A Priori Forecasting of FTTH uptake

Connecting Segmentation Forecasting to Timing Forecasting

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Abstract—**In the launch of every new product or technology, it is very important to get a good estimate of the reachable market and get an idea of who would be likely to adopt both in the short term as well as in the long term. This is especially the case in a FTTH rollout which involves tremendous investments and can only be justified if the network is sustainable and has sufficient uptake. This paper presents a combined methodology of quantitative survey and additional statistical analysis that can be used to segment and predict this uptake. It introduces the PSAP methodology as a means to categorize respondents based on their adoption potential and shows how cumulative Bass and Gompertz adoption curves can be fitted to survey adoption timing estimation data. The combined methodology is applied to a survey on FTTH in Flanders that shows that indeed clearly distinct curves can be fitted for the different adoption segments and that this approach can be used in the future to assess the uptake of new technology both for the short as well as the long term.**

Keywords:FTTH, forecasting, adoption diffusion, segmentation, techno-economic analysis

I. Introduction

As applications grow increasingly visual, connected and responsive, they demand for an ever higher bandwidth network. Especially the so called access network is the main bottleneck. An operator can gradually upgrade his existing network to keep pace with this trend. The operator, or any other interested party (e.g. community) can also choose to deploy a fully new underground infrastructure consisting of fiber, a network which has much better specifications to transport data both in bandwidth as in distance. In this paper we focus on such a fiber to the home network rollout. The installation of a Fiber to the Home network would open up higher bandwidth network connectivity to the customer than is currently available and would allow even much higher bandwidths to come available to the customer at a later stage.

Still the customers are not guaranteed to take to this new technology as some skepticism and fear might exist, some customers are not interested in higher bandwidth, prices might not be the same, etc. Customers will only gradually move to this new technology, which is well known in techno-economic modeling as customer adoption.

Rolling out a fiber network involves tremendous costs and as such it is of crucial importance to have a good idea of the chances of the sustainability of the network. In order to get an idea of this, detailed techno-economic analysis or differently put a very detailed business case will be required. There exist a broad realm of literature on the economics of FTTH networks [1], [2] and [3], and the costs of most of the studies are all in the same line and only impact the costs per customer with 10-20%. Additionally the rollout of a buried FTTH network requires all potential customers to be connected, or at least to have a dedicated fiber passing this house. Given the costs, the sustainability of the business case will be highly depending on the uptake of the new network.

This paper gives an overview of the methodology for estimating a priori the adoption of FTTH in Flanders based on a survey and additional statistical analysis. Section II will describe the survey that was made up to get the input data from Flemish potential customers in more detail. Section III shows how the data of this survey is used to determine to which of five segments, from innovator to laggard, the customer belongs. The section will explain how this product specific adoption potential (PSAP) is taken into the survey and translated into the customer segmentation. Section IV explains how an adoption timing estimation assessment is added as well to the survey and will be used to forecast the timing of adoption for different people and for the different segments. In section V both are combined into a statistical fitting to the existing adoption models of Gompertz and Bass. The section contains both the statistics as the resulting adoption curve which can be used in techno-economic modeling. This last step is also taken to Section VI which will conclude the paper and which will also indicate where the results of this paper will be used in the techno-economic model and demonstrate the importance of good a priori estimation in techno-economic research.

II. Survey on FTTH

The empirical data presented in the paper were collected by means of an offline quantitative survey. The questionnaire that was used was partially based on a preliminary research with (technical) experts. The assessment of the market demand for FTTH has been limited to the case of Flanders, (Belgium), which has a population of approximately 7 million inhabitants.

Striving for representativeness, it was necessary to reach a considerable amount of respondents of both those who have access to the internet at home (the online population) and those who don't. Therefore, an offline survey method was chosen, using a quota sample approach to obtain a representative sample. Eventually, 786 respondents completed the survey. By comparing the sample with official statistics of the Flemish Government [4], the sample can be considered to be sufficiently representative for the total population of Flanders, as depicted in table 1. The topics addressed in the questionnaire were internet access, internet usage and interest in FTTH and its applications. The two main topics that are addressed in this paper are the adoption potential estimation and expected timing of adoption of FTTH. It is important to note that the broadband penetration is relatively high in this area (estimated at roughly 75%) since this can affect the adoption potential of FTTH.

Table 1: Comparison of survey gender and age distribution to the Flemish population

		% in the survey	% SVR
Gender	Men	51%	49%
	Women	49%	51%
Age	<19y	13%	22%
	20-29y	17%	12%
	30-39y	16%	13%
	40-49y	16%	15%
	50-59y	15%	14%
	60-64y	7%	6%
	>65	15%	18%

III. PRODUCT SPECIFIC ADOPTION POTENTIAL

The adoption potential assessment in the FTTH survey for Flanders was performed by means of the Product Specific Adoption Potential scale [5-7]. The Product Specific Adoption Potential scale (PSAP) was developed as a valid alternative to traditional single-intent questions used in traditional market research, which systematically lead to over- or underestimation of the adoption potential of innovations. The model has been validated for several innovations [7, 8]. Instead of a single intent question asking for the adoption likelihood of an innovation, three questions are asked. The adoption intention is measured for both optimal and suboptimal product offerings. A calibration heuristic based on the answers on all 3 intention questions assigns the respondent to the appropriate adoption segment [5]. First, the respondents received an introduction about the FTTH and its features by means of the following short introductory text:

Technological developments have resulted in a high-speed internet connection based on fiber optic technology. A fiber optic network makes it possible to develop new applications that require more bandwidth and it allows more service providers. In some European countries the deployment of such fiber network is being accomplished. In the city of Amsterdam e.g., fiber is offered at a price of € 60 a month. It is expected that in the near future these superfast internet connections will also be available in Belgium.

Consequently, the first intention question was asked (PSAP question 1): "To what extent are you interested in adopting an FTTH connection?" The answering scale provided 5 possible answers ranging from "totally not interested" to "very interested".

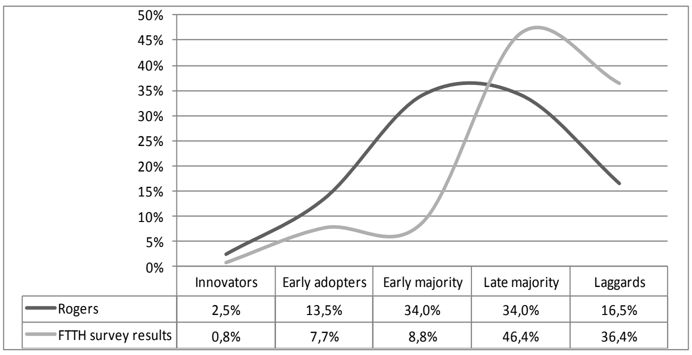
After this first question, a second, more specific intention question was asked (PSAP question 2). This time, a realistic price of €50 per month for a superfast internet connection, was linked to the offer. The respondents were again given five answering possibilities:

- I would definitely not respond to the offer
- Chances are low that I would respond to the offer
- I'd rather wait a little, maybe later
- Chances are high that I would respond to the offer
- I would immediately respond to the offer

Finally, a third intention question was asked (PSAP question 3). This time, the adoption intention for the innovation at a price €70 per month for an FTTH connection was measured on the same five point scale as in PSAP question 2. The idea behind assessing the adoption intention for a price that is higher than what the price on the market would be, is to check how strong the adoption intention remains at higher prices.

Based on a calibration heuristic, checking for the consistency in intention statements over the different answers on the 3 PSAP questions, each of the respondents got assigned to one of the adopter segments: innovators, early adopters, early majority, late majority and laggards. These segments, originally described by Rogers [9], can be considered to follow upon each other chronologically during the diffusion of an innovation in a social context. Innovators will typically adopt the innovation first, followed by the other segments until ultimately laggards, being the least innovative segment, adopt. According to Rogers [9], this spread follows a normally distributed curve in which 2.5% innovators, 13.5% early adopters, 34% early majority, 34% late majority and 16% laggards can be distinguished. Figure 1 compares this theoretical distribution with the results from our survey for FTTH based on the outcomes of the PSAP methodology.

Figure 1: PSAP Customer segmentation outcome



If the results of the PSAP survey are compared with the theoretical distribution, it can be assumed that there is a rather limited adoption potential for superfast broadband internet in the short term. Whereas theoretically we expected a 2.5% innovators segment size, the innovator segment only accounts for 0.8% of the FTTH market according to our results. We also witness significantly less early adopters than expected (7.7% compared to 13.5%) The same is even more apparent for the early majority segment (8.8% compared to a theoretical 34%). In general, 16% of the market is often considered the bridge to the mass market (i.e. the combination of the early and late majority segments). Especially the later majority and the laggard segments are considerably larger than theoretically assumed, which suggests a limited market potential in the short run, but might imply a larger potential in the longer run. Further analysis of the characteristics of the segments suggests that today, subscribing to FTTH is only considered by a niche audience ('broadband freaks'), which needs more speed and bandwidth for specific purposes (gaming, downloading, etc.). We assume these people have a higher willingness to pay for broadband than other segments. Consequently, they are willing to pay a premium price on top of their existing Internet subscription fee to enjoy the benefits provided by FTTH. Other parts of the market currently seem not attracted to these benefits (as they do not need higher data speed or more bandwidth) and have no arguments to pay more.

An important question that poses itself here is over which period of time these segments will be likely to adopt FTTH. Therefore, an assessment of estimated adoption timing was performed in the survey as well.

IV. Adoption Timing Assessment

Asking people when they intent to buy a product is not as easy as asking a simple question. When making such estimation, various factors related to the actual purchase and the product characteristics are made. The longer the gap between the intention and the behaviour, the more likely it becomes that unexpected situations lead to changes in the actual behaviour [10, 11]. Warshaw and Davis [12, 13] proposed the use of behavioural expectations (BE) in this matter. They define BE as a construct that allows to capture some of the factors that can cause a change in the intention of an individual to perform a certain behaviour over time. It is a measure of the probability that someone may perform certain behaviour. According to Venkatesh et al. [14] a behavioural expectation incorporates anticipated changes in the expected behaviour.

Table 2: Estimating the adoption timing from questionnaire

I estimate the chances of me buying a super fast internet connection …	**0%**	**20%**	**40%**	**60%**	**80%**	**100%**
within 1 month	x					
within half a year		x				
within 1 year			x			
within 1,5 year				x		
within 2 years					x	
within 3 years						x
within 5 years						x

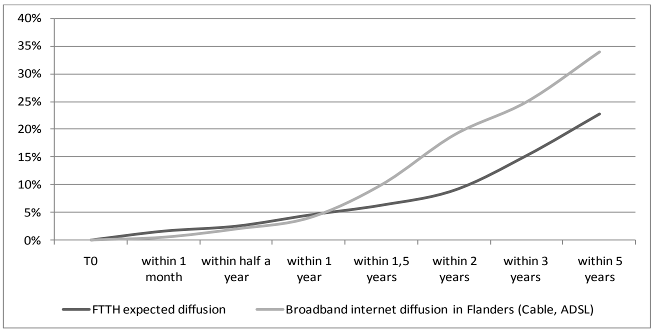
Research on the expected timing of an intention is scarce. Recent research that attempted to use behavioural expectations to predict adoption of new technology products is the cumulative timed intent approach [15]. The aim of this research was to develop and validate a response scale that allows predicting whether and when the adoption of a new technology product will take place in the future. The response scale is an attempt to be product specific, which means that the time horizon used in the scales (number of months or years) is based on the diffusion of analogue products. The respondents don't have to choose one of the given time intervals in which they intend to adopt. Instead, for each of the given intervals they are asked to give their probability of adoption, as depicted in table 2. We integrated this means of estimating adoption timing in our questionnaire.

The respondents were asked to provide us with an estimated chance of adoption of FTTH for each given time period (at a price of €60 per month). A necessary condition for correct answers on the question is that the respondent answers in cumulative way. This means that the chance for adoption in a given time period can't be lower than the chance in the preceding period. E.g. if a respondent estimates that there is a 20% chance that he/she will adopt a fiber internet connection within half a year, the chance of adoption in the next period (within 1 year) has to be 20% or higher. Although the question seems hard to answer for a respondent, only 22 out of 786 respondents did not complete it. The data of every respondent was checked for a correct answering pattern and missing data. Few adjustments had to be made to the data, apart from imputation of some missing data.

For the analysis of the data, a moment of adoption was determined for every respondent. This was done by selecting the period at which the respondent stated to be 100% sure of adoption. Figure 2 illustrates the results of this assessment.

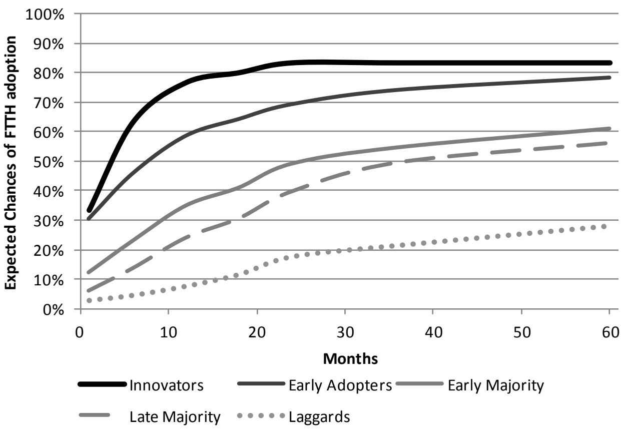
Based on the expectations of the respondents, FTTH should reach 20% penetration five years after its launch. To check whether the estimation was realistic one, a comparison was made with the diffusion of broadband internet (cable, ADSL) in Flanders. From figure 2 it is clear that our estimation for FTTH follows the diffusion of broadband in Flanders rather closely in the short term. After two years, the curves start to diverge. Our estimation expects a somewhat slower uptake of FTTH than the diffusion of broadband internet.

Figure 2: Customer expected adoption rate FTTH vs. broadband diffusion in Flanders



Consequently, the results of both the PSAP methodology and cumulative timing question were combined. This allows us to get an estimation of the speed of adoption within the five adopter segments. The results confirm a sound match between the two methods. Figure 3 illustrates the rapid expected uptake of innovators in the first year after market introduction. Early adopters have a somewhat slower expected adoption rate. Early majority, late majority and laggards expect to start their adoption to take off significantly later than innovators and early adopters do (approximately two years after market launch).

Figure 3: Customer expected adoption rate split per segment according to the PSAP segmentation



While self-reported expectations formulated in quantitative surveys are believed to be good predictors of behaviour in the short term, they are far less applicable for predicting behaviour in the long term. The cumulative timing assessment can however be used as a valuable data source for econometric modeling and forecasting over long term time frames.

V. FITTING TO EXISTING ADOPTION MODELS

In any techno economic evaluation of a new technology or a new product, any investor will want to have an estimation of the customers they could expect. Clearly the lack of existing products on the marketplace will require basing the estimations on a priori knowledge as shown before. As such a good estimation should be based on both the outcome of the PSAP as well as the cumulative timing.

The outcome of the estimation should not be solely based on the segmentation outcome as this will give no idea of the possibility that they will really adopt the technology and when each segment would do so.

Basing the outcome solely on the timing information increases the risk of overestimation of the adoption as most probably not all segments (e.g. late adopters) will be inclined to move to the technology and should be left out of the estimation when estimating the economics of a new launch.

In techno-economic research, the estimation of the customer base growth of a function of time is called customer adoption and there exist several models in literature which try to closely represent the actual perceived growth of new technology adoption. In this paper we used the most well known two adoption models – Bass and Gompertz – and made a least squares fit of the cumulative timing values for the different PSAP segments to both curves. In extension we compared the outcomes of both fits both in values – the form of the adoption curve – as well as in the statistics of the fitting – how well the adoption model resembles the data.

A. The Gompertz and Bass adoption model

Two commonly used models for adoption prediction are the Gompertz model, named after Benjamin Gompertz and the Bass model which was developped by Frank Bass. The cumulative version of both models has a sigmoid functional form in which the market potential “m” is multiplied with a factor, monotonically increasing with time “t” and converging to unity.

The functional form of the Gompertz equation is given in equation (1). It can be parameterized by adjusting the inflection point “a” and pace “b”. The inflection point indicates the point in time at which the number of new adopters is the highest, at this point the growth starts decelerating. The pace influences how fast the function converges to the adoption potential.

Equation 1

$$S(t) = m.e^{-e^{-b(t-a)}}$$

Contrary the Gompertz curve which is a general purpose growth curve, the Bass curve has been developed specifically with the adoption of new products in mind. It is theoretically founded on the diffusion model of Rogers in that it focuses on two aspects of adoption: innovation and imitation. The impact of these aspects on adoption is captured by the parameters p and q, respectively. Both these parameters are restricted to the set of positive real numbers. The functional form can be found in equation (2).

Equation 2

$$S(t) = m.\frac{1 - e^{-(p+q)t}}{1 + (\frac{q}{p})e^{-(p+q)t}}$$

B. *Fitting the Data to the Adoption Models*

Based on the cumulative timing data collected in the survey we made an estimation of these two curves for the uptake of FTTH in Flanders. We made an aggregated estimate for the total sample and we made estimates for the different subsamples that could be divided based on the PSAP categories.

We fitted the curve using the least squares package of the Eviews econometrical software suite. Least squares is a parametric estimate in which the sum of squared residuals (vertical difference between the fitted curve and the observed values) is minimized over the parameter space. In concreto we estimated the parameters “m”, “a” and “b” of the Gompertz model and “m”, “p” and “q” of the Bass model. Table 3 summarizes the results. Figure 4 maps the fitted adoption curves on the data. The standard practice is to represent the data by a scatter plot, but since the setup of the survey limited the responses to certain values a scatter plot would not be informative enough. Overlapping dots would not visualize information on the relative importance of the different responses. This is why we opted to overlay the curves on a bubble chart in which the area of the bubble indicates the frequency of the response.

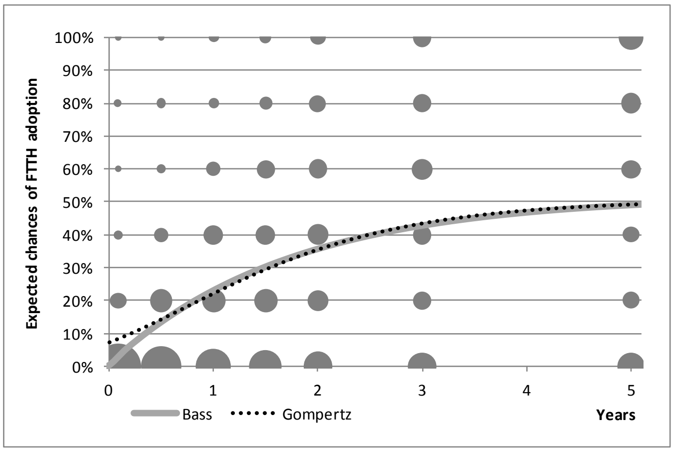
Table 3: Parameter estimations for fitting to Gompertz and Bass of the aggregated data and the different PSAP segments

	Agg	*Inn*	*E.A.*	*E.M.*	*L.M.*	*Lag*
AIC Gomp	9,7963	10,018	9,6915	9,7828	9,7760	9,0984
m	0,4995	0,8292	0,7707	0,6079	0,5780	0,2985
a	0,7888	0,0469	-0,01745	0,4859	0,9189	1,3552
b	0,8461	2,7947	1,1920	1,0067	0,9052	0,7502
AIC Bass	9,8004	10,040	9,7569	9,7932	9,7781	9,1001
m	0,5138	0,8062	0,7139	0,6010	0,6236	0,3938
p	0,5768	4,3886	2,3035	0,8727	0,4949	0,2570
q	0,000	0,0000	0,0000	0,0000	0,0000	0,0000

If we compare both curves visually we don’t perceive much difference. The only apparent difference lays in the early stages of adoption. This can be explained by the freedom the Gompertz definition leaves for shifts along the x-axis through changes in the inflection point, whereas the specification of the Bass function forces the curve through te origin whether that fits the data or not. This also explains why the q factor of the Bass fitting is 0.

With respect to goodness of fit, we can compare the Akaike Information Criterion of the different fittings. This statistic is also added to Table 3. AIC is a goodness of fit score that penalizes overfitting, i.e. the act of involuntarily modelling noise by allowing too much parameters to vary during the least squares minimization. AIC is the difference between double the number of parameters (3 in our case) and the log of the likelihood of the parameter estimates. The likelihood of a set of parameters is defined as the probability of the sample given the parameters (The probability that a sample occurs that is as least as extreme as the observed sample in terms of deviation from the conditional means). This results in a lower AIC score indicating a better goodness of fit. According to this criterion the Gompertz model outperforms the Bass model in each subsample of the survey.

Figure 4: Customer expected adoption rate (scatter) with overlay of the fitted curves of Gompertz and Bass on the aggregated data



C. *Results based on PSAP score*

Figure 5 shows the results for the complete sample using the Gompertz curve (best fit). Additionally the standard deviation is shown on the figure. The values for these are: m = 0,0143 – a = 0,05505 – b = 0,06825. Figure 6 and Figure 7 show the fitted curves for the different subsamples under the Gompertz and Bass specifications respectively. On first sight we see a clear distinction between the different adoption categories.

Figure 5: Customer expected adoption rate fitted to the Gompertz adoption curve with standard deviation

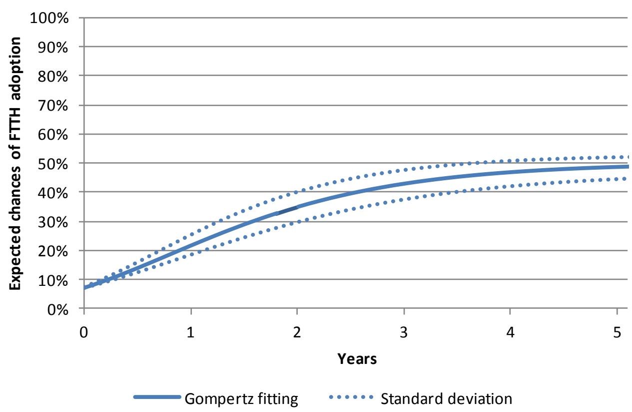


Figure 6: Customer expected adoption rate fitted to the Gompertz adoption curve per PSAP segment

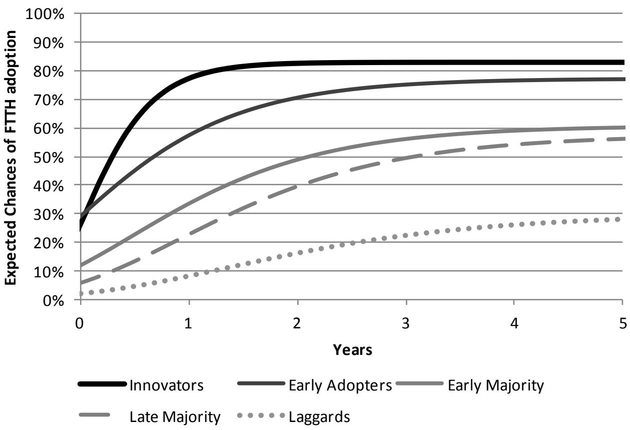
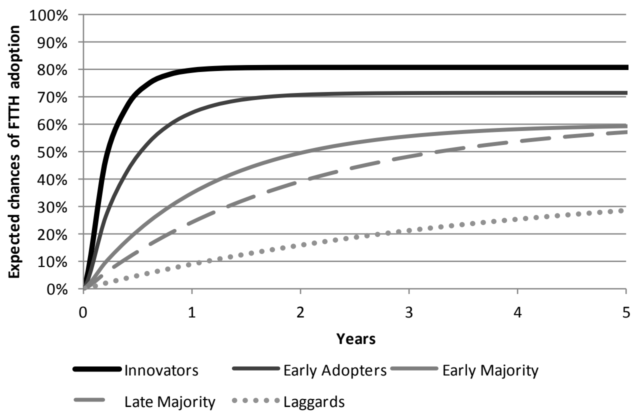


Figure 7: Customer expected adoption rate fitted to the Bass adoption curve per PSAP segment



The perceived differences between the groups apply to the different aspects of adoption; both the adoption potential as well as the slope of the curves clearly differs between the various categories. This is confirmed by the numbers that can be found in Table 3. There is apparent inter group variation for the parameters m, a, b and p. For the resulting imitation parameter of the Bass model we already introduced the extreme fitting behaviour which fixed this parameter on zero. On first sight these results indicate that the PSAP scores, which are calculated completely independently from the cumulative timing scores, succeed in grouping people in distinct categories.

On the other hand one would suspect that the difference in adoption potential between the different groups would not be as distinct as appears in this analysis. The adoption potential of the laggards is less than half that of the innovators. We would rather expect that the differences manifest themselves more on the timing of adoption, rather than the potential. Acknowledging that it is extremely difficult to explain human behaviour we note that this might result from the possibility that the respondents of the survey underestimated the impact network effects and imitative behaviour resulting from technological adoption by their peers.

VI. IMPORTANCE FOR TECHNO-ECONOMIC MODELS

Adoption is an important part of any techno-economic model and any changes in this could have a large impact on the outcome of the business case estimation. An underestimation could well lead to a potentially positive business case not being pursued; an overestimation could lead to a financial disaster when the real customer take-up does not follow the expected adoption. We have developed a toolkit for easily and intuitively building a detailed techno-economic analysis using generic and logical modeling syntax. This allows quickly making up and calculating a reliable business case for a new network rollout. The description in [16] contains a more thorough description of the building blocks used from this toolkit to build up a cost model for a generic FTTH network rollout. Combining the generic model from [16] with an adoption and revenue model, we have a full business case for such an FTTH network. Regardless of the technology and implementation of the network, a change in the inputs could have a big impact on the outcome of the calculations.

Figure 8: Cost per customer per year for a Pt2Pt rollout of a FTTH network

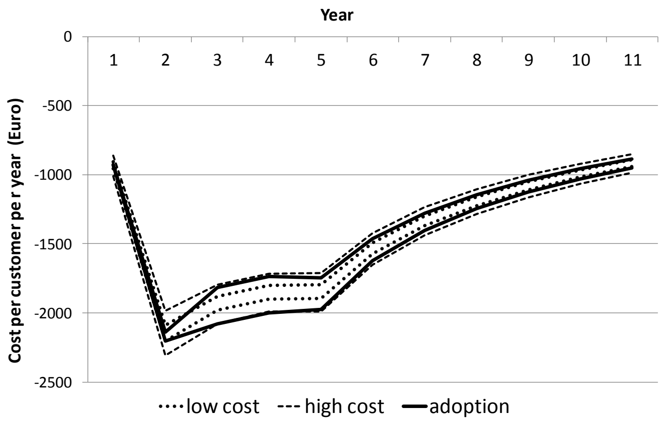
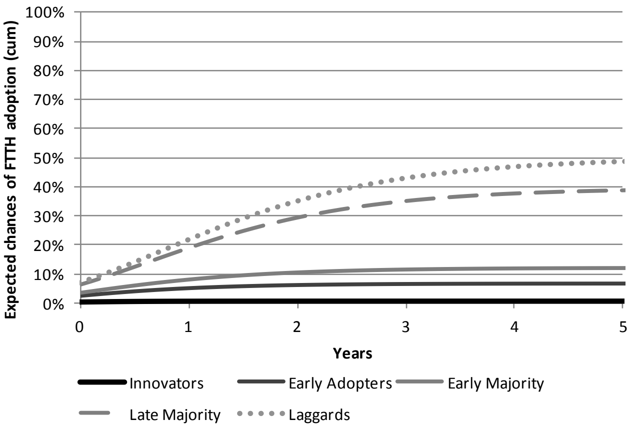


Figure 8 shows the impact of unknown cost figures in which a 3% (low) and 8% (high) change is possible in the different cost components. In the same manner as taking the uncertainty of costs into account, we can also base the uncertainty of the adoption on the standard deviation of our fitting. Clearly an increasing adoption will decrease the cost per customer and at the same time increase the costs of installation and operations. The outcome of the business case has prohibitive costs for the considered adoption with a market potential of 50%. An adoption reaching to 100% would give half the costs per customer and a possibly sustainable business case.

Even when the costs can be significantly reduced, e.g. by means of a multipoint technology, it is essential that the business case takes into account that adoption might stop at a given segment – typically laggards or late adopters which is in line with a chasm in the adoption. This would lead to the adoption to top at much less than the full market potential as shown in Figure 9. If the latter segments of customers would be not be adopting the technology after all, this would ruin the business case shown before, regardless the cost reduction, a risk that should be considered in detail and for which segmentation and timing information is essential.

Figure 9: Customer adoption as fitted to the Gompertz curve cumulative for the consecutive adoption segments



Clearly the impact of the adoption of an FTTH network will be very important for the business case and a reliable forecasting is critical in this. We've shown how a survey using the product specific adoption potential (PSAP) methodology can be used to segment the potential customer base and how the cumulative timing assessment gives vital information on the timing of the customer's adoption. In extension the paper combined both methods into a fitting to the existing adoption models of Gompertz and Bass. The adoption curves found show a good fit with the data. The fitting also gives indications on the standard deviation of the input for these models. A comparison of Gompertz to Bass also clearly shows that Gompertz was easier to use out of the box and gave a better fit than the Bass function. The results of the fitted curves will be used in TE-studies for the city of Ghent in the scope of the TERRAIN project, in which both sensitivity and real options extensions will be used in the analysis.

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