The Concept of Shadow Price to Monetarize the Intangible Value of Expertise

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Abstract— **The pricing of knowledge based services should be based on the three following components: the cost structure, the competition and the perceived value by the client. Practically, it is mainly based on the cost structure which does not account for the real value provided to the client. Based on an integrated optimization model combining an aggregate planning model with a share of choice model, we produce implicit values of expertise. Preliminary results will be presented about a travel agency.**

Keywords— shadow price; intangibility engineering; perceived value; service design.

I. INTRODUCTION

We propose a new theoretical framework to model the pricing of knowledge based services. The knowledge based services are delivered by highly educated and informed employees responding to specific diagnosed customer demands by offering and delivering customized value-added solutions and relations [8].

Our approach rests on the paradigm of the mathematical optimization. Indeed, optimization allows us through the theorem of the duality to establish a formal link between the planning of the resources used to produce the services and their pricing. Most of the existing pricing models for the services that come from disciplines such as econometrics as well operational research are also based on the optimization paradigm. However, these latter models are only applicable to domains where the services have reached a high level of standardization. It is the case of "yield management" models employed in airline companies and hotels to price seats and rooms. Same for "rating/pricing" models used in banks to determine the solvency of customers and price their loan (i.e. interest rate).

In our approach, we focus on categories of service markets, which have not reached a sufficient level of standardization to be considered as service commodities. Consequently, the pricing is not defined from the market, but from a surrogate market which results from the optimization of the resources allocation (mostly human in the case of knowledge based services) allowing the production of service.

Due to their intangible and heterogeneous natures, the modelling of the production of services is not easy. First of all the life cycle of the service is determined by the contractual relationship established between the provider and its client. It begins with the signature of the contract and normally ends at its term. Moreover, whereas the good production obeys a logic of supply chain, the "raw material" of the service often comes from the customer itself and intervenes at various levels of the production process.

Most of the composing factors of services correspond to human qualities ("soft skills") which are by nature subjective and not quantifiable. On this matter, we will use developments realized in the field of social sciences and psychology (parametric and non-parametric conjoint analyses). Indeed we cannot rely on classical supply chain models. This contribution is thus based on interdisciplinary research. The pricing model essentially borrows academic findings arising from Environmental Sciences, Marketing, Operations Management and Service Science. To sum up, we propose an innovative method to tackle the problematic of pricing for the knowledge based service and implement it on a travel agency application.

This short paper is organized as follows. In Section II, we introduce some elements of pricing for the knowledge based services. In Section III, we present the equations of the travel agency pricing model. In Section IV, we introduce a simple demonstration case. In Section V, we present numerical results for the demonstration case. Finally, in Section VI, we conclude and present directions for future research.

II. A PRICING SYSTEM FOR THE KNOWLEDGE BASED SERVICE

The main contribution of this paper is to integrate dollar-based (or cost-based) valuation methods, normally used in the valuation of ecological services, to support the development of a pricing scheme for services. The dollar-based valuation approaches are typically used when externalities are associated with a significant degree of intangibility (i.e. an ecological service).

Ideally, the pricing of services should be based on the three following components: the cost structure, the competition and the perceived value by the users. In practice, the pricing of services is mainly based on the cost structure which does not account the real value provided to the client.

The academic findings related to the pricing of services are numerous (see for instance [19] for an exhaustive literature review) and essentially comes from the Marketing discipline.

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In this paper, we structure our brief literature review according to the following categorization of pricing systems for services:

- Multi-product, stochastic models
- Customized pricing
- Differential pricing
- Perceived value pricing
- Cost-based valuation methods

A. Multi-product, stochastic models

This corresponds to the well know Yield management approach that is the case with single resource used to satisfy a set of different demand classes differentiated by identified characteristics. In the context of Yield Management models, we assume that single resources are used to satisfy a set of different demand classes differentiated by identified characteristics. This pricing scheme is particularly useful for those industries having perishable capacity and a stochastic and price sensitive demand and is thus critical to revenue management [4].

B. Customized pricing

In practice, the seller has the ability to decide which specific configurations will be available to customer [4]. Thus, in the case of customized pricing schemes the aim is to to decide which specific configurations will be available to customer [4].

C. Differential pricing

The aim is the same as the customizing pricing scheme [11]. The main intention is to administer the differential scheme without alienating customers. Typically, buyers compare their outcomes with other buyers and form fairness judgments [24]. We also learn that perceived unfairness of pricing generates perceptions of financial risk [22].

D. Perceived value pricing

In the context of perceived value pricing scheme, the goal is to find out the optimal formulation design of the product [10]. Indeed, customers will usually have some sense of value (a very large range throughout which they do not want to be overcharged), on the other end we consider that they have no real ideal how to value it properly [6], [14], [18]. However, this approach is tedious to operationalize since customer demand and price sensitivity information must be gathered through sophisticated market research [6]. However, we learn that perceived unfairness of pricing generates perceptions of financial risk [22]. Consequently, it is crucial to take into account a form of perceived value pricing when tackling service production (see for instance [6], [14], [18]. It remains that including the perceived value in the pricing scheme is very difficult to operationalize since customer demand and price sensitivity information required can solely be gathered through sophisticated market research [6].

E. Cost-based valuation methods

Cost-based valuation methods correspond to a subset of cost-benefit analyses and are generally used to value ecological services. Due to growing public concern, governments tend to take very seriously damaging events affecting the environment. Companies which are found guilty of the damages must pay huge fines in order to restore the landscapes as they used to be originally. The main difficulty is then to settle on the actual amount of the penalties. Indeed, many aspects of the damage are so specific that market mechanisms could be of no help to calculate a "fair price". According to [1] there are 3 main families of dollar-based valuation approaches: implied market decisions, experimental market methods, and surrogate market techniques. We have opted for the latter techniques and in particular for the shadow price approach.

We are currently exploring the shadow prices approach through an optimization problem called the "share of choice" model (see for instance [9], for an application of share of choice models for services). This concept of shadow pricing has already been used to price CO2 emissions in the case of uncertain energy demands see [2]. The model proposed in this paper attempts to optimize the design of a service by selecting its attributes according to the perceived value of a sample of clients. Perceived value is expressed by utility functions obtained from conjoint analysis (see for instance [8]). Conjoint analysis techniques enable to construct path-worth or utility functions for each respondent regarding the different attributes of the service. Each attribute of the model can only be defined by one characteristic (for instance the advice provided by the travel agent to the customer can be either "Basic" or "Customized"). Logical constraints compare the total utility (summation of every attribute path-worth) of each respondent with the total utility of their current service bought from the competitors. This is done again through the use of binary variables: with the value 0 when the utility of the new service is inferior or equal to the actual service bought and with the value 1 when it is superior. The solution process attempts to find out a combination of attribute characteristics that maximize the utility of the new designed service compared to the competition (or alternative service). Integer programming problems lost their continuity properties and thus provide no dual solutions. The mains solution process is the Branch and Bound algorithm. It is however possible to produce shadow prices from the Lagrange relaxation of the problem (all integer variables are dropped from the model and optimized like a convex continuous mathematical program). This process just gives a proxy. If we want to keep the integer version of the model, the only way to calculate shadow prices is to conduct multiple runs, which is known to be quite challenging in terms of computing time executions. This latter solution has been used in the demonstration case presented in the following sections.

III. The Travel Agency Model

Travel agencies are crossing difficult times these days. In the past most of their revenues was generated via commissions they earned by selling airline tickets. Nowadays they must rely on other sources of income in order to survive: the generally adopted pricing scheme is a single fee charged with no link to the service provided to the client. Moreover, the Internet seems to play a more and more prominent role in this industry as a direct competitor for traditional travel agencies. In the following part, we describe the main equations needed to model a travel agency: the production side, the clientele and the competition.

To sum up, the general model replicates the typical activities of a travel agency business. First, the manager must design a travel agency service based on the main attributes as perceived by the clientele. In our example we have retained three attributes, which are "Advice", "Price" and "Hospitality". Consequently, the manager must find the optimal combination of levels of attributes to get the best perceived design. While providing the desired design, the manager must allocate the resources (human, design implementation and restructuration costs). The ultimate goal is to maximize the profit. The pricing information is then obtained from the dual version of this integrated model.

First we need to determine the sets for the algebraic formulation of the model:

Respondent	k	=	$1 \dots K$.
Attribute	i	=	$1 \dots I$.
Level of attribute	j	=	$1 \dots J_i$.
Period	t	=	$1 \dots T$.

Then, the data is included as follows

$d_f(t)$	forecasted demand without new consumers at period t.
$d_\Delta(k,t)$	increase of demand for period t if respondent k becomes a consumer.
$u(k,i,j)$	utility of respondent k for attribute i and attribute level j.
$u_c(k)$	current utility for respondent k.
$u_\Delta(k)$	minimum increase of utility to turn respondent k into a consumer.
$c(i,j)$	cost of implementing the attribute level j for the attribute i.

We have the following decision variables

$H(t)$	new workers hired at period t.
$F(t)$	workers fired at period t.
$O(t)$	overtime at period t.
$X(i,j)$	service configuration. 1 if attribute i is set to level j and 0 otherwise.

and as a result the following dependent variables

$W(t)$	workers at period t.
$D(t)$	total demand at period t.
$P(k)$	preference for respondent k. 1 if respondent becomes a new client 0 otherwise.

The two variables $X(i,j)$ and $P(k)$ are binary variables whereas $W(t)$ is an integer variable.

The share of choice model can thus be presented as follows. For each respondent $k = 1 \dots K$, the following two inequalities must hold

$$\sum_{i=1}^{I}\sum_{j=1}^{J_i} u(k,i,j) \cdot X(i,j) \geq (u_c(k) + u_\Delta(k)) + ((P(k) - 1) \cdot M, \quad (1)$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J_i} u(k,i,j) \cdot X(i,j) < (u_c(k) + u_\Delta(k)) + P(k) \cdot M, \quad (2)$$

where M is a big number.

For each attribute $i = 1 \dots I$, we must have the normalization

$$\sum_{j=1}^{J_i} X(i,j) = 1. \quad (3)$$

For the total demand the following equations must hold for all periods $t = 1 \dots T$

$$D(t) = d_f(t) + \sum_{k=1}^{K} P(k) \cdot d_\Delta(k,t). \quad (4)$$

Regarding employees flow equations, given $W(0) = w_0$ the initial number of employees, the following must hold for $t = 1 \dots T$:

$$W(t) = W(t-1) + H(t) - F(t). \quad (5)$$

Let θ be the maximal overtime hours per worker in a period, then for each period t, the overtime capacity constraints are given by

$$O(t) \leq \theta \cdot W(t). \quad (6)$$

Given μ the labour hours per travel sold and η the regular working hours for a worker during a period, then the total capacity constraints for each periods t, are given

$$D(t) \cdot \mu \leq W(t) \cdot \eta + O(t). \quad (7)$$

The design cost is given by

$$\sum_{i=1}^{I}\sum_{j=1}^{J_i} c(i,j) \cdot X(i,j), \quad (8)$$

where $c(i,j)$ is the cost of implementing the attribute level j for the attribute i and $X(i,j)$ is the service configuration. The labour cost is given by

$$\sum_{t=1}^{T} \left(\sigma \cdot W(t) + \varsigma \cdot O(t)\right), \quad (9)$$

TABLE I

QUESTIONNAIRE BASED ON A CARD SYSTEM

Advice : basic Price : fixed fees 200 Hospitality : simple	Advice : basic Price : 5% total invoice Hospitality : sophisticated
Advice : customised Price : fixed fees 200 Hospitality : simple	Advice : customised Price : 5% total invoice Hospitality : sophisticated
Advice : basic Price : fixed fees 200 Hospitality : sophisticated	Advice : basic Price : hourly price 50 Hospitality : simple
Advice : customised Price : fixed fees 200 Hospitality : sophisticated	Advice : customised Price : hourly price 50 Hospitality : simple
Advice : basic Price : 5% total invoice Hospitality : simple	Advice : basic Price : hourly price 50 Hospitality : sophisticated
Advice : customised Price : 5% total invoice Hospitality : simple	Advice : customised Price : hourly price 50 Hospitality : sophisticated

where σ is the regular salary per worker and period and ς is the overtime wage rate per hour.
The restructuration cost is given by

$$\sum_{t=1}^{T} \left(\omega^+ \cdot H(t) + \omega^- \cdot F(t)\right), \tag{10}$$

where ω^+ is the cost of hiring a new employee and ω^- is the cost of firing an employee.

Let λ be the wealth associated with a new client. The total new client wealth contribution is given by

$$N = \lambda \cdot \sum_{k=1}^{K} P(k). \tag{11}$$

Finally, the objective is to maximize the total profits

$$\Pi = R - C + N, \tag{12}$$

where

- Π: profits,
- R: revenues,
- C: costs,
- N: new clients wealth.

IV. PRESENTATION OF A SIMPLE TRAVEL AGENCY CASE

Table I presents a questionnaire based on a card system. To design the service of the travel agency we have identified 3 salient factors: advice, price and hospitality. Advice has two levels: basic and customized. Price has 3 levels: fixed fees at 200, hourly price at 50 and 5% of total invoice. This leads to 12 possible combinations of service design. Each respondent needs to rank the card according to its preferences. We use then a non-metric algorithm of conjoint analysis available in SPSS to calculate additive utilities. For this simple example we gathered a sample of size 15 that is presented in Table II. Each figure in the table corresponds to a path-worth. In the "current favourite" column is the total utility associated with the service provided by the competition. We see for instance that client 1 could easily beat his current value perception of the service (offered by the competition), if our travel agency would design its service with a customized advice, an hourly price of 50 and simple hospitality management. So ultimately we need to optimize the design of our travel agency through the share of choice model in order to have a maximum of potential clients who will become ours.

TABLE II

$u(k,i,j)$: RESPONDENTS'S UTILITY FOR THE DIFFERENT ATTRIBUTE LEVELS

	Advice		Price			Hospitality		
k	Basic	Customised	Fixed 200	5% total invoice	Hourly price 50	Sophistic.	Simple	Current Favourite
1	-1.833	1.833	-1.75	0.75	1	-1.833	1.833	0.75
2	-3	3	-1.5	1	0.5	0.167	-0.167	-2.167
3	-3	3	0	2	-2	-0.5	0.5	5.5
4	-3	3	-0.5	0	0.5	-0.5	0.5	3
5	-0.167	0.167	0.75	0	-0.75	-0.333	0.333	-0.166
6	-0.167	0.167	0.5	-1.25	0.75	-1.5	1.5	1.833
7	0.333	-0.333	0	-1.75	1.75	1.167	-1.167	-3.25
8	-3	3	0	-2	2	0.5	-0.5	-5.5
9	0.5	-0.5	1	-0.5	-0.5	3	-3	-4
10	0.5	-0.5	-1	0	1	3	-3	-3.5
11	0.5	-0.5	0.25	-0.75	0.5	0.167	-0.167	-1.417
12	0	0	2	0	-2	-0.5	0.5	-0.5
13	1.5	-1.5	2	-1.5	-0.5	-2.333	2.333	5.833
14	0.5	-0.5	1	-2.25	1.25	0.167	-0.167	-1.583
15	-3	3	0.25	0.5	-0.75	0.667	-0.667	2.917

TABLE III

A SUMMARY OF THE DATA USED IN THE AGGREGATE PLANNING MODEL

Parameter	Value
T	4
$d_f(1)$	3000
$d_f(2)$	4000
$d_f(3)$	4000
$d_f(4)$	3000
$d_\Delta(k,t)$	10
$u_\Delta(k)$	0.2
w_0	9
θ	20
η	160
μ	4
σ	5000
ς	50
ω^+	10000
ω^-	15000

V. NUMERICAL RESULTS AND PRICING ANALYSIS

In this numerical example, the three pricing possibilities (fixed fees at 200, hourly price at 50 and 5% of total invoice) charge on average the same amount for a travel. Therefore, the client's preference for the pricing method is not biased by an economical reason.

We run the model for different values of λ. The values of the other parameters are given in Tables III and IV. The share of choice model has 15 respondents and is coupled with a four periods aggregate planning model. The resulting meta-model has been written in GAMS and has 60 single equations, 51 single variables and 26 discrete variables. The results are summarised in Table V and an efficient curve is proposed in Figure 1.

TABLE VII

COST OF CHANGING THE OPTIMAL DESIGN

	Change advice		Change Pricing				Change hospitality	
λ	new advice	cost	new pricing	cost	new pricing	cost	new hospitality	cost
0	custom	20000	percentage	2000	hourly	2000	sophisticated	18000
2'000	custom	14000	percentage	4000	hourly	4000	sophisticated	16000
4'000	custom	8000	percentage	6000	hourly	6000	sophisticated	14000
6'000	custom	2000	percentage	8000	hourly	8000	sophisticated	12000
8'000	basic	4000	percentage	34000	hourly	3000	sophisticated	20000
10'000	basic	10000	percentage	42000	hourly	5000	sophisticated	20000

TABLE IV

$c(i,j)$: COST OF IMPLEMENTING THE DIFFERENT ATTRIBUTES LEVELS

Advice		Price			Hospitality	
Basic	Customised	Fixed 200	5% total invoice	Hourly price 50	Sophisticated	Simple
60000	80000	0	0	0	50000	30000

TABLE V

NUMERICAL RESULTS FOR DIFFERENT VALUES OF λ

λ	0	2000	4000	6000	8000	10000
Profits	2000	16000	30000	44000	62000	82000
Design, advice	Basic	Basic	Basic	Basic	Custimized	Customized
Design, pricing	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Design, hospitality	Simple	Simple	Simple	Simple	Simple	Simple
Workers $t = 1$	9	9	9	9	10	10
Workers $t = 2$	11	11	11	11	12	12
Workers $t = 3$	11	11	11	11	12	12
Workers $t = 4$	11	11	11	11	12	12
Overtime $t = 1$	40	40	40	40	-	-
Overtime $t = 2$	120	120	120	120	80	80
Overtime $t = 3$	120	120	120	120	80	80
Overtime $t = 4$	-	-	-	-	-	-
New clients	7	7	7	7	10	10

Through a parametric analysis, we are able obtain shadow prices associated with the demand for travel agency service. In Table VI, we show the shadow price provided by an additional employee for different wealth value of a new client. We also show the shadow price of the current cap on the overtime (20 hours per period) compared with the impossibility of having overtime. We also show the shadow price of doubling the overtime cap and the shadow price for the sale of an additional travel. In Table VII, we show the value of the design. Through multiple runs, we are able to determine the price for changing the design.

Fig. 1. Profits for different values of λ

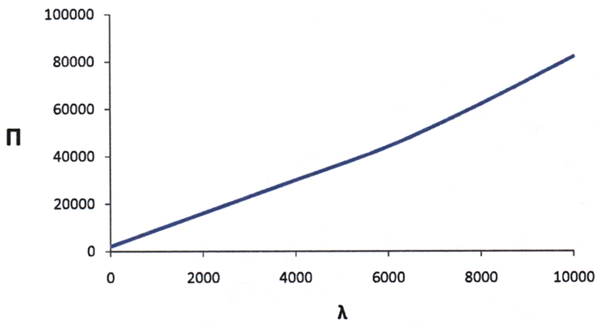

TABLE VI

SHADOW PRICES FOR DIFFERENT VALUES OF λ

λ	0	2000	4000	6000	8000	10000
Value of an additional employee	7000	7000	7000	8000	10000	10000
Value per hour of the current overtime cap	57.14	57.14	57.14	57.14	106.25	106.25
Value per hour of doubling the overtime cap	28.13	28.13	19.23	30.77	28.13	28.13
Value of an additional travel	50	50	50	50	50	50

Although this simple model is just here to prove the concept, we see that these results are relevant. Indeed discussing with several travel agents in Switzerland, they told us that these prices were realistic. Now that we have proved the concept, we intend to develop more sophisticated models that better represent a true application of a travel agency.

VI. CONCLUSION

The production of knowledge based services relies more and more on human expertise and know how. It thus become crucial to develop pricing models that also take into account the perceived value of the service by the client. In this paper we propose an original pricing scheme grounded on the notion of shadow pricing. The concept consists in modelling simultaneously the production and the demand sides through an optimization model. As these services are intangible by nature equations of the model reflect behavioural patterns of human production and elements of perception regarding benefits offered by the service. The shadow prices associated with the solution of the optimization model provides a proxy for the price of the expertise delivered.

To prove the validity of the concept, we have developed a simple model for the travel agency. We obtain from this model prices qualifying the expertise of travel agents, as well as intangible values of acquiring new customers. In a future research we intend to develop more realistic models. It means that we need to conduct thorough survey analyses to feed the model with accurate data. Moreover the new models due to their inherent complexity and size, will require the development of appropriate heuristics and algorithms. Finally, we also would like to include stochastic variables in the model to better tackle the typical randomness issue associated with service production (see [12], [13]).

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