The pre-adoption process of a new technology: a percolation study of artificial skin for medical diabetes treatment.

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September 4 - 8, 2016
Waikiki Beach Marriott Resort & Spa
Honolulu, Hawaii, USA

Abstract

Current economic models are likely to analyse the market scenario form the moment when the new product (or the new technology) is entering it. This study aim is to report that there are rooms for improvements dealing with market variables in the pre-market phase.

Through the study of one of the most revolutionary technology under development of these years, applied to one of the most common medical issues of the actual society, using a very recent diffusion model, this study aims at pointing out the relevance of further researches in this direction. The artificial skin technology, applied to the diabetes case is thus analysed in the light of the percolation model.

A specific individual adoption function has been identified. It has been consequently used for the modelling of the collective percolated behaviour and for the definition of ex-ante marketing technics tailored to the specific market.

Acknowledgment

The authors would like to thank Dr. Sarial Abi Zehra Gulen from Bocconi University, Univ.Prof. Dr. Thomas Reutterer and Univ. Prof. Dr. Martin Schreier from Wirtschaftsuniversitat and Prof. Marco Valente from Università dell'Aquila. Also a thank to Mag. Pharm. Corinna Nagelreiter, from the University of Vienna, faculty of life sciences – department of Pharmaceutical Technology and Biopharmaceutics for her precious help. A special thank to the community of diabetic people (especially the association Diabete Zero) which allowed this study execution.

The authors would like to thank the Hi-Tech Center in Vienna, Austria. The Hi-Tech Center is a multi-national, multi-regional industry-university partnership. It is funded by the European Union's fund for regional development and by various local government agencies.

Agenda

1. The Artificial Skin Technology and the Diabetes in Italy
2. Percolation
3. Individual Utility function
4. The percolation applied to the SIG
5. Lessons learnt
6. Suggestions for work extension
7. References
8. About the Authors
9. Appendix

The Artificial Skin Technology and the Diabetes in Italy *(Nature Nanotechnology 9, 397–404; 2014)*

THE ARTIFICIAL SKIN

Sticky patch sized 4 cm x 2 cm x 0,3 mm, composed of:

- sensors to detect temperature and motion; RAM for data storage; Local battery → with the function of monitoring
- Micro-heaters and drugs → to treat the health condition after the diagnosis

DIABETES IN ITALY

- **Massive case**: 5,4 % of the population is affected by diabetes.
- **Medicine is proven to help**: Prompt diagnosis and constant monitoring reduces by 10-25% minor complications and 10-55% the major ones.
- **Economic relevance**: A diabetic spends 2600 Euro per year on health, with an impact of 5,6% on National Healthcare expense and 0,29% on GNP.

The Pre-market phase

From the work by Falcone, M. (2015), the starting point of the modelling through percolation is the patient's behaviour. It is then important to study which individual features could explain the final adoption:

The diabetes is an individual pathology: each patient is affected in a different way

↓

Each patient needs a personalized diagnosis and individual treatment

↓

The treatment has to be carried out constantly and very precisely

↓

Technologies are developing to simplify the treatment of the disease (insulin pumps, pens…)

↓

ARTIFICIAL SKIN FOR MEDICAL DIABETES TREATMENT

PERCOLATION

In physics: movements of fluids through a porous material. Applied to the economic context: «***a diffusive process of deterministic movements through a random medium***» *(BROADBENT, Simon R. et al, 1957)*

2 important elements characterize a percolation regime:

Considering a two-dimensional lattice made of infinite number of nodes.

- PROPAGATION THROUGH MEDIUM*: the network structure presenting randomly allocated open nodes*

- SPREAD DYNAMICS: the probability *p* defines the numbers of nodes which can connect (deterministic movements)

Why percolation could apply?
(Solomon, S. et al, 2000 & GOLDENBERG, J. et al, 2000)

1. HETEROGENEITY ISSUE: Each agent has a certain p(i) indicating the quality expectation. Patients will adopt only if the perceived utility of adoption is higher than that threshold.
2. INDIVIDUAL ISSUE: Individual models acknowledge differences between consumers (in utility and their effect on adoption). Each decision is stochastically independent. With percolation is possible to examine the effect of changes in the parameters at the individual level on the aggregate level (interaction).
3. LOCAL NETWORK: The technology which takes off is the one positioned in a high density cluster. Depending on the type of network and thus on the interactions which happen, the behaviour changes.
4. THRESHOLD: The percolation transition implies that even if the probability distribution of the p(i) across the lattice is totally uniform, one ends up with localized clusters and sub-clusters of all scales including macroscopic inhomogeneity leading to macroscopic sales rate fluctuations.

Research Questions

1. HOW DOES THE INFORMATION AND COMMUNICATION BEHAVIOUR DEVELOP WITHIN THE DIABETES SPECIAL INTEREST GROUP (SIG*)?

2. IS IT POSSIBLE TO DESCRIBE IT THROUGH A PERCOLATION MODEL?

** There exist several diabetic communities, i.e. the Special Interest Group (SIG):*
When, among a larger organization, is possible to identify a community sharing some unified traits, this is defined as a Special Interest Group (DELRE, S.A., Jaeger, W., and Janssen, M.A, 2007)

Study Settings

1. The patch can be easily applied
2. The patient doesn't have to monitor him/herself anymore
3. The patch is removable
4. The patch is rechargeable
5. Memory inside the patch keeps on tracking the health status
6. Integration of the battery with further research

The Individual Utility Function (U_i)

To supply the need for treatment, the new technology should own some characteristics which are able to maximize the individual adoption utility: if this happens, is reasonable to think that a patient would adopt the new medical solution.

What is this individual utility (U_i) made of? *(DELRE, Sebastiano A., et al, 2010)*

β_i = Market under consideration

$$U_i = \beta_i x_i + (1 - \beta_i) y_i$$

x_i = INDIVIDUAL PREFERENCE

y_i = SOCIAL INFLUENCE

INDIVIDUAL PREFERENCE

- Perceived Usefulness (PU): the identified level of help that the patient get when using this specific technology (in the living with the illness)
- Perceived Ease of Usage (PEoU): personal judgment about the easiness of usage of the device during normal daily activities

TAM *(DAVIS, Fred D., 1989)*

SOCIAL INFLUENCE

- Trust toward the source of information (T)
- Reliability of the information (R)
- Education (E)
- Status (S)

Sample

Respondents	194*
Age	12 - 82
Nationality	Italian (94%)
Education	Heterogeneous
Diabetics	80%*
Years of disease	17,44 (avg.)

The data were collected through Qualtrics, pushed by social networks and emails addressed to the diabetic communities and various organizations. The process lasted for 2 months (see the appendix: 1. The survey).

**The sample size was determined considering data dimension big enough to give (statistically) significant results for the type of analysis carried out (see appendix: 2. The model). The accuracy and the richness of the results can be improved in further researches.*

Sample

Respondents	194
Age	12 - 82
Nationality	Italian (94%)
Education	Heterogeneous
Diabetics	80%*
Years of disease	17,44 (avg.)

In the research carried out, the "social environment", namely the SIG has been reproduced through the consideration not only of diabetic people, but also relatives, doctors, people working with this disease and people in contact with patients, representing the remaining 20% of the sample.

**The exact percentage was not fixed initially. It came out of the data collection and has been considered big enough to "influence" the diabetic community.*

INDIVIDUAL UTILITY OF ADOPTION

$$U_i = \mathbf{3,054} + \beta_i(\mathbf{0,433} * \boldsymbol{PU} + \mathbf{0,130} * \boldsymbol{PEoU}) + (1 - \beta_i)(\mathbf{0,113} * \boldsymbol{E} - \mathbf{0,237} * \boldsymbol{T} + \mathbf{0,094} * \boldsymbol{conTRUST})$$

INDIVIDUAL PREFERENCE — SOCIAL INFLUENCE

Directly from the empirical analysis: the utility of adoption is a weighted function of Individual preference and Social Influence. The coefficients have been determined using the **individual responses** collected through the survey. These numbers are then going to be used for the percolation simulation.
This means that the percolation analysis rests on the individuality of each respondent (each member of the SIG community) plus a social component.

** The 'individual characteristics' are the attitudes, preferences and so on of each respondent. These characteristics have been recorded through the empirical study. Then they have been elaborated to define the coefficient of the variable 'individual preference'. (HOHNISCH, M., 2010)*

INDIVIDUAL PREFERENCE (IP):

$$U_i = \beta_0 + \beta_i(\mathbf{0,433} * \boldsymbol{PU} + \mathbf{0,130} * \boldsymbol{PEoU}) \text{ + social influence}$$

IP components:
- Perceived Usefulness (**PU**): The higher the evaluation of usefulness of the artificial skin, the higher the utility to adopt.
- Perceived Ease of Usage (**PEoU**): Positive impact - one point more in the evaluation scale of PEoU lets the final utility value increase by 0,130.

The obtained model showed: R Square = 0,578 and Adjusted R Square = 0, 567 (see appendix: 2. The Model)

SOCIAL INFLUENCE (SI)

$U_i = \beta_0 + \text{ind. pref.} + \beta_i(1-\beta_i)(\mathbf{0,113} * \boldsymbol{E} - \mathbf{0,237} * \boldsymbol{T} + \mathbf{0,094} * \boldsymbol{conTRUST})$

SI components:

- Education (**E**): More educated people are more inclined to have higher adoption utility, thinking about the artificial skin as presented.
- Trust toward the source of information (**T**): The source of information matters, but in a negative way. The more people are informed about the disease and how to treat their pathology, the less they want to rely on the so-called "authority" because they can search for and understand what is better for themselves.
- New variable acquires (positive) statistical importance: **conTrust.** Patients' decision to adopt is positively influenced when the trust toward the source of information (in this case the doctor, as an expert) is also combined with a higher perception of control of the disease through the new technology.

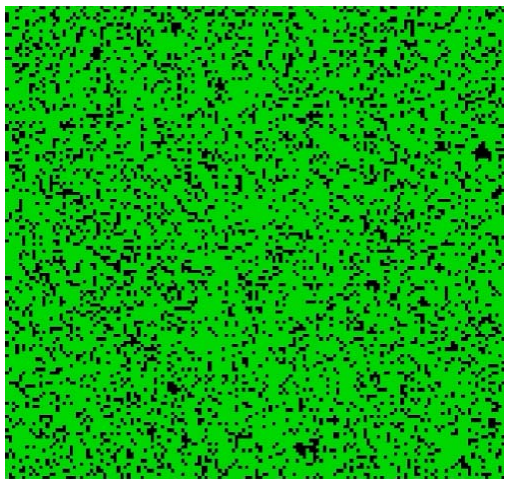
Results: the SIG percolates!

*The special interest group of diabetic community, with respect to the artificial skin technology as it was presented would decide to generally adopt the technology so to allow the spread of the device through the majority of the population considered.**

*P value of the studied SIG: **0,8061**
Based on the replication of the model of Solomon at al. (2000), against a percolation threshold of p= 0,59

Graphically…

This is the **graphical software result**: **each green dot** represent a member of the community (the SIG) for whom the simulated individual adoption utility (derived from the survey response) resulted higher than the percolation threshold (computed by the software, based on the information derived from the empirical part of the study). The **black dots** are members for whom the utility of adoption is lower than the threshold. Since there are enough green dots to link the 4 sides of the squares, the result is a percolation.



To sum up

The utility of adoption is a **weighted function of individual preference and social influence**.	The decision making process is an individual decision. However, is **socially transmitted**. *(HOHNISCH, M., 2006)* → **Social hubs** (people suffering from diabetes since more than 10 years).
Non-anonymity effect: When people interact with each other, trust is created and the type of interaction is not the same as with people we don't know. (*COWAN, R. 2005)*	The **most relevant** variable is the **PU** among the Individual preference and the **conTRUST** in the Social Influence.

How to approach this market before entering it

- Lead Users prefer a direct communication:
  → Is fundamental to explain the exact technical features and ensure a full understanding of how efficient is the innovation for the control of the diabetes symptoms and consequences.
- The choice of the more educated people (among the special interest group) would ensure a faster spreading of the technology.
- The whole process of adoption speeds up when the neighbour is used to inform about the new technology.

Possible study extension

- Increase samples size
- Simulations through a scale-free network and comparison of results using different simulation techniques
- Test the speed of percolation
- Test the percolation process among different sub-clusters
- Implementation of market tests
- Knowledge about the percolation dynamics might be used to dynamically optimize their marketing effort, by targeting the diffusion front at any given time, to ensure actual percolation.

Conclusions

- The **market entry** is the condition sine qua non the market success is not realizable. Thus, this work stresses the importance of an analysis toward this direction.
- The percolation is able to account for individual characteristics in an aggregate result.
- The individual utility of adoption also depends on the social environment. Thus, **social percolation** seems to represent the best modelling.

Thank you for the attention.

Now… Q&A

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Sitography

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Appendix

1. The Survey

0 Welcome! I really appreciate your participation in this survey that will help my research about a very interesting topic for my master thesis. I am looking forward to know what are your impressions about it! (Please consider that once you move to the next page, is not possible to modify your previous answers)

1 The following questions will assess your general behaviour. Imagine to receive an information about something new (a new product in the market, a new shop etc…) happening in your city.

Q1 Considering only the informer (who/which gives you the news) to what extend would you believe in the news? Please rate the following from 1 (I don't trust this person/tool at all) to 5 (I totally trust this person/tool).

_____ I do trust my doctor (1)

_____ I do trust internet/articles (2)

_____ I do trust people I don't know assuming is true that they already experienced the newness (3)

_____ I do trust people I know assuming is true that they already experienced the newness (4)

Q2 Considering now only the content of the information (what is told to you) to what extend would you think the news is reliable? Please rate the following from 1 (I do somehow hesitate) to 5 (I do not hesitate at all).

_____ Do you think an information given by your doctor is reliable? (1)

_____ Do you think an information found on the internet is reliable? (2)

_____ Do you think an information given by your friend/relative is reliable? (3)

2 The artificial skin

4 The artificial skin is a sticky patch containing a device roughly 4 cm long, 2 cm wide and 0.3 mm thick. It is the first device able to combine patient treatment and monitoring, since it is able to store information and deliver medicine directly and in an autonomous way into the patients' body, according to their needs. It is made of sensors to detect temperature and motion, a RAM for data storage, microheaters and drugs. The problem is that scientists are still hardly working on how to integrate a power supply and data trasmitter into the artificial skin to made them as flexible as the human skin is. One day, such a technology would help patients with very dangerous diagnoses such as Parkinson's disease or epilepsy.

6 For now, it is possible to think about applying this technology to diabetes, in order to let the artificial skin controlling the level of blood sugar into the patients' body. This would imply for the patient that: the second skin would be applied (like a normal sticking plaster) on the upper-inner part of the arm, to be less exposed to collision and to not limit the person's actions. the patient is not required anymore to monitor the body conditions by him/herself. In case of contact with water (e.g. shower) the artificial skin can be removed and then placed again by the user itself. and regarding the device per se: the actuator has to be "recharged/substituted" each 30 days to carry the medicine --> this means that the patient has to go to the doctor or to a pharmacy every 30 days. the memory remains the same and improve month by month (knowing the user more and more). the battery can be integrated with further researches so is possible to assume is integrated.

8 From the Journal Nature Nanotechnology, March 30th, 2014.

Q3 Imagine the artificial skin is available on the market and imagine your doctor is informing you (face to face appointment) about this new way of diabetes control, what would you do? Please select as many answers as you want.

Buy it (1)

Not buy at all because the information is not reliable (2)

Not buy for the moment because I need to know more but I wait (3)

Not buy for the moment because I need to know more, and so I will make some research on the web (4)

Not buy for the moment because I need to know more, and so I will ask if someone else knows (5)

Not buy for the moment because I need to know more, and so I will ask to a friend/relative what he/she thinks about it (6)

Look for people already using it because I am really interested in it (7)

Just consider it as a possibility for the future (8)

Q4 Imagine the artificial skin is available on the market and imagine you read on the internet an article presenting this new way of diabetes control, what would you do? Please select as many answers as you want.

Buy it (1)

Not buy at all because the information is not reliable (2)

Not buy for the moment because I need to know more but I wait (3)

Not buy for the moment because I need to know more, and so I will ask to my doctor (4)

Not buy for the moment because I need to know more, and so I will ask if someone else knows (5)

Not buy for the moment because I need to know more, and so I will ask to a friend/relative what he/she thinks about it (6)

Look for people already using it because I am really interested in it (7)

Just consider it as a possibility for the future (8)

Q5 Imagine the artificial skin is available on the market and imagine your friend/relative informs you (face to face) about this new way of diabetes control, what would you do? Please select as many answers as you want.

Buy it (1)

Not buy at all because the information is not reliable (2)

Not buy for the moment because I need to know more but I wait (3)

Not buy for the moment because I need to know more, and so I will make some research on the web (4)

Not buy for the moment because I need to know more, and so I will ask if someone else knows (5)

Not buy for the moment because I need to know more, and so I will ask to my doctor (6)

Look for people already using it because I am really interested in it (7)

Just consider it as a possibility for the future (8)

Q6 To what extent would you agree with these statements? Please rate each the followings.

_____ Considering an overall evaluation, I like this technology (1)

_____ The the artificial skin will be useful for the illness control (2)

_____ The artificial skin will be helpful to relieve the pain (3)

_____ The artificial skin will help in living with the diabetes (4)

_____ The artificial skin will be difficult to use (5)

_____ Being a diabetic patient, I would use the artificial skin for diabetes treatment (6)

_____ Considering an overall evaluation, the artificial skin will improve the daily routine (7)

_____ I would worry of having this device on my body (8)

Q7 Why would you worry about having the device on your body? Please select as many answers as you wish.

worry of damaging it during daily activities (1)

worry because I don't know how to use it (2)

worry of showing it to other people during daily activities (3)

worry of feeling pain during daily activities (4)

worry because it would be in part inside my body (5)

worry because I can't control its work (6)

worry because I could have some allergic reactions (7)

No, I/people would not worry (8)

Q8 In which aspects do you think could it change the daily routine? Please rate each the followings.

_____ I will eat differently (no worries) (1)

_____ I will eat in a more controlled way (2)

_____ I will avoid the annoyance of injections by myself (3)

_____ I will feel pain (4)

_____ I would feel safe (5)

_____ I will worry about showing this device on my body (6)

_____ The battery capacity will limit my freedom (7)

_____ It will not be comfortable to wear (8)

_____ I will spend more than now in health care (9)

Q9 Do you think you would feel unsure when using it? Please select one of the following answers

Yes, I can't trust the device working properly as I trust my actual method (self-made injections or pills) (1)

Yes, I have to see what happen to other people before using it (2)

Yes, because it's something new (3)

Yes, because it's something I don't know (4)

No, I would not feel unsure (5)

Q10 How do you think people would consider you while wearing this device? Please select as many answers as you wish.

I would not show the device to other people (1)

I will be considered as always (2)

I would be considered differently (in a bad way) from what other people normally think about me (3)

I would be considered as a technological person (4)

I would be considered as cool (5)

I would be considered as a guide (lead user) for them (6)

Q11 Would you care about their opinion (please consider that 1 means I would not care at all and 5 I would care a lot)?

_____ consideration (1)

Q12 How would you consider yourself while wearing this device? Please select as many answers as you wish.

Cool (1)

Loser (2)

No differences (3)

Innovator (4)

High-tech (5)

Inspiring for other people (6)

Leader (7)

Q13 Would this previous answer influence your decision of using it (please consider that 1 means I will not be influenced at all and 5 I will be influenced a lot)?

_____ degree of influence (1)

Q14 To what extent do you agree with the following statements? Please rate each of the followings.

_____ In general, people will use the artificial skin for diabetes treatment (1)

_____ People will use the artificial skin after that I will suggest them it (2)

_____ People will use the artificial skin after that they can see me using it (3)

Q15 To what extent do you agree with the following statements? Please rate each of the followings.

_____ I could try the artificial skin for 30 days if is offered for free (1)

_____ I could try the artificial skin for 30 days if is offered for half of its price (2)

_____ I could try the artificial skin for 30 days if is offered for its normal price (3)

Q16 How much would you pay for that? Please select one answer.

The State should provide it for free because people need it (1)

I would be willing to pay a part of its price (%) (2) _____

I would pay the whole amount as is a very innovative product (3)

Q53 Are you diabetic?
Yes (1)
No (2)
Se Yes È Selezionato, Quindi passa a Since how many years are you diabetic...Se Yes È Non selezionato, Quindi passa a Gender

Q54 Since how many years are you diabetic? Please insert a number.

Q17 Gender
Male (1)
Female (2)

Q18 Age

Q19 Nationality

Q20 Level of education
Middle school (1)
High school diploma (2)
Bachelor degree (3)
Master degree (4)
Phd or higher (5)

Q21 Type of job

Q22 Lifestyle (table)

	It is not representative of me at all (1)	It represents me a bit (2)	It represents me in a part (3)	It represents me quite well (4)	It is totally representative of my self (5)
I'm friendly (1)	○	○	○	○	○
I'm ambitious (2)	○	○	○	○	○
I'm focused and efficient (3)	○	○	○	○	○
I'm relaxed (4)	○	○	○	○	○
I'm open-minded (5)	○	○	○	○	○
I'm sunny (6)	○	○	○	○	○
I want to have fun (7)	○	○	○	○	○
I'm devoted to my culture (8)	○	○	○	○	○
I'm looking for new experiences (9)	○	○	○	○	○
I like to experiment new things (10)	○	○	○	○	○
I'm trendy (11)	○	○	○	○	○
I use Internet a lot (12)	○	○	○	○	○
I'm a leader (13)	○	○	○	○	○

2. The model

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,760 a	,578	,567	,728

a. Predictors: (Constant), Interaction_trust_control, PEoU, Education, Trust_doctor, PU

ANOVA a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	136,431	5	27,286	51,550	,000 b
	Residual	99,512	188	,529		
	Total	235,943	193			

a. Dependent Variable: Evaluation_adoption
b. Predictors: (Constant), Interaction_trust_control, PEoU, Education, Trust_doctor, PU

Coefficients a

Model		Unstandardized Coefficients		Standardi-	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,054	,267		11,419	,000
	Trust_doctor	-0,237	,081	-0,220	-2,929	,004
	Education	,113	,045	,124	2,531	,012
	PU	,433	,084	,391	5,172	,000
	PEoU	,130	,053	,117	2,437	,016
	Interaction_trust_control	,094	,018	,521	5,213	,000

a. Dependent Variable: Evaluation_adoption