex-ante* choice, seller's ad hoc choice, etc.)
- **Tie-breaking.** What happens if two buyers make the same bid for the same object? (Random, earliest bid, largest quantity)

Information revelation policy

The information revelation policy rules which information about trades or bids are available for the buyers and sellers during the bidding or afterwards.

- **Price Quotes.** Which information is revealed to buyers and sellers? (ask, offer, details, etc.)
- **Quote Timing.** When is this information revealed? (No price quotes, scheduled, random, bidder activity, bidder inactivity, etc.)

- **Order Book.** Is the order book open, and if it is, which details are revealed? (Closed, winning bids, open, etc.)

- **Transaction History.** Is there also information about historical transaction and quotes available?

5.7.2. Mechanisms for Knowledge Assets Transfer

There are several possible knowledge-transfer mechanisms. Figure 5.6 shows a classification of knowledge-transfer mechanisms. We focus on the highlighted ones. We analyze the following six knowledge-transfer mechanisms which we shall also experimentally evaluate in Chapter 6. Finally, we use the previously presented parametrization of market mechanisms to describe the different knowledge transfer mechanisms.

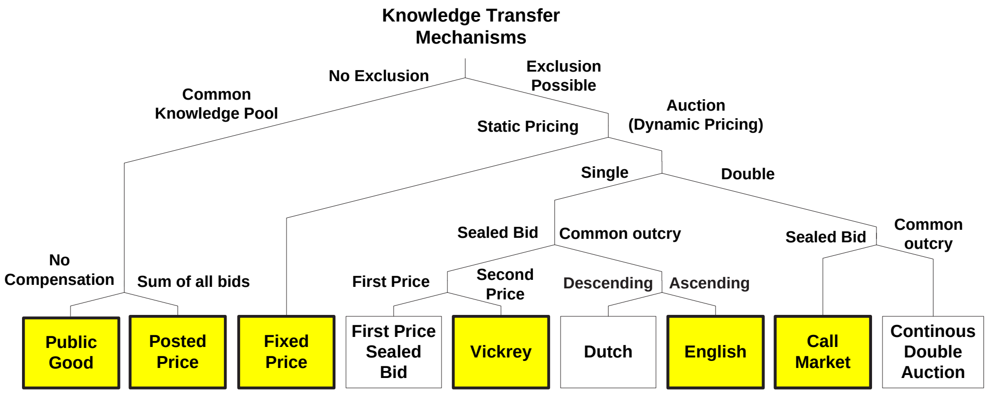

Figure 5.6.: Classification of different Knowledge-Transfer Mechanisms

Public-Good Situation. The purpose here is to motivate people to voluntarily provide knowledge assets to an open knowledge repository, which can be accessed by every player. When a player provides knowledge assets, there will be no financial compensation by the other players. This situation is also analyzed in Chapter 3 and serves as a baseline.

Posted-Price Auction. Each player determines an overall selling price for a knowledge asset. The knowledge asset is published, if the sum of all bids exceeds this predefined price. Then each player has to pay his individual bid and the knowledge asset will be added to a public knowledge repository.

Fixed price sales. Each player can sell knowledge assets for a "take-it-or-leave-it" price. The knowledge asset is not transferred to the open repository but is only usable for the player who bought it—without the right to resell the asset.

English Auction. This mechanism is based on a common-outcry–ascending auction, in which the price is increased until there is exactly one interested bidder left. The auction will be terminated after a predetermined time span has expired.

Vickrey Auction. The bids of each player are sealed. The highest bid will win the auction—but for the price of the second highest bid. We use a variation of this auction: The k highest bids win for the price of the k+1th highest bid [194, p. 24]. In the experiment in Chapter 6 we use $k = 4$ with 8 players.

Call Market. The offerers make their offers and the bidders make their bids. The system then matches the offers and the bids and determines the overall market price for the knowledge assets.

In Table 5.2 the market mechanisms are described according to the parametrization of Section 5.7.1 (see also [85, 81]).

Parameter	Public Good	Posted Price	Fixed price	English Auction	Vickrey	Call Market
Bidding policy						
Buyers-Sellers Cardinality	n:1	n:1	n:1	n:1	n:1	n:m
Bid Expressiveness Seller	Decision of contribution	Set minimum selling price	Set price	Set minimal price	-	sealed selling bid
Bid Expressiveness Buyer	N/A	Closed Bid	Accept Price	Open Bid	Simultaneous closed Bid	sealed buying bid
Dominance	N/A	N/A	N/A	Own bid has to be increased	N/A	N/A
Beat-the-quote	N/A	N/A	N/A	Yes	N/A	N/A
Withdraw	No	No	No	No	No	No
Expiration	No	No	No	No	No	No
Activity required	No	No	No	No	No	No
Clearing policy						
Allocation Function	Everybody	Everybody	All buyers	highest bidder	highest k bidder	All selling bids that are higher (or equal) than quote and all buying bids that are lower (or equal) than quote
Pricing Function	Free	Individual Bids	Seller Price	Highest bid	k+1 th highest bid	A quote that maximizes trade (Intersection between demand and supply curve)

Parameter	Public Good	Posted Price	Fixed price	English Auction	Vickrey	Call Market
Clear Timing	N/A	After scheduled time out	After scheduled time out	After scheduled time out	After all sealed bids arrived	After bidding
Closing Conditions/Repetition	Once	Once	Once	Seller's ex ante choice	Once	Once
Tie-breaking	N/A	N/A	N/A	Random	Random	Random
			Information revelation policy			
Price Quotes	Asset is contributed or not	Seller price	Seller price	Minimal price, current quote, time till auction closing, actual selling price	Actual market price	Quote
Quote Timing	During market	After clearing	During the auction	During the auction and after closing (selling price)	After closing	After clearing
Order Book	N/A	Bidders are anonymous. Bids are sealed	Bidders are anonymous	Bidders are anonymous. Current quote is open.	Closed. Bidders are anonymous	Bidders are anonymous. Bids are sealed. Current quote is open.
Transaction History	No	No	No	No	No	No

Table 5.2.: Market Parameter for Knowledge-Transfer Mechanisms

5.7.3. Relevant Auction Theory

In this section, a short introduction in the relevant auction theory is given. Also, an overview of the economic experiments regarding auctions is presented.

There exists extensive auction literature (see [116] and [108] for a survey). We briefly present the three most popular models in theoretical auction literature and their implications [206]. These are

- the symmetric independent private value (SIPV) model,
- the common value model and
- the affiliated values model.

Symmetric Independent Private Value (SIPV) Model

The symmetric independent private value (SIPV) model has the following assumptions [206, p.186]:

- A single unit of a non dividable good is auctioned.
- Bidders and sellers are risk-neutral.
- Each bidder has a private valuation about the object, but no other bidder knows this valuation.
- All bidders are indistinguishable (symmetry).
- The private valuations are from an independent, identical and continuous distribution.

The interesting question arises, as to how high the revenue is in the different standard auction formats (English, Dutch, Vickrey, first price). The main result from the SIPV model is the revenue equivalence theorem. This surprising result states that for risk neutral bidders, all four auction formats generate the same revenue for the seller and the same expected payoff for the bidders.

If there are risk averse bidders, then the revenue equivalence theorem is valid not anymore. Then first price and Dutch auctions yield higher expected revenue than English or Vickrey auctions [129, p.718]. Also, the revenue equivalence collapses if there is no symmetry of the bidders or the valuations are not independent [205].

Common Value Model.

The common value model has the following assumptions identical with the SIPV [205]:

- A single unit of a non-dividable good is auctioned to one of several bidders.
- Bidders and sellers are risk-neutral.

However, the common value model differs in these assumptions:

- The object has the same value for each bidder.
- This common value is *ex-ante* unknown to the bidder.
- Every bidder has an imperfect estimate about the common value.

A frequently observed phenomenon in the common value model is the winner's curse [205]. In the winner's curse the winner bids more than the true value of the object. This is because the auction selects the bidder with the most optimistic estimation as the winner. The optimal bidding behavior therefore anticipates this adverse selection effect and response by shading the bid. Therefore, bidding in the common value model is strategically more complicated for the bidders than in the private value model.

Affiliated Value Model

Milgrom and Weber [132] introduced the so-called *linkage principle*. It assumes that the bidders' private information about the true value are statistically affiliated. The linkage principal gives a ranking over several single-unit auction mechanisms. The linkage principal states that the revenue can be enhanced by providing as much information as possible to the bidders. Therefore, a common outcry auction generates more revenue than a sealed-bid auction. However, Perry and Reny [151] show that the linkage does not extend to the multi-unit auction situation. Because the presented auctions in Section 5.7.2 are all multi-unit auctions the applicability of the linkage principal for these auctions is questionable. Also, Kagel [103] shows in experiments that the effect is much smaller than predicted by the theory and is often even not significantly different from zero.

Experimental Results

In the previous sections several theoretical results of the auction literature were presented. However, the actual behavior in auctions differs partially from the theoretical predictions (see [52] and [103] for a survey). This *bounded rationality* can be explained by cognitive and socio-cultural constraints. Therefore, it is important to experimentally study the real actions and decisions in a knowledge asset auction. The theoretical and experimental auction literature mainly focused on goods in scarce supply like physical products. However, market experiments for knowledge assets are not well known. The main differences between knowledge assets and physical products are (i) that knowledge assets have a value in enhancing a decision or action and (ii) that digitally documented knowledge can be reproduced for marginal costs. For a more detailed analysis of the characteristics of knowledge assets, see Chapter 2. Therefore, an experimental analysis of knowledge markets is needed. In the next section we suggest three propositions for ranking the market mechanisms of the former section. These propositions shall then be experimentally tested in Chapter 6.

5.7.4. Propositions

In public-good games, it has been observed that private contribution often leads to free riding and to an undersupply of the good [171]. According to our analysis of Section 3.1.1, we predict free-riding behavior in the public-good situation because there is no sufficient reward for knowledge sharing.

Proposition 20. *Knowledge-transfer mechanisms with compensation outperform mechanisms without compensation.*

The posted-price auction gives a compensation for the knowledge sharer. However, because there is no exclusion from the common knowledge pool, there is a "second-degree" social dilemma. Everybody hopes that the others will bid enough so that the knowledge asset is published openly.

Proposition 21. *Knowledge-transfer mechanisms with exclusion outperform mechanisms without exclusion.*

In the situation of fixed prices the problem often arises as to how to set the optimal price with a lack of accurate market data. If the take-it-or-leave-it price is set too high, too few assets will be sold. If the price is too low, the earning per asset will be too small. It is often more efficient to use auctions compared to fixed prices [206]. The reason is that auctions often let the bidders reveal information about their valuations. In some auctions bidding the true valuation is an optimal strategy [206].

Proposition 22. *Knowledge-transfer mechanisms with dynamic pricing outperform mechanisms with static pricing.*

The propositions are tested in Chapter 6.

5.8. Matching

In the information phase the market participants try to find appropriate trading partners. This can be achieved by simple full text search, browsing of categories or matching.

Matching in the context of electronic markets can be defined as a function that has as arguments a finite set of supply profiles and one demand profile [193, p.2]. The output is a ranking of the supply profiles. The problem of matching thus entails finding a preference order on the set of supply profiles given one demand profile [120].

5.8.1. Matching for Online Expert Advice

In the following, we concentrate on matching for an expert market.

Let $a_i \in \mathcal{AC}$ be an actor, where $\mathcal{AC}$ is called the set of actors. The expertise of the actors can be described by several different skills $s_j \in \mathcal{S}$, where $\mathcal{S}$ is called the set of skills.

The decision matrix $\mathbf{D} = (d_{ij})$ relates an actor a_i against each skill s_j. Each row is identified by the expertise of an actor $a_i \in \mathcal{AC}, i = 1, 2, \ldots, |\mathcal{AC}| = n$. Each column is identified by a skill (goal criterion) $s_j \in \mathcal{S}, j = 1, 2, \ldots, |\mathcal{S}| = m$ with value set $dom(s_j)$ measured on an at least ordinal scale. A mapping to a cardinal scale may be necessary depending on the matching method. In the following, we assume cardinal scales. Each row measures the expertise of the actor $a_i \in \mathcal{AC}, E_i := (d_{i1}, d_{i2}, \ldots, d_{im}) \in \text{X}\ dom(s_j)$.

$$\mathbf{D} = \begin{pmatrix} \mathbf{E}_1 \\ \vdots \\ \mathbf{E}_i \\ \vdots \\ \mathbf{E}_n \end{pmatrix} = \begin{pmatrix} d_{11} & \ldots & d_{1j} & \ldots & d_{1m} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ d_{i1} & \ldots & d_{ij} & \ldots & d_{im} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ d_{n1} & \ldots & d_{nj} & \ldots & d_{nm} \end{pmatrix} \tag{5.3}$$

An advice seeker tries to find an expert for a question (i.e. problem). The user can define a weighting vector to express the relative importance of the relevant skills for the question:

$$\mathbf{w} = (w_1, w_2, \ldots, w_m) \tag{5.4}$$

Hence matching can be seen as a decision problem. MCDM (Multiple Criteria Decision Making) methods are used for discrete decision situations [120] and can therefore be used in this context.

It is the task of a matching function to perform a comparison between the alternatives and make a decision about how to rank the expertise vectors according to the question. To make the different skills comparable a transformation or normalization has to be performed. For a detailed overview about scaling, transformation, normalization, and distance functions, see [148].

In Section 5.8.3, we shall show how we can use Multi-Criteria Decision Making methods to match experts to advice seekers.

5.8.2. Matching for Digitally Documented Knowledge

The goal of matching in markets for digitally documented knowledge is to match a question with a set of documents. In contrast to online expert advice, here we can use the unstructured information of the document itself. Information retrieval research has developed numerous methods to rank documents according to a search query [20, 170].

We concentrate on a situation where the documents are described by quality criteria. There are some approaches that try to extract quality criteria and other meta data from unstructured text [37, 48, 70]. Naumann [143] has developed methods for discovering quality meta data for sources and quality-driven querying of distributed sources. We assume in the following that the knowledge assets are already described by quality criteria.

Let $\mathcal{T}$ be the set of documents and $\mathcal{C}$ the set of quality criteria. We assume that each quality criterion $c_i \in \mathcal{C}$ can be described with value set $dom(c_j)$ measured on an at least ordinal scale. An advice seeker tries to find digitally documented knowledge for a question.

We assume that the quality criteria of the documents can be described by quality levels in much the same way as expert skills—so we can construct a decision matrix and define weightings for the importance of the topic and of the quality meta data.

Therefore, the matching problem of digitally documented knowledge and online expert advice can be mapped to the same Multi-Criteria Decision Making methods. In the following sections we concentrate our examples on online expert advice.

5.8.3. Multi-Criteria Decision Making Methods

The actual procedures for finding a solution vary greatly depending on the structure of the underlying decision problem. In this work, methods are examined with respect to their suitability for finding a solution to a matching problem for a knowledge market. For this reason only those methods that appear promising are discussed in greater detail. Detailed explanation of all methods would be beyond the scope of this work, but if sought this can be found in the works of Lenz and Ablovatski [120], Figueira et al. [68], Hwang and Yoon [97], and Zimmermann and Gutsche [210].

A further classification is often made within Multi-Criteria Decision Making methods into compensatory and non-compensatory methods. Compensatory in this context means that a lower value in one criterion can be compensated for by a higher value in another criterion, meaning values can therefore be combined across different criteria. With non-compensatory methods, combination of criteria is not possible in this way. With regard to comparing various supplier profiles for a knowledge market, compensatory methods are especially useful. In the case of a request for an expert with three years commercial Oracle programming experience for example, those with only 2 years might also be listed, with the deficiency compensated for by outstanding achievements in another required area.

We present a short overview of different matching methods. In Section 5.8.3.1, we discuss the simple additive weighting method. Then we examine outranking procedures: Instead of a real number being assigned to each alternative, outranking attempts to obtain a binary relation on the set of all alternatives, which is known as the *outranking relation* [210, p. 205]. We distinguish between *pairwise preference* (see Section 5.8.3.2 and 5.8.3.3) and *ideal point* methods (see Section 5.8.3.4).

5.8.3.1. Simple Additive Weighting

Simple Additive Weighting (SAW) is a widely-used method for aggregating several criteria [97, p. 99]. The method involves adding together criteria values for each alternative and applying weightings to individual criteria. Criteria must be maintained using the same scale for this to be possible. Once values for all alternatives have been aggregated, the alternative with the highest (or lowest) value is then selected as the comparatively optimal solution. The SAW score of the expertise of actor i is then

$$score(i) = \sum_{j=1}^{m} d_{ij} w_j \quad . \tag{5.5}$$

5.8.3.2. ELECTRE

The ELECTRE (ELimination Et Choice Translation REality) method was developed in the 1960s by Benayoun et al. [24]. The idea of the method is to make a pairwise comparison of the alternatives, with each criterion examined to find out which alternative outranks the other. An outranking relation, i.e. a kind of dominance relation between two alternatives, allows a certain degree of disunity, discrepancy, or contradiction. It uses what are known as concordance and discordance sets to ascertain the particular dominance relationships (see also [210, p. 207]). An alternative is considered to be dominant if it exceeds a threshold value which was fixed for the criterion beforehand. The result depends very much on the threshold values used. ELECTRE does not necessarily produce a total ordering of the alternatives, but can give a partial ordering.

5.8.3.3. PROMETHEE

PROMETHEE (Preference Ranking Organisation METHod for Enrichment Evaluations) [32, 33] is an attempt to resolve certain deficiencies that exist with the ELECTRE procedure. The biggest disadvantage of ELECTRE is the arbitrary fixing of threshold values which do not have any real direct significance [97, p. 125]. PROMETHEE relies to a great extent on a broadening of the concept of a criterion. The decision-maker's choice between two alternatives a and b is made with the help of this preference function and a weighting vector. It results in an outranking relation for all alternatives.

The preference index here is the measurement for the strength of preference of alternative a over alternative b. The result of the PROMETHEE method is a ranking of alternatives according to the so-called *net flow*. This is calculated from the sum of the strengths minus the sum of the weaknesses for each alternative a in relation to alternative b. The measure for the strength of an alternative is also known as *output flow* and corresponds to the concordance in ELECTRE. The weakness of an alternative, *input flow*, corresponds to the discordance. For a more detailed example of PROMETHEE, see [210, pp. 220-234].

5.8.3.4. TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a method which finds an ideal solution on the basis of the best/worst possible criteria values. The closeness of each individual alternative to an ideal point is determined. The alternative that is closest to the ideal solution is selected.

In Figure 5.7 the ideal solution $\mathbf{E}^+$ and the negative-ideal solution $\mathbf{E}^-$ for the expertise is shown. Four further expertise profiles ($\mathbf{E}_1$ to $\mathbf{E}_4$) are plotted.

For each alternative one calculates the Euclidean distances to the ideal solution and to the negative-ideal solution. In TOPSIS both distances are considered.

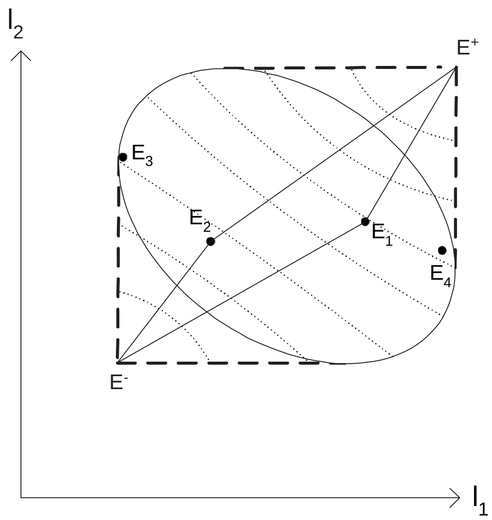

Figure 5.7.: Euclidean Distance to ideal and negative-ideal Solution in two-dimensional Space [97, p. 129]

The TOPSIS method consists of the following 6 steps [97, pp. 130]:

1. Normalize the decision matrix **D**:

$$\mathbf{R} = (r_{ij}) = \frac{d_{ij}}{\sqrt{\sum_{i=1}^{n}(d_{ij})^2}} \quad (5.6)$$

2. Establish a weighted normalized decision matrix **V**:

   By using a weighting vector, preferences of the decision maker with respect to the importance of one criterion can be incorporated into the decision matrix.

$$\mathbf{V} = \mathbf{R} \cdot \mathbf{w} \quad (5.7)$$

   $\mathbf{V}_i$ is the i row of the Matrix **V** and represents the weighted normalized expertise vector of the actor i.

3. Calculate ideal and negative-ideal solutions $\mathbf{E}^+$, $\mathbf{E}^-$:

   The ideal solution $\mathbf{E}^+ = (e_j^+)$ and the negative-ideal solution $\mathbf{E}^- = (e_j^-)$ are calculated as follows:

$$e_j^+ = max_i\{v_{ij}\} \tag{5.8}$$

$$e_j^- = min_i\{v_{ij}\} \tag{5.9}$$

   If the minimum level of a criterion is more favorable than the maximum level—e.g. with costs—the negation of the criterion is used.

4. Calculate the separation measures S^-, S^+:

   The separation of alternative i from the ideal is $S_i^+ = d(\mathbf{V}_i, \mathbf{E}^+)$ and for the negative-ideal solution is $S_i^- = d(\mathbf{V}_i, \mathbf{E}^-)$, where d is the Euclidean distance between the alternatives.

5. Calculate the relative closeness of profile E_i to the ideal solution as $C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-}$ with $0 \leq C_i^+ \leq 1$.

6. Rank alternatives E_i in descending order based on C_i^+.

5.8.4. Usefulness of the different Matching Methods for Knowledge Markets

The major disadvantage of the SAW method (cf. Section 5.8.3.1) is that it is only possible to compare attributes with a uniform scale. Many electronic knowledge markets have attributes with mixed data, making SAW unsuitable.

We shall commence our conclusion about decision-theoretical methods by looking first at *pairwise preference* methods. Despite all their algorithmic differences, ELECTRE (cf. Section 5.8.3.2) and PROMETHEE (cf. Section 5.8.3.3) both demonstrate specific characteristic properties.

Pairwise preference. ELECTRE and PROMETHEE are initially concerned with comparing two alternatives [210, p. 235]. Their advantage is that there is no attempt to aggregate values on different scales. Unlike SAW for example, an absolute total value is not calculated from target values for different alternatives at the outset. Statements are made regarding pairs of alternatives only. The advice seeker can express the importance of skills by selecting weightings. In this way, one criterion considered more important than another may thus be emphasized more.

Restricted compensation. In ELECTRE and PROMETHEE very poor values for one criterion cannot be compensated by excellent values in other criteria in all cases [210, p. 235].

Inability to compare certain alternatives. In their results, neither ELECTRE nor PROMETHEE supply a complete ranking for all alternatives and there are cases where certain alternatives cannot be compared [210, p. 235].

Both methods would be suitable as a matching algorithm for an electronic knowledge market. However, one argument against using ELECTRE is the strong influence of threshold values that are determined arbitrarily, and which have no direct real significance [97, p. 125]. Another disadvantage is the complexity of the procedure [75]. In the case of PROMETHEE, we are dealing with an algorithm that is flexible and easy to comprehend, and which has already been widely used in practice. Having to define a preference function for each criterion is a disadvantage, however. PROMETHEE has a range of 6 different preference functions [210, pp. 221-226]. Knowledge market users need to be able to use matching functions without learning special methods or having to undergo training beforehand. In this respect, both of these methods are unsuitable (see also [204]).

The advantage of TOPSIS (cf. Section 5.8.3.4) is that it is very simple to operate and can be used intuitively. There is no need to determine preference functions or define threshold values beforehand. Preferences with regard to a property are expressed using weighting vectors. The various alternatives are not compared in pairs, but by using a multidimensional comparison of various property vectors. Only the distance of a property to a theoretical ideal solution is observed.

Because TOPSIS offers the advantages of ELECTRE and PROMETHEE without their associated disadvantages, this method would appear to be the most suitable as a matching algorithm for a knowledge market and therefore we use it in the prototype implementation *KnowMarket*, see Chapter 7.

5.9. Fulfillment Services

Fulfillment services are services that the market provides to fulfill the agreed contract. Document services are needed in markets for digitally documented knowledge. Online expert advice often requires a high level of interaction. Therefore, communication services are necessary.

5.9.1. Document services

Document services can include the following elements:

Document Delivery. These services provide the secure digital delivery of documents to the buyer.

Digital Rights Management. Digital Rights Management systems verify that only the buyer has access to the delivered document and that no resale is possible.

Document Storing. The marketplace can offer the seller to store the document on their behalf. In the case of an accidental deletion of the document on the buyer's side a storage can also be beneficial for the buyer.

5.9.2. Communication Services

There are different possibilities for the communication between market participants. A common method is communicating through web sites. Email, voice, and instant messaging may also be used for interaction in the fulfillment. The use of video enables facial expressions and gestures to communicate emotions. Application sharing enables experts to work together with an advice seeker directly using one program and analyze any problem situation far more quickly than when first made aware of it by the advice seeker. Virtual workplaces enable the participants to have a project place with supporting applications for longer consulting projects. Sometimes it is also desirable to have a logging service that logs the communication of the participants for later usage by the buyer or for possible claim management.

5.10. Quality Assurance

In Section 5.10.1, we define quality for knowledge assets. In Section 5.10.2, we discuss if the value of information theory can give us some insights into the quality and price of knowledge assets. The information about the quality of the knowledge assets is distributed unequally between seller and buyer. In Section 5.10.3, we show that this information asymmetry can even hinder the proper operation of the knowledge market. Quality assurance is intended to convince the potential buyers of the quality they will receive, so that they are prepared to pay the asked price for the knowledge commodities. In Section 5.10.4, quality assurance methods are presented that can overcome the quality risk of the buyer.

5.10.1. Quality

The quality of a knowledge asset can only be assessed after receiving it, i.e. it is an experience good (cf. Section 2.2.3). Knowledge markets should assure quality before reception, because recipients are not willing to search and pay for goods of unknown quality. Quality assurance is also important for organizations that try to motivate their in-house experts to share knowledge by providing them with incentives.

The quality management literature (e.g. [131]) provides concepts that are suitable to our problem. The objective of a quality management system is to define a set of specific quality assurance criteria methods and tools in order to ensure their fulfillment. According to DIN 55350 T.11, quality is defined as the suitability of a product or activity to fulfill predefined requirements. In ISO/TC 176, the eight principles of quality management and quality assurance in an organization concern (1) customer focus, (2) leadership, (3) involvement of people, (4) process approach, (5) system approach to management, (6) continuous improvement, (7) factual approach to decision making, and (8) mutually beneficial supplier relationships.

Endres and Fellner identify a set of quality criteria peculiar to digitally documented knowledge assets [61, p. 301]:

- The asset must be relevant to both the problem specification and the recipient's prior knowledge.
- The asset must be original or innovative. This refers mostly to specific types of knowledge assets, like scientific publications and patents.
- The knowledge asset (e.g. facts, relationships, rules) must be true (cf. Section 2.1.1).
- The asset must be clearly and compactly expressed.
- The asset must be consistent and not in contradiction with "relevant" assets on the same subject. Relevance is applied in terms of both terminology and content.
- The asset must be truth provable (cf. Section 2.1.1). This is usually achieved by internal proofs and by citations to other assets.

5.10.2. Value of Information

Economic theories provide methods to calculate the value of information according to its impact in decision making (cf. [118] and [168, p. 487]). There is a series of research papers that discuss value of information. Arrow [17, p. 134] summarizes that the information value can be linked to models which evaluate the usefulness of channels perceived by the receiver. McGuire [130] introduces a quantitative model of the impact of information for optimal decision making: His model consists of a Markov transition matrix, a finite set of states and a finite set of signals under a closed world assumption. Given a predefined set of actions for each state, the matrix gives the conditional probability for every signal. The recipient selects the action that maximizes the expected payoff, given a sequence of observed signals.

This thread of research models value of information from the viewpoint of the recipient. In the context of pricing in knowledge marketplaces it shows the following shortcomings: (a) The closed-world assumption does not hold, because the set of signals cannot be defined in advance. In fact, we shall see that the interaction itself between an expert and a recipient in a knowledge marketplace generates new, unaccounted knowledge assets. (b) While the value of information is determined by the recipient, the price is determined in advance, at least partially, by the expert. This implies that the recipient is contractually bound to pay for an asset before acquiring it. The recipient is also not willing and often not able to express the utility of the information beforehand. This fact, together with the open-world assumption, prevents a mapping of information value to a price for a knowledge asset in real world situations.

5.10.3. Asymmetric Information

The buyer can only evaluate the relevance and quality of the knowledge after the purchase. That means that knowledge assets are experience goods. The seller however has more information about the quality of the knowledge asset or he can even determine the quality himself. This kind of asymmetric quality information can lead to a *market for lemons* [11]. The effect would be that poor quality is crowding out the higher quality.

The following example is partially derived from [201, p. 140]. Let's assume Ann wants to found an internet start-up in China and needs some adequate expert advice. There are two experts: Bob and Cid. Bob's advice has a specific value of 1 € for Ann, because Bob has never founded a company himself, nor has he ever been to China. Bob's costs for answering a question are 0.5 €. Cid's answer has a value of 11 € and the costs for himself are 8 €. Since Ann does not know the individual quality of the experts but only the expected value of the answers, she is willing to pay at most the expected value of the knowledge asset (as well as would every other member of the market).

This means that the expected value is ($\frac{11+1}{2} =$) 6 € and therefore the market price is at most 6 €. However, at this market price Cid would withdraw from the market, because his costs are even higher than the expected return price. Then, Bob would be the only offerer left, and the expected value of the offer would decrease to 1 €. This means the maximum market price would be 1 €, and the market for high-quality expert advice would collapse.

In the case where the seller can determine the quality of the knowledge asset, opportunistic behavior can occur (see also Section 3.4.2). Opportunistic behavior in this context is characterized by the seller taking advantage of the asymmetric quality information through producing a knowledge asset of inferior quality. Rode [167, p.31] points out that the danger of opportunist behavior is particularly great with knowledge commodities. This is because the knowledge provider knows that the quality of knowledge commodities is not only difficult to assess before the purchase but also afterwards—even after it has been used. This is because it is often difficult to attribute the success or failure of an action directly to an expert advice. There is thus little incentive for an expert to make any extra effort when preparing and communicating knowledge. In Section 5.11, the quality choice is part of the behavior dimension.

5.10.4. Mechanisms to overcome Quality Uncertainty

There are several mechanisms to overcome quality uncertainty. In the following, we shall analyze the appropriateness for knowledge markets of the following quality mechanisms: reputation building, reputation systems, guarantees, previewing, reviewing, and certificates.

Reputation Building

An inducement for a provider not to act opportunistically in this situation is that he can build up a reputation [192]. A provider's reputation rests on having an uninterrupted series of transactions with a positive outcome. By maintaining a series of transactions with the same advice-seeker, an expert is given an incentive not to act as an opportunist. However, in cases where the likelihood of coming across the same advice seeker more than once is very low, building up a reputation in this way will make little sense for the expert.

Opportunistic behavior of experts is alleviated to a certain extent in electronic marketplaces where a critical mass of experts and advice seekers interact frequently and thus have a mutual interest in long-term quality assurance.

Reputation Systems

Reputation building can be further promoted by a reputation system that aggregates ratings of other market participants about the quality of experts and makes them public among the advice seekers [163, 175, 56, 73, 164, 165, 209]. In this way, an advice seeker evaluates an expert in the form of a grade system and comments every time a successful consultation takes place. Public ratings discourage opportunistic behavior of the experts, even if the expert is not likely to interact with the same advice seeker more than once.

Guarantees

Money-back guarantees are an often-used means of increasing an advice seeker's confidence beforehand. However, as it is difficult for an advice seeker to give knowledge back, there is a danger that guarantees will be abused. Opportunistic behavior of advice seekers can be expressed as a misuse of guarantees. Since knowledge assets cannot be returned when the transaction is cancelled, it is appropriate that a guarantee is combined with a review of the knowledge asset through a trusted-third party. In an electronic marketplace, the complete interaction between expert and recipient can be recorded, so that knowledge combinations can be traced and the contribution of expert and recipient to the output knowledge asset can also be evaluated.

Previewing

In previewing, the potential buyer can get part of the good for inspection, e.g. a trailer for a motion picture [192]. Previewing the knowledge assets in the form of an abstract allows knowledge evaluation for relevance, but not necessarily for quality. Another problem with previewing is that it is difficult to ensure a buyer does not receive too much knowledge so that there is no longer any need to proceed with the purchase.

Some electronic marketplaces for expert advice cater to previewing: The expert provides an excerpt or an abstract of the knowledge asset, which the advice seeker can evaluate with respect to relevance. For example, in the *E-lance* market place (see Section 5.14.2), advice seekers perform a call-for-tenders for their projects and experts can provide excerpts of their intended advice.

Reviewing

One form of quality testing that has been established for scientific publications and patents is reviewing [192]. An article may only be published or a patent awarded after a review has been made by other experts. It is possible to have knowledge assets appraised in the same way by experts before this is passed on to an advice seeker. Reviews of this type also have their disadvantages however: they are time-consuming and costly. If the expert advice is needed urgently or if an advice seeker has only limited budget, it may not be possible to carry out an appraisal beforehand.

For digitally documented knowledge assets inside an organization, reviewing is a feasible option. Nonetheless, its realization is difficult for many institutions either due to lack of human resources that can be assigned to this task or due to political constellations. It should be noted that the policies and unwritten codes of ethics governing a review process of a scientific community cannot simply be transferred to a company. A reviewing process is less appropriate for expert advice. A reviewer should understand the problem specification, be competitive in the expert's knowledge domain, and have adequate resources to monitor the interaction between expert and advice seeker.

Therefore, reviewing adds a trusted third party to the marketplace. This is related to the concept of knowledge brokers [203], who should also ensure the quality of the traded knowledge.

Certificates

While the quality of expert advice can only really be evaluated once it has been distributed, it is possible to try to draw some conclusions about the ability of an expert to give advice on the basis of representative features that may be accounted for beforehand such as training or certificates. This is, of course, only possible to a certain extent. Statements from experts about education or certificates can be checked as a part of quality assurance by the marketplace operators. This again is no guarantee of good advice however.

Summary

Summarizing, opportunistic behavior of experts can best be prevented through a reputation system with public ratings. Certificates may help to predict the ability of experts to help an advice seeker. Opportunistic behavior of the recipients can be avoided by preventing abuse of guarantees through a check of a third party and motivating recipients to establish quality assurance themselves through ratings.

5.11. Behavior

All decisions of the market engineer aim to influence the behavior of the market participants. This behavior is not under the direct control of the marketplace engineer, but is influenced by the design of the corresponding market elements (see Section 5.3).

This are the following behavior dimensions that are important to the market outcome:

Participation Decision. The market actors can decide whether to participate in the marketplace at all.

Bidding Behavior. The bidding behavior consists of the search and the choice of the appropriate asset to bid and the individual bidding in an auction according to the market mechanism.

Quality Choice. Finally, the seller can choose the quality of the knowledge assets he produces.

5.12. Outcome

The outcome is the final allocation of all the resources or the final state of the all allocations. It consists of the following elements:

Allocation. The allocation of the knowledge assets controls who gets which knowledge assets from whom. This is determined by the market mechanism that processes the bids of the participants as an input and gives the allocation as an output.

Price. The terms of each knowledge transfer— that means the prices—are also determined by the market mechanism.

Quality. The producer of a knowledge asset can partially determine the quality of the knowledge asset by using more time or care. The decision of the quality of each knowledge asset and under which conditions the different qualities are traded and allocated are influenced by the *quality assurance* methods of the marketplace.

5.13. Evaluation Measures

The evaluation measures define and measure the performance of a marketplace corresponding to goals of a market operator or sometimes also a regulator. Therefore, the marketplace strategy (see Section 5.5) is important for the choice of the right measure. Depending on the marketplace owner and the goals, different measures can be chosen, for example *revenue*. However, a marketplace regulator can also have possible conflicting goals which can be quantified with corresponding measures, for example *efficiency*.

Number of Transactions. Exchange only happens when both parties anticipate that they will benefit from the exchange. Therefore, the more transactions a marketplace can generate the more beneficial a marketplace is to the participants. In Chapter 6 we use the number of transactions as a measure.

Decision Quality. Knowledge assets are bought to enhance decisions and actions. Therefore, the decision quality can also be taken as a measure of success. However, the enhancement of the decisions is in practice difficult to observe (see Section 5.10.2). In Chapter 6 we were able to observe the decision quality in an experimental setting and used it as a back-up measure.

Revenue. The revenue measures the total transaction volume. It is similar to the measure of the *number of transactions*, but also gauges the value of a transaction.

Efficiency. In an efficient allocation the goods are distributed to the buyers that value them most and therefore there is no need for further trading or exchange [80, p. 486]. One measure for efficiency is to count the fraction of bidders that valued the good most but did not get it. In a total efficient allocation this fraction would be zero.

5.14. Examples of Electronic Knowledge Marketplaces

In the following, we want to present three existing knowledge markets: Knexa, Ingenio, and E-Lance.

5.14.1. Knexa

Knexa [7] is a knowledge market for documented knowledge. The market Knexa has a time-dependent price system, that mixes elements of Dutch and English auctions. The seller fixes an initial asking price, a number of winning bids after which the price increases, and the amount raised. He also sets the time after which the price decreases and the decrement. Moreover the seller sets a minimum and a maximum price. The bidder can either buy at the current price, or determine a bid price and a validity for the bid. If the quote reaches the bid price within the time frame, the transaction is executed. The market mechanism ensures a certain binding of the price development, since price changes are controlled by Knexa. However, the seller can always remove the good from the market or change the auction parameter.

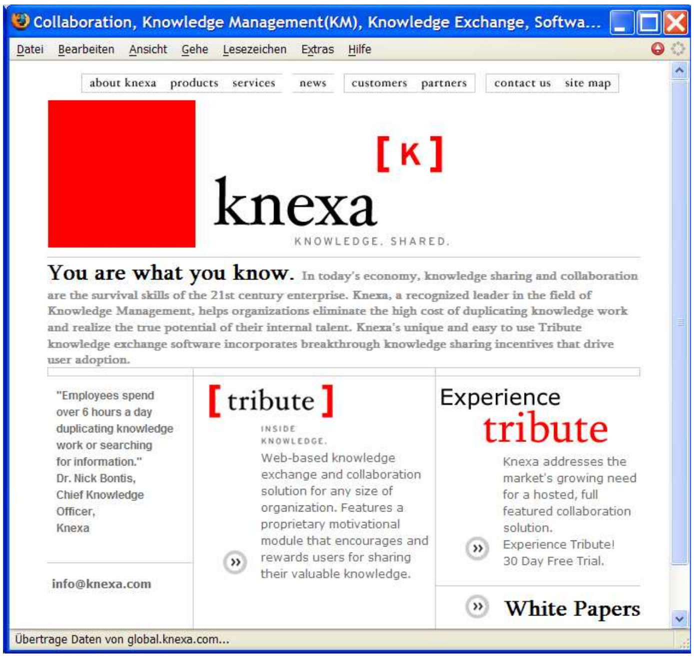

Figure 5.8.: Website of Knexa [7]

There is a reputation system which shows the recent ratings. The buyer can rate the purchased good as either *positive*, *negative*, or *neutral*. There is only a full-text search function available. The risk of the buyer is high, since many documents have no rating.

5.14.2. E-Lance

E-Lance [5] provides experts for a variety of projects including consultations. Experts can describe their expertise, advice seekers can publish their projects, search for experts in relevant areas and invite them to make offers using project advertisement services.

Experts apply to carry out advertised projects with an offer price. Once an inquirer has made a decision based on the offer price and expertise, E-Lance offers a virtual workplace for the expert, which provides support for the duration of the project.

E-Lance also processes the payments to the experts. The advice seeker then evaluates the expert's performance and provides comments. This evaluation is part of a reputation system. Evaluations and information from earlier projects also appear in the knowledge profile for each expert. The sales volume for each expert can also be viewed.

5.14.3. Ingenio

Ingenio [6] is an electronic marketplace for expert advice, combining a web-based environment for the information, agreement and after-sales phases with a phone-based service for the execution phase. The actual consultation takes place over the telephone. Alternatively, an inquiry may be made and reply received using email.

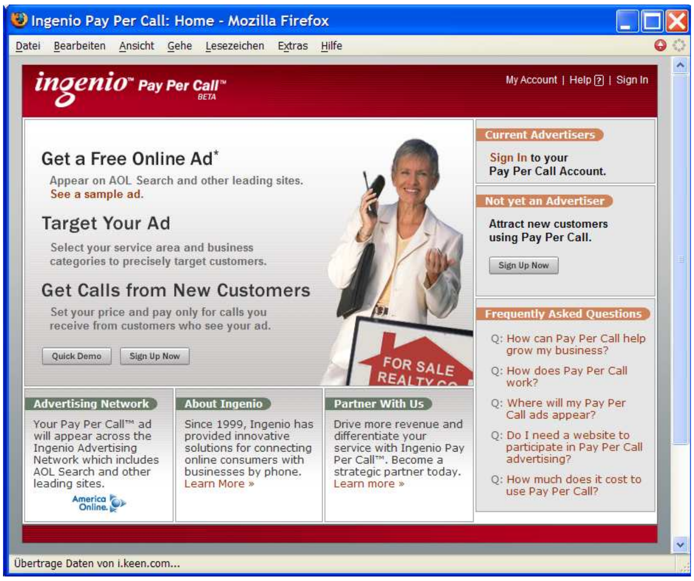

Figure 5.9.: Website of Ingenio [6]

Experts outline their area of knowledge, set a price per minute, then inform Ingenio when they are available. The advice seeker searches the website for a suitable available expert according to subject areas, ratings and the expert's description. After the selection, Ingenio calls the expert and advice seeker and the consultation takes place by telephone. The expert therefore remains anonymous throughout. After the call, the advice seeker evaluates the expert.

The pricing model of Ingenio is time-based: Each expert determines a price per minute for his advice. The price for advice is not negotiable.

Ingenio provides several modalities to assure the quality of advice being provided. First of all, experts are rated and ratings are published; this allows one to build up a reputation. Secondly, Ingenio offers the verification of the certificates and academic qualifications of its experts. Third, Ingenio provides quality guarantees: If an advice seeker is dissatisfied with a consultation, he can make a complaint. Ingenio then investigates the case and, if the criticism is found to be justified, the advice seeker does not have to pay.

The market place of Ingenio is characterized by a simple pricing model combined with strong incentives for reputation and quality assurance. While many marketplaces allow for participants to use pseudonyms, Ingenio pays particular effort to preserving the anonymity of the experts by operating as an intermediary for all contacts.

5.14.4. Discussion of the Markets

The three knowledge markets can be further analyzed with our framework (cf. Section 5.3). Table 5.3 shows the different elements of our knowledge trading model for each example.

Parameter	Knexa	E-Lance	Ingenio
Marketplace Strategy			
Target Group	SME, Individual Experts	SME, Freelancer	Freelancer, Individual Experts, Public
Marketplace Strategy:Knowledge Asset Selection			
Online Expert Advice		X	X
Digitally Documented Knowledge	X		
Marketplace Strategy:Financial model			
Participation Fees		X	
Transaction	X	X	X
Advertising			X
Other Services			
Matching			
Full Text Search	X	X	X
Browsing	X	X	X
Matching			
Quality Assurance			
Reputation Building	X	X	X
Reputation System	X	X	X
Guarantees			X
Previewing			
Reviewing			
Certificates		X	X

Parameter	**Knexa**	**E-Lance**	**Ingenio**
		Fulfillment:Document Services	
Document Delivery	X	X	
Digital Rights Management			
Document Storing	X	X	
		Fulfillment:Communication Services	
Web	X	X	X
Email	X	X	X
Voice			X
Instant messaging			
Video			
Application sharing			
Virtual workplaces		X	
Logging service		X	X
		Market Mechanisms	
		Market Mechanisms:Bidding policy	
Buyers-Sellers Cardinality	n:1	1:n	n:1
Bid Expressiveness Seller	(Initial ask, ask increase, number of sales until increase, ask decrease, time until decrease, min. ask, max. ask)	Make Bid	Set price
Bid Expressiveness Buyer	(Offer, expiration time)	Make Offer, Accept Bid	Accept Price
Dominance	No	No	N/A

Parameter	Knexa	E-Lance	Ingenio
Beat-the-quote	No	No	N/A
Withdraw	Yes	Yes	No
Expiration	Yes	Yes	No
Activity required	No	No	No
Market Mechanisms:Clearing policy			
Allocation Function	offer $\geq$ ask	Chosen Seller	All buyers
Pricing Function	Ask Price	Bid Price	Seller Price
Clear Timing	Scheduled	After acceptance	After acceptance
Closing Conditions/Repetition	Seller decides	Once	Many
Tie-breaking	N/A	N/A	N/A
Market Mechanisms:Information revelation policy			
Price Quotes	Ask	No	Seller price
Quote Timing	Scheduled	N/A	During the auction
Order Book	Closed	Open for Buyer	N/A
Transaction History	No	Yes	No

Table 5.3.: Market Examples analyzed with the Knowledge Trading Framework

The analysis of the presented knowledge markets gives the following insights:

- For the information phase the markets mainly offer full text search and browsing. There is no sophisticated matching support such as we described in Section 5.8. Experts and advice seekers therefore have to spend a lot of time searching for the right requests and offers.
- The markets use different market mechanisms. Therefore, an experimental examination of market mechanisms as we present in Chapter 6 is necessary.
- The interaction with the markets is web-based. Only Ingenio also uses phone. The coupling of the knowledge market with other systems or programs like Office could integrate the markets better into the daily work. This integration could be made possible by a Web Service oriented architecture as we present in Chapter 7.

5.15. Related Work

After our first works [140, 139, 136, 135] on knowledge markets have been published, Kafentzis et al. [102, 15] presented another framework (INKASS) for knowledge asset marketplaces and analyzed different prerequisites for knowledge trading. Skyrme [180] analyzed how to market knowledge goods and also examined several existing online knowledge markets. However, both have not analyzed different market mechanisms in detail (cf. Section 5.7) nor experimentally tested the effectiveness of different market mechanisms for knowledge trading (cf. Chapter 6). They also have not discussed different methods for matching (cf. Section 5.8) or presented an IT architecture as we shall do in Chapter 7. Wille et al. [203] introduced the concept of *filtered markets* to enable an intra-organizational knowledge market. The quality of the knowledge assets should be ensured by *knowledge brokers*. The knowledge broker concept addresses the quality assurance problem and is only one of different possible solutions for it (see Section 5.10). They have not analyzed other important features of knowledge trading like market mechanisms or matching. Also, Desouza and Awazu [57] discussed the possibilities of internal knowledge markets. However, their analysis is based on mini-cases and is rather anecdotal. Their research did not lead to a coherent knowledge market framework as presented here.

5.16. Summary

After showing the advantages of the knowledge trading game theoretically and analyzing the different transaction phases, we have proposed a model for electronic knowledge markets. The foundation of the model is the economic, social and cultural environment and the characteristics of the knowledge assets. The model elements which are under the direct control of the market engineer are the knowledge marketplace strategy, the knowledge trading process, the market mechanism, the matching, fulfillment and quality assurance services as well as the IT infrastructure. These model elements influence the behavior of the market participants and the overall market outcome which can be judged by different evaluation measures.

We analyzed different market mechanisms in Section 5.7 for their usefulness for knowledge asset trading and state some propositions about their relative ranking. We shall experimentally test these propositions in the following chapter.