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The role of incentives' policies, word of mouth and "0$ marketing budget" in photovoltaic technology diffusion.

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ABSTRACT

Considering the increasing importance of green technologies today, I decided to analyze which are the mechanisms that underline their diffusion.
In particular, I analysed a widespread green innovation, that is solar power technology. I mainly focused on incentives and word of mouth effect as drivers for the diffusion of this kind of technology.

Starting from a global point of view, I focused on Italian photovoltaic market. Moreover, I developed a mathematical model able to assess the importance of incentives' policies and peer effect in solar power technology diffusion rate.

In the second part of my dissertation I described how word of mouth process has influenced the solar power adoption process and how the peer effect is present nowadays in one of the most cutting-edge companies like Tesla.
This company, through the strategy " 0$ marketing budget" is basing its marketing strategy almost entirely on costumers' positive experiences.

INTRODUCTION

This dissertation focuses on the analysis of the main drivers which foster and support the adoption process of green technology.

After having identified them, I tried to investigate how and how much these drivers affect the technology development of a specific green technology, i.e. photovoltaic technology.

What brought me about analysing this kind of subject, is the increasing global consideration of green technologies; a process which is revolutionising the economic development and that is fundamental to avoid environmental damages and to not base our economy just on exhaustible fossil fuels.
What is interesting is that despite the green technology diffusion process has an enormous potential, we don't entirely take advantage of it.
My goal is this, to identify which are the processes capable of facilitating and accelerating the diffusion of green technologies.

In chapter one, it has been provided a global overview of the green technology sector.
In particular, has been found out that two of the main remarkable drivers within this industry are incentives policies issued by governments and the word of mouth effect, a process able to disseminate the technology among individuals.
I analysed in detail the Italian rebates policy, called Feed-in-Scheme ("Conto Energia" in Italian), aimed to support the photovoltaic technology diffusion, as I believe it's an efficient way to demonstrate how an incentive policy can accelerate the adoption rate of photovoltaic technology.
In order to have an overview of the real effectiveness of the Italian reform, the contribution of Luca Gatto, business developer of VP Solar, professional distributor of energy efficiency related products and photovoltaic systems, has been fundamental.

The two drivers taken into account are congruent with the main technology diffusion theory developed by Bass (1969) and with the interaction network theory (Newman 2010), both described in chapter 2.

Consequently, we tried to capture how much these drivers influence the adoption process, consequently affecting consumers' purchasing choices.

To this aim, we created a stylized mathematical model described in chapter 3, developed taking a leaf from Lobel, Perakis (2011).
Thanks to the model is possible to forecast consumers' purchasing behaviour regarding photovoltaic systems, considering several variables, as cost components, the rebates' level and the information spread process.
The model analysed accounts for the two main entities of the photovoltaic adoption process - that are market demand and policy-maker strategies.
I decided to focus on the first one, as I believe it is paramount to capture what is the right mix of variables that allows to reach the maximum level of utility perceived by costumers, therefore what will drive consumers' decision and so the market evolution.

In chapter 4, by implementing the model using Matlab, it has been possible to calibrate the adoption curve obtained by the model to compare it with the diffusion of photovoltaic technology in Italy.
The calibration is important in order to understand which variables mostly influence the two adoption curves.

Secondly we ran some comparative statics, basically to capture how much incentives' policies and word of mouth effect impact on the adoption rate curve.

The fifth chapter of this dissertation provides a more detailed analysis of word of mouth along with a way to assess its influence in photovoltaic adoption, i.e. measuring how a new photovoltaic installation in a given place – designated by its zip code - affects the probability of an additional installation in the neighbourhood.

Furthermore, the chapter analyses a cutting-edge company which bases almost entirely its marketing campaign on peer effects, spending around $0 in advertisement, that is Tesla.

The conclusive part of this thesis includes the results obtained by the comparative statics run on Matlab, which seem to be conformed with the theories claimed in previous chapters.
It provides also a spark aimed to foster new possible interpretations of this sector which probably represents the forthcoming future.

CHAPTER 1.

GREEN TECHNOLOGY DIFFUSION

1.1 The international green economy picture

Nowadays, especially because of an increasing awareness and interest towards the ecosystem damage and natural resources' destruction, green economy development is a worldwide central issue.

On one side, the paramount importance of economic growth - both in developing and developed countries alike - is obvious, nevertheless, this cannot occur at the expense of planet biosphere's equilibrium, and thus our very survival.

Therefore, a mutual effort is needed. On one hand, struggling in order to stabilise and nurture the economic growth, on the other hand trying to find renewable sources to sustain that process.

If this kind of ambivalence has to be respected, countries - especially developing ones -, will need a high innovation level of planning and development, focused on green innovations that allows carrying out an economic growth aim, simultaneously reducing natural resources' consumption and ecosystem damages.

Consequently, due to the increasing attention throughout renewable energies (RE) and considering the situation from a politic and international standpoint, what those countries really need is strategic objectives, capable of driving a safety development of energetic supplying, softening the economic squandering that cause climate change.

However, the struggle against climate is taking on, using different political instruments and international agreements, above all the Kyoto Protocol, in which industrialized

countries and the developing ones pinpoint an agreement to reduce of the 8% (5.2% during the first fulfilment period 2008-2012) their emission levels of gas producing greenhouse effect, comparing them with measures and values recorded in 1990. (Kyoto protocol, UNFCCC 1998).

The Intergovernmental panel on climate change (IPCC) has published a report in which considering the period 1970-2014, greenhouse gas emissions increased by 70%. (IPCC report, 2014).
Considering data collected during 2014 about the main greenhouse wells, greenhouse emissions has increased of 80% and represents the 77% of total greenhouse gas emission from human sources. Sectors that mainly contributed to this have been transport field, industrial production and electricity supply.

The situation is still complicated considering IPCC conference hold in 2014. It has been calculated that electricity is causing at least 25% of global greenhouse gas emission, as shown in Figure 1. (IPCC 2014 annual report).

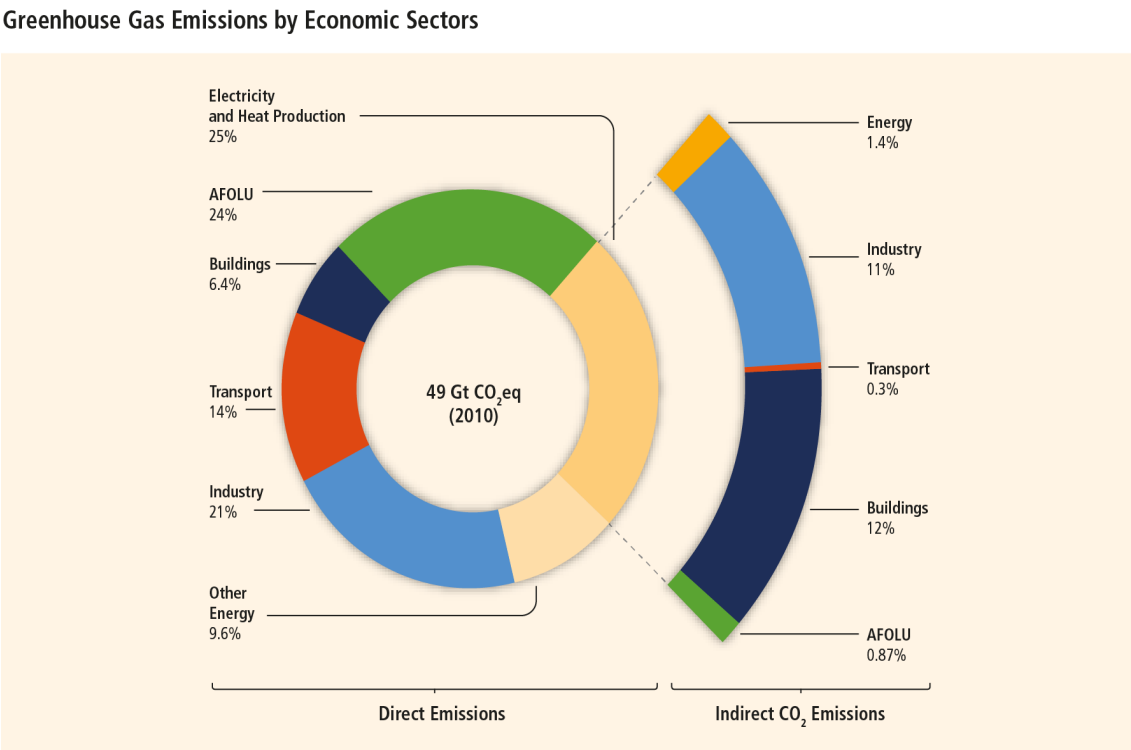


Figure 1: Greenhouse gas emission by economic sector, source: IPCC 2014 report

The main goals of electricity supply optimization, will be pursued essentially trying to reduce vulnerability of energetic deficit, searching for primary energy sources different from petrol or natural gas.

Those are the main reasons why the research of renewable sources - as solar power - is increasing its importance year-by-year. Indeed, considering the underlying scenario it's quite clear how this situation should be dealt with.
One possible road map could be working towards a kind of technologic innovation able to develop new products and services that allow us to exploit renewable sources.
New technologies are already available, but sometimes people simply cannot afford it or cannot understand in toto their prospective value.

Therefore, it would be useful and interesting to figure out which are the ways to better spread out these essential innovations. I decided to focus on the ways to foster photovoltaic technology diffusion, as I believe (as showed in figure 2) it is an interesting example of a booming green technology.

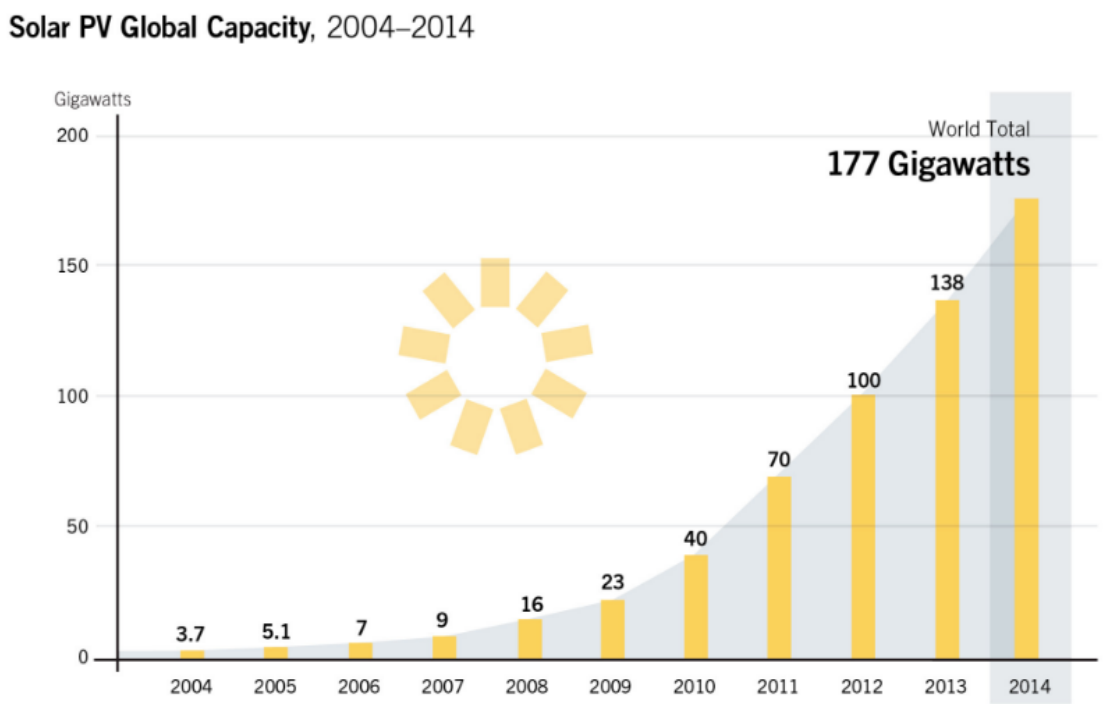


Figure 2: solar PV global capacity. Source: Renewables 2015, global status report

Starting from a global overture on incentives to promote green technologies spreading, I'm going to describe how the fiscal policy directed to support the photovoltaic diffusion has been managed by Italian government, and so what could be the future developments of this renewable energy source.

Considering the fast-growing rate of the overall photovoltaic capacity worldwide (figure 2), it would be interesting to understand which are the main drivers of these kinds of technological development.

Given that, the adoption cycle of these kind of technologies is not simply an automatic process, rather, several variables may be used in order to spread it out.
So, the main point of my thesis is to analyse and thus understand how much these variables have influenced the spread of this technological innovation.

According to Rogers, the adoption process of an innovation the key variables that foster its diffusion are the quality of innovation itself, communication channels, time and the social system (Rogers 2003).
Nowadays this process is surrounded by two others different dissemination systems, that are word of mouth (included within communication channels) and fiscal policies, translated into incentives.
This is why I decided to focus more in detail on these two main drivers that underpins green technologies adoption.
In this chapter, I will deal with incentives' role in green innovations, while in chapter 3 I will provide and apply a mathematical model, based on a previous one described by Lobel and Perakis. This forecasting model is able to predict consumers' choices about the adoption of green technologies, even considering an incentives' policy.

The interesting thing here is to understand how much tax incentives influence the innovation adoption curve, and how Italian government is trying to manage this powerful normative instrument.

On the other side, I will analyse another fundamental driver in this context, that is the peer-to-peer adoption spread, analysing it within the model developed, in order to

figure out how much this mechanism influences consumers' choices and therefore, companies' choices and strategies.

This concept is based on the fact that several firms devise their marketing campaign on customers' experiences and there is also who, as Elon Musk, founder of Tesla, has based his advertising strategy just on word of mouth, deciding to spend $0 in posters, advertisements on newspapers and TV commercials. Anyway, I will talk thoroughly about this particular and futuristic communication strategy in chapter 5.

Undoubtedly, technology innovation diffusion - especially green technologies development - should be fostered by structural governments policies, with the aim to increase positive externalities in the long term.

Particularly, in the following section I will focus on Italian photovoltaic incentives' system, in order to show how important are these drivers in spreading the photovoltaic innovation and which have been the results gained by Italian fiscal policy, in terms of both power and plants installed and in terms of social results obtained.

1.1.2 Incentives directed to green economy. A global overview.

One field in which incentives play a fundamental role, is the one of green economy.

Too often, the price of goods and services does not consider environmental impacts determined by their enjoyment. The result is an over-exploitation of common resources that depletes the community. This consequence could be corrected - at least partially- by the adoption of appropriate fiscal green policies.

These reforms include instruments focused on taxing the activities that cause environmental damage and overuse of natural resources, redirecting public and private investments directed to the exploitation of fossil fuels to low-carbon alternatives, fostering the development of the green economy and thus give the right signals and incentives to encourage sustainable investments on a long-term perspective.

It's also clear how tax reforms of this nature can increase the cost of production in the countries that adopt them, thus reducing the international competitiveness of enterprises which reside in these countries, as well as can be disadvantageous for certain areas if they are not properly designed and applied.

In order to promote environmental protection and climate change containment, regulatory and fiscal frameworks should be adopted in a coordinated, international way, in order to avoid competitive penalisations of those countries that have adopted more stringent environmental policies and so limiting the social impacts, particularly in developing countries.

Allowing the reinvestment of revenues from environmental taxes in infrastructure, those revenues may drive a reduction in distortionary taxes. Given that, tax income could be used to support research and development projects within the green-field.

However, despite the many benefits of green taxes, these are not the only possible tools that governments need to evaluate in order to sketch out a sustainable economic growth.

Other vehicles to foster green economic growth are for example the effective incentives for investments in renewable energy - such as solar, geothermal, wind sources- which guarantee a fixed tariff for all the energy produced and fed into the grid over a certain period (up to 20 years in some cases) and then gradually eliminate public support.

In this way, they increase the share of renewables in the energy mix and establishes their competitiveness compared to fossil fuels at once. Such investment support is critical at the beginning, in order to properly redirect the flow of capitals, which would otherwise be high-carbon-energy directed.
Nevertheless, this process is not immediate, basically for three reasons:

1) First, because of the absence of an environmental policy to internalize the negative pollution externality. So, that means there is a lack of competitiveness

between carbon free technological options available for energy production and traditional fossil inputs, with the first still not enough available on the market and often too expensive to be mass consumed.

2) Secondly, energy sector is characterised by long-lived capital stock and significant sunk investments in existing (fossil-fuel) plants, hence changes in electricity production are slow-paced and dependent primarily on the age of the capital stocks, and so their amortisation.
3) Third, even if low or free carbon technologies were cost-competitive with fossil, over-regulated energy markets may prevent access to the grid to renewable energy producers (Vona, Verdolini 2015).

Therefore, existing infrastructure for fossil energy extraction, refinement and distribution have required substantial long-term investment, which slows its conversion to the production of energy from renewable sources.

As a consequence, in order to get a severe change, structural incentives occur. Some governments are also developing programs aimed at supporting the acquisition of energy efficient appliances.
These schemes, though worthy of attention, require a deep understanding of consumer behavioural habits to be properly applied and managed.
For example, it has been demonstrated that the application of these programs in housing is more effective if residents are owners of the property or come from high-income backgrounds. (Ameli, 2015).
Developed countries are not the only ones to implement innovative schemes, and the energy sector is not the only ingredient to foster this necessary reform.
For instance, the Tunisian government has invested $24 million in public funds to promote the use of solar panels. (GGKP, Annual Conference Report, 2015).

At present day Mauritius, which are dealing with a tax reform through the instrument of environmental taxation, are developing a series of green tax measures, including excise duties on petroleum products and price hikes on inefficient energy products.

These policies show that it's possible to stimulate changes both at the level of consumption and production. In fact, they have generated a yield of 2.6% of the country's GDP in 2013: a capital that can be reinvested to further support on green economy development.

We know that the necessary transition to a green economy will not be achieved if we continue to hide the true cost of current consumption patterns subsidizing on fossil fuels.
Savings coming from such green aid in energy and production regulation, would free funds and resources that cn be used in a more efficient and effective way, such as financing social development: for instance, in Kenya, the government has improved the country's electricity network through the funds released from elimination of such subsidies. (GGKP, Annual Conference Report, 2015).

Disinvesting from energy sources based on fossil fuel, especially in cities and in intensive transport areas, not only encourages the move towards a green economy, but also has direct positive effects on health, allowing governments to save money in the balance sheet item devoted to national health care.
Disinvesting from fossil fuels appears to be a paramount priority, particularly in developing countries, where huge numbers of incentivised fossil fuels are involved, compared to those intended to finance climate. (Whitley, 2013).

In addition, in order to remove harmful subsidies for the environment, governments can also encourage clean and sustainable energy development by introducing production subsidies and tax incentives dedicated to foster innovation, installation and production of technologies directed to the exploitation of renewable energy resources.

As we said, the development of green tax policies, in addition to free countries from their dependence on fossil fuels, is also able to guarantee an overall savings and several social benefits.
Why, then, these measures have not spread like wildfire on a worldwide scale? There are four main obstacles. (Carraro, 2015) that hinder that major change.

First, the perception of law-makers and decision-makers involved is to severely damage the economic competitiveness of their countries if they implement environmental policies when other countries do not.
Second, green fiscal instruments would be more easily accepted by citizens if they were provided as part of a broader tax reform plan.
Third, it is often difficult to communicate effectively the economic, social and environmental effects of these reforms, especially long-term benefits.
Finally, as with other radical reforms, these underlie major negative side effects for the market and some powerful stakeholders.
In this sense, governments can provide normative and financial support for economic groups who suffer financial losses and competitive disadvantages.

Indonesia, for example, to protect his domestic economy against inflation effects, achieved an important reform on fossil fuels subsidies, redirecting these financial resources to support health care, rice production, development of new infrastructure and to provide scholarships for economically more 'vulnerable groups.
In Indonesia and other developing countries that are putting in place similar reforms, these protection plans are fundamental, considering that the fossil fuel subsidies involve a more significant public spending of the expenditure on health, education and social protection combined. (GGKP, Annual Conference Report, 2015).

It's clear that the plain removal of such subsidies, breaking certain economic balances, can only lead to major political and social tensions. Because of this, compensatory measures are needed. The green tax reforms must therefore be carefully designed and implemented, in order to be effective and able to be maintained over time.

According to this, what is the way forward?

The green tax policies have certainly an important role to play in the transition towards a green economy, and the limits that's facing this major changing are anything but insurmountable.

Given that, governments must begin to think more creatively and go beyond the mere implementation of environmental taxation and legal retaliation, in particular in the context of developing countries.

We should stop seeing these reforms as useful only from the environmental point of view, and begin to explore how to make them acceptable to interest groups which are mainly involved.
Combined with a solid tax reform, government have to put in place a transparent, constructive communication, fostering true commitment among the major stakeholders involved, as well as implementing a better monitoring system.

One way could be the adoption of complementary policies to increase the effectiveness of these reforms, such as initiatives to achieve behavioral changes that may promote the adoption of energy-efficient and low-carbon action. (Sirini Withana, 2015)

Further, we don't have to forget about the importance of putting together habits' changes, cultural and technological developments, in order to foster the acceptance of reforms that will lead us towards a future low-carbon emissions. (Elke Weber, 2015).

Indeed, taking into account the paramount importance of these two aspects, I decided to analyse first the behavioural one - through a discussion about word of mouth, in chapter 5 - and so the governmental one - the very milestone of promotion and implementation of this fundamental change in the energy sector on a global scale.

1.2 Incentives types directed to speed up the rate of innovation adoption

The main reason behind incentives' policy adoption is to support and facilitate a new technology adoption by customers, actively promoting its diffusion.

In general, two different kinds of incentives exist: direct payment of cash, or indirect payment of cash. Incentives can be awarded to different projects.
These can be directed to innovative start-ups or interventions, to foster energy re-

qualification, R&D investments and projects, or in this specific case, in order to speed up the rate of innovation adoption and implementation.

According to Rogers, incentives can be awarded in different forms (Rogers 2003):

- *adopter versus diffuser incentives:* that can be paid directly to the adopter of an innovation, or to another entity with the aim to persuade the adopter;
- *individual versus system incentives:* this method promotes decisively the word of mouth effect. Instead of steer payments toward an individual entity, these are aimed toward the system to which they belong;
- *positive versus negative incentives:* positive incentives are the ones that promote an innovation diffusion or the ones directed to a behavioral change. In this case an individual is encouraged to change through the incentive payment. In another case, their effects could be to penalise an individual imposing a penalty in order to avoid a specific behavior. An example of these are the increasing taxation imposed on cigarettes, in order to discourage smokers from harm;
- *monetary versus non-monetary incentives:* incentives could not be just cash payments but also something not-monetary, as commodities or specific advantages in favor of the recipient;
- *immediate versus delayed incentives:* the majority of incentives are awarded at the time of adoption. Others could be become effective later.

Therefore, one of the reasons why governments award incentives is to speed up a new technology adoption or, more broadly, to reach a specific target, as for example a predetermined level of demand, encouraging the clients' consumption.
The fine point, however, is that it is not easy to set an incentive that allows reaching a desired target, maintaining low government expenditure at the same time.
There are always two forecasting-sides:

- on one side, a big part of the issue depends on the future costumers' response, that obviously, is not previously known;
- on the other side, it is not easy to forecast suppliers' behaviour too, because of the highly unpredictable nature of such variable.

Even if most of incentives are paid directly to clients, green technologies' suppliers play a fundamental role as well, because their internal policies and strategies (production quantities, price sales, etc..) will be driven by consumers' behavioural action.

Given that, we can say that is all about figuring out what drives the consumers' adoption of green technologies and companies to invest money in developing related services and products.
According to this, in chapter 3 I will provide a stylised mathematical model, aimed to forecast consumers' purchase decision within this area of interest.

1.3 Incentives to promote photovoltaic diffusion: Italian policies.

I decided to study Italian photovoltaic subsidies' policy, especially because Italy has implemented interesting incentives policies during the last 20 years. Moreover, it comes first as photovoltaic contribution to electric supply.

Considering other 22 countries where solar power covers at least 1% of electricity consumption, Italy occupies first place with a brilliant 8%. (Photovoltaic Power System Program, Snapshot of Global PV Markets 2016)

Globally speaking, the installation rate is increasing, with the ex-new markets - like China and Japan - that are prevailing, with a higher pace of adoption.
Bearing in mind that these are responsible of more than a half of new added capacity, these countries are obtaining the biggest share of photovoltaic market.
This is especially since three of the most important modules and cells producers are from China.

Anyway, within this context it will be interesting to understand which position Italy is going to maintain among the other countries.
This vague future is due to several reshuffles produced by Italian government that have

almost abruptly stopped photovoltaic growing, registering a power decreasing of 32% from installed plants in 2015 rather than plants installed in 2014. (Energy Revolution, Greenpeace 2015).

Who in Italy has a central role in promoting and developing renewable sources is Gestore Servizi Energetici (GSE) that is the main authority that manages incentives system for energy produced by renewable sources.
In Italy, in order to provide incentives for electricity production by photovoltaic source, several ministerial decrees have come in succession.

The incentives size has progressively decreased both in order to uniformly spread the incentives amount established by government over the years, and to reach grid parity. It represents the point at which the cost of energy produced using photovoltaic and the price of energy bill match.
It is influenced by different factors, among others plant installation price variation, which has been considerably reduced year after year.

1.3.1 The Feed-in scheme

Feed-in scheme (named "Conto Energia" in Italian) represents the government subsidy linked to electric production obtained by photovoltaic plants during a 20-year period long.
This mechanism, already provided by legislative decree number 387 of 29/12/2003 has become operative after the 28/7/2005 and 6/2/2006 decrees produced by Economic Development Minister, and became laws with the name of First Feed-in scheme (see table 1).

The newness of Feed-in scheme policy is based on the fact that in order to dispense the rebates so that the government doesn't weigh on its own financial resources, instead it uses a tariff indicated with the code "A3" within every bill.

This component described as "promotion of energy produced using renewable sources"

weighs for 18% on the electric bill.
The amount obtained finances GSE. In that way, it is able to acquire energy produced by renewable sources with a bargain price.

Feed-in scheme policy has replaced previous government approach that was based on non-repayable loans. The underlying idea is that thanks to Feed-in scheme are not photovoltaic plants incentivised but energy production as a whole.

The national goal of the first decree was to install 100 MW of total capacity of the plant (60 MW for systems below 50 kWp and 40 MW for plants between 50 kWp and 1 MWp). Due to a strong demand for access to such incentives, the limit was increased to 500 MW by the Ministerial Decree of 06/02/2006.
First Feed-in scheme reveals three different tariff categories, following plants' effective power.

PV plant	Power(kW)	Incentive tariffs
Class 1	1 ≤ P ≤ 20	0,445 (net metering) 0,460 (electricity transfer)
Class 2	20 ≤ P ≤ 50	0,46
Class 3	50 ≤ P ≤ 1000	0,490 (max value)

Table 1: First Feed-in scheme, source: 2012 Activities report, GSE June 2013, p.6.

Individuals can only possess systems of Class 1, as without VAT. It applies a different rate and a different calculation method between those who opt for the exchange on the spot and who choice energy sales:

- The exchange on the place allow the user to store up the energy that is not self-consumed, that is returned to the electricity network at a later stage. The first Energy Bill encourage only the production of self-consumed energy.

• The sale network makes allows the user to resell the energy not self-consumed directly to a third party, entity and the like. With the first Feed-in scheme, the whole process of energy production is encouraged.

Legal entities can also access both Class 2 and 3 systems, receiving incentives for all the energy produced by them. The proposed incentive undergoes an annual decrease of 5% from 2007.
This Feed-in scheme received an unexpected number of requests but due to the complex bureaucratic process only 47% of the implants were actually completed and put into operation.

This delay was due to a cumbersome investigation phase, which involves the use of a large number of documents.

In order to cut the red tape, it has been emanated a ministerial decree (D.M.19/2/2007) named Second Feed-in scheme, that has simplified access rules to subsidy tariffs.

The new tariff proposed eliminates the limit of 1000 kW of maximum power of the single system, without imposing new restrictions. The new incentives take into account, in addition to the power of the plant size, also the very integration of it on the territory, as follows (table 2):

- Not integrated plants
- Partially integrated plants
- Integrated plants

	Incentive tariffs		
Plant power (kW)	**Not integrated**	**Partially integrated**	**Integrated**
$1 \leq P \leq 3$	0,4	0,44	0,49
$3 < P \leq 20$	0,38	0,42	0,46
$P > 20$	0,36	0,4	0,44

Table 2: Second Feed-in scheme, source: 2012 Activities report, GSE June 2013, p.6.

From Table 2 it can be seen that the higher tariffs are applied to integrated equipment with low power capacity, while the smaller ones to non-integrated systems of large size.

The proposed rates are valid for 20 years and are reduced by 2% after 2008, then the rate are stabilised for the remaining years.

The following ministerial decree (Third Feed-in scheme) provided the introduction (from 1st of January, 2011) of specific incentives concerning photovoltaic integrated plants with innovative characteristics and concentration photovoltaic plants.

The main purpose of the Third Feed-in scheme is a gradual reduction of tariffs, due to a decrease of the cost of installation of photovoltaic systems.

The Decree has the objective to lower the incentives by 18% by the end of 2011. The prize for an efficient use of energy systems integrated with innovative features of buildings amount to 30% of the fare.

The Decree also provides that the power limit for incentives steps from 1,200 MW to 3,000 MW, in addition to 200 MW for concentrated photovoltaic and 300 MW for integrated plants with innovative features.

The brand-new goal is to install 8,000 MW of power by 2020.

Classes of incentivised plants have been modified. There were eliminated implants named "partial integrated", thus forming four new categories:

- Photovoltaic solar systems that are divided between implants placed on buildings and "other facilities" (Table 3)
- Photovoltaic systems integrated with innovative features (Table 4): they differ from a normal photovoltaic system because they are composed of parts and special modules that replace architectural elements of the building, complementing the structure.
- Plant a concentration (Table 5): they involve a new technology that allows conveying sunlight on a tube through some reflective surfaces. The concentration plant also allows you to adjust the energy supply according to demand. They can own concentration plants only legal and public bodies fibula.
- Photovoltaic systems with technological innovation: they use modules and components with an high level of technological innovation.

	A) Plants entered into service after 31/12/2010 and within 30/4/2011		B) Plants entered into service after 30/04/2011 and within 31/8/2011		C) Plants entered into service after 31/8/2011 and within 31/12/2011	
Power (kW)	**Plants on buildings**	**Others PV plants**	**Plants on buildings**	**Others PV plants**	**Plants on buildings**	**Others PV plants**
1 ≤ P ≤ 3	0,402	0,362	0,391	0,347	0,38	0,333
3 < P ≤ 20	0,377	0,339	0,36	0,322	0,342	0,304
20 < P ≤ 200	0,358	0,321	0,341	0,309	0,323	0,285
200 < P ≤ 1000	0,355	0,314	0,335	0,303	0,314	0,266
1000 < P ≤ 5000	0,351	0,313	0,327	0,289	0,302	0,264
P > 5000	0,333	0,297	0,311	0,275	0,287	0,251

Table 3: Third Feed-in scheme, source: 2012 Activities report, GSE June 2013, p.9. Photovoltaic solar plants.

Power (kW)	Incentive tariffs
$1 \leq P \leq 20$	0,44
$20 < P \leq 200$	0,4
$200 < P \leq 5000$	0,37

Table 4: Third Feed-in scheme, source: 2012 Activities report, GSE June 2013, p.9. Photovoltaic integrated plants.

Power (kW)	Incentive tariffs
$1 \leq P \leq 200$	0,37
$20 < P \leq 1000$	0,32
$200 < P \leq 5000$	0,28

Table 5: Third Feed-in scheme, source: 2012 Activities report, GSE June 2013, p.9. Concentration photovoltaic plants.

Fourth Feed-in scheme (ministerial decree 5/5/2011) has been introduced with two main purposes:

1. equalise tariffs level with new photovoltaic technology costs evolution;
2. introduce an annual cumulative cost limit of incentivised plants in the amount of 6 billion of euros.

The rates proposed by Fourth Feed-in scheme - as in the case of the previous account-, is fixed for 20 years from the starting date of the system.

Since 2013, however, the non-self-consumed energy is measured with a special all-inclusive rate, called feed-in tariff. In this way, they have created two different rates, each for the energy fed into the grid and the energy self-consumed.

	First semester 2012		Second semester 2012	
Power interval (kW)	**Plants on buildings (€/kWh)**	**Others PV plants (€/kWh)**	**Plants on buildings (€/kWh)**	**Others PV plants (€/kWh)**
1 ≤ P ≤ 3	0,274	0,24	0,252	0,221
3 < P ≤ 20	0,247	0,219	0,227	0,202
20 < P ≤ 200	0,233	0,206	0,214	0,189
200<P≤1000	0,224	0,172	0,202	0,155
1000 < P ≤ 5000	0,182	0,156	0,164	0,14
P > 5000	0,171	0,148	0,154	0,133

Table 6: Fourth Feed-in scheme, source: 2013 Activities report, GSE. June 2013, p. 12. Solar photovoltaic plants.

Power interval (kW)	First semester 2012	Second semester 2012
1 ≤ P ≤ 20	0,418	0,41
20 < P ≤ 200	0,38	0,373
P > 200	0,352	0,345

Table 7: Fourth Feed-in scheme, source: 2013 Activities report, GSE. June 2013, p. 12. Photovoltaic integrated plants.

Power interval (kW)	First semester 2012	Second semester 2012
1 ≤ P ≤ 200	0,352	0,345
200 < P ≤ 1000	0,304	0,298
P > 1000	0,266	0,261

Table 8: Fourth Feed-in scheme, source: 2013 Activities report, GSE. June 2013, p. 12. Concentration photovoltaic plants.

For the new Feed-in scheme, GSE has allocated an additional 700 million euro financing, with the aim of a cumulative annual cost of 6.7 billion euro by 2013.
Main objective of the Fifth Feed-in scheme is a progressive reduction in tariffs, in accordance with the previous statement.

The decrease in rates between the Fourth Feed-in scheme and the first half of the fifth was approximately 60%, with the aim in the near future to achieve the grid parity.

After reaching the threshold level of 6 billion of euros, Italian government emanated the ministerial decree on 5/5/2012.
This final decree has introduced new rules, creating two types incentives:

1. regarding the percentage of net production input in the network:

   - plants with nominal power ≤1 MW: can access a feed-in tariff incentive;
   - plants with nominal power >1 MW: can access an incentive equal to the difference between the feed-in tariff and the hourly zone price;

2. regarding the percentage of net production consumed, a premium tariff.

First semester:

	Plants on buildings		Others PV plants	
Power interval (kW)	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**
$1 \leq P \leq 3$	208	126	201	119
$3 < P \leq 20$	196	114	189	107
$20 < P \leq 200$	175	93	168	86
$200 < P < 1000$	142	60	135	53
$1000 < P \leq 5000$	126	44	120	38
$P > 5000$	119	37	113	31

Table 9: Fifth feed-in scheme incentive tariffs, photovoltaic plants. Source: fotovoltaiconorditalia.it.

Second semester:

	Plants on buildings		Others PV plants	
Power interval (kW)	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**
1 ≤ P ≤ 3	182	100	176	94
3 < P ≤ 20	171	89	165	83
20 < P ≤ 200	157	75	151	69
200 < P < 1000	130	48	124	42
1000 < P ≤ 5000	118	36	113	31
P > 5000	112	30	106	24

Table 10: Fifth feed-in scheme incentive tariffs, photovoltaic plants. Source: fotovoltaiconorditalia.it

Third semester:

	Plants on buildings		Others PV plants	
Power interval (kW)	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**
1 ≤ P ≤ 3	157	75	152	70
3 < P ≤ 20	149	67	144	62
20 < P ≤ 200	141	59	136	54
200 < P < 1000	118	36	113	31
1000 < P ≤ 5000	110	28	106	24
P > 5000	104	22	99	17

Table 11: Fifth feed-in scheme incentive tariffs, photovoltaic plants. Source: fotovoltaiconorditalia.it.

Fourth semester:

	Plants on buildings		Others PV plants	
Power interval (kW)	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**
$1 \leq P \leq 3$	144	62	140	58
$3 < P \leq 20$	137	55	133	51
$20 < P \leq 200$	131	49	126	44
$200 < P < 1000$	111	29	107	25
$1000 < P \leq 5000$	105	23	101	19
$P > 5000$	99	17	95	13

Table 12: Fifth feed-in scheme incentive tariffs, photovoltaic plants. Source: fotovoltaiconorditalia.it.

Fifth semester:

	Plants on buildings		Others PV plants	
Power interval (kW)	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**	**Feed-in tariff (€/MWh)**	**Premium tariff on in-site consumed electricity (€/MWh)**
$1 \leq P \leq 3$	133	51	130	48
$3 < P \leq 20$	128	46	124	42
$20 < P \leq 200$	122	40	118	36
$200 < P < 1000$	106	24	102	20
$1000 < P \leq 5000$	100	18	97	15
$P > 5000$	95	13	92	10

Table 13: Fifth feed-in scheme incentive tariffs, photovoltaic plants. Source: fotovoltaiconorditalia.it.

Fifth feed-in scheme has ceased its application as soon the annual cumulative indicative cost of incentives of 6,7 billion of euros has been reached.

Consequently, after Fifth feed-in scheme, government ceased to allocate incentives. Therefore, which fiscal advantages could join a new photovoltaic plant owner?

- It will be still possible to economically take advantage of energy produced by photovoltaic plants through the modality of net metering. This mechanism allows to obtain a compensation between the economic value linked to electricity produced and input in electricity grid, and the theoretical economic value linked to electricity collected and consumed in a different period than in which the electricity production happens. (GSE guide, 2016).

- In specific cases, will be possible taking advantage of 50% tax credit. In other words, the 50% of plant installation costs will be refunded in 10 years.

As showed in figure 3 Feed-in scheme has created an incredible growth in power installed, nevertheless this increasing tendency seems to be stabilized in last two years.

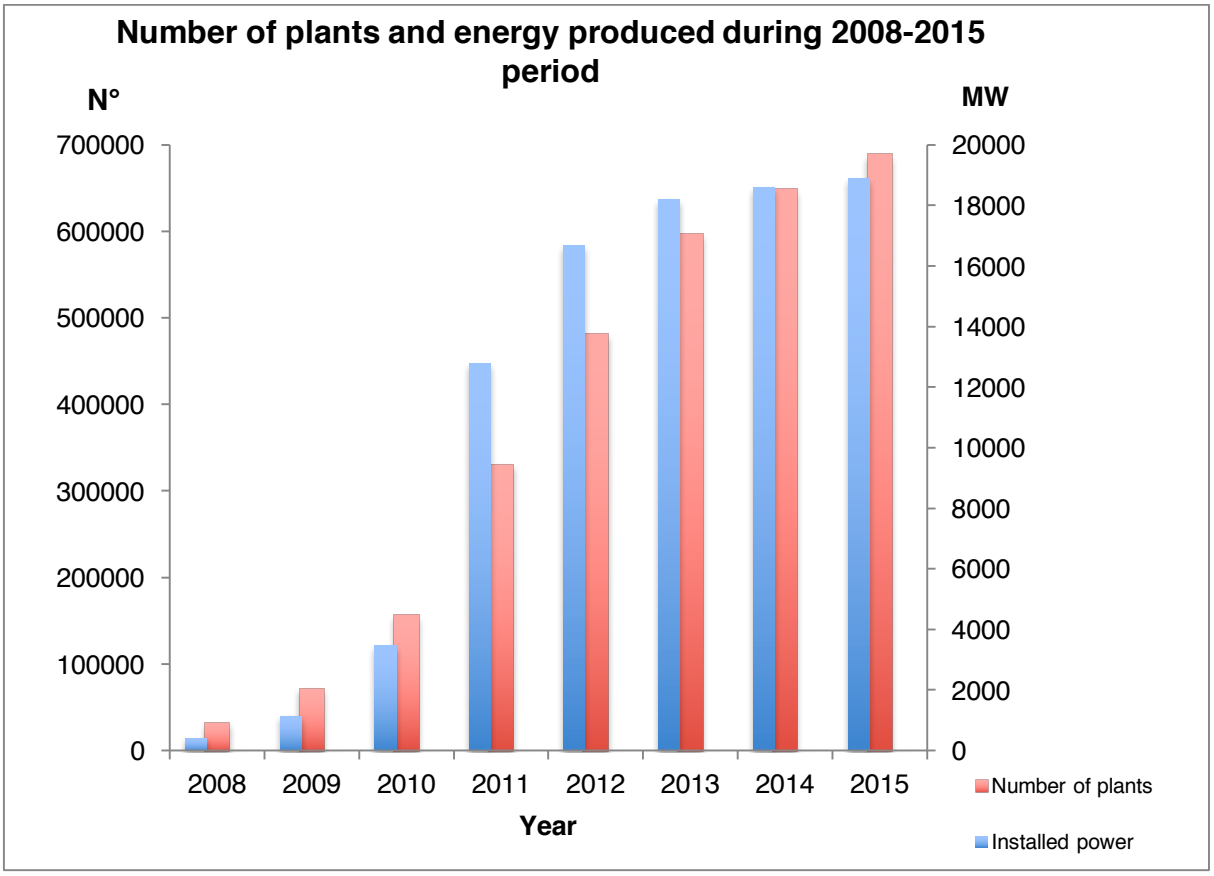


Figure 3. Source: QualEnergia.it

Undoubtedly, the lowering incentives fall produced a sharp decrease in the number of plants and power installed.

Tax credits seem to be not enough to reach the installation rate achieved during central years of Feed-in scheme.

This disinvestment process basically started at the end of Feed-in scheme policy, and brought to a general skepticism in last years. (figure 3).

I focused my thesis on Italian photovoltaic installation rate variation over the period 2014/2015 -more than a year after last Feed-in scheme -, in order to demonstrate the negative trend derived by the suspension of incentives' mechanism.

This is evident in percentage variation columns in table 14.

	Installed in 2014		Installed in 2015		Var % 2015/2014	
Power classes (kW)	**n°**	**MW**	**n°**	**MW**	**n°**	**MW**
1<=P<=3	19169	51,5	15201	40,3	-20,7	-21,7
3<P<=20	31375	185,2	23845	148,4	-24	-19,9
20<P<=200	1401	105,5	1091	75,6	-22,1	-28,4
200<P<=1000	108	58	62	25,6	-42,6	-55,9
1000<P<=5000	9	23,7	3	7,9	-66,7	-66,8
P>5000	-	-	-	-		
Total	**52062**	**424**	**40202**	**297,8**	**-22,8**	**-29,8**

Table 14: Italian PV installations in 2014/2015, source: GSE report 2015

During 2014, Italy has registered an installation rate of 385 MW. From January to October 2015 have been installed in Italy 244,68 MW of new power, especially thanks to small size plants favoured by tax credits. (Gaudì, Terna 2015).

However, this falling parabola, due to the end of Feed-in scheme, is believed to make a U-turn.

In 2020 the value-added will be of 1.060 million of euros, with 26.903 employees and new annual capacity installed will be of 1.650 MW. (EY Solar Photovoltaics Jobs & Value, 2015).

Beyond these optimistic numbers, in fact, Italian photovoltaic prospective diffusion will be not easy to forecast, especially because this prediction is linked to the national regulatory structure evolution, and so the future legislative process.

1.3.2. Further considerations on Feed-in-scheme.

Following to the Italian incentives' policy analysis, is interesting to understand which have been the effects of this kind of policy.
In other words, is interesting to analyse the incentives' formula effectiveness, whether it has been conducted in the most efficient way and least, what have been the policy's social cost.
Undoubtedly, in order to get an answer to this question I decided to interview[1] someone who is directly involved in this sectors' dynamics. The person concerned is Luca Gatto, business developer of VP Solar, professional distributor of energy efficiency related products and photovoltaic systems.

Therefore, what follows is a brief analysis from the inside, of the Feed-in scheme, fundamental to understand what are the main dynamics of this sector, which are not often automatically inferable.

For sure, talking about Feed-in-Scheme means coping with a thorny dynamic which affected the Italian social and economic development. "That has represented an effective driver for renewables' sector development, even if the structure and realization times brought to huge disadvantages to operators", claims Gatto.
If we analyse the situation under a global point of view, for better or worse it's happening the same also in other countries. For instance, the photovoltaic domestic market experienced a setback after the 2016 summer, due to a reduction of Kw/Pv (kilowatt/photovoltaic) selling prices. "The mechanism is paradoxical: the higher is prices' reduction, the lower is the sales' level. That is because of people waiting something able to further reduce prices, happens", affirms Gatto.

According to this, why did prices reduce? The main reason is that in June 2016, Cina has tightened the belts and this brought to a surplus in panels' supply which have been offloaded onto the global market, therefore increasing considerably the supply. This

[1] The interview has been conducted in part during a Skype-call lasted 1 hour, and in part in person during the meeting "Sistema impianto efficiente, il ruolo dell'impianto solare termico e fotovoltaico" in Asolo on the 12th October 2016. That event was aimed to inform architects of the new products related to photovoltaic technology.

mechanism has forced some photovoltaic producers to lower the prices in order to sell out the reserves.

Anyway, it's clear how an incentivising policy can be considered as a driver in a renewable energy sector, as it allows to spread the innovation, increasing the market demand function. The point is whether, in Italy, it has been used in the most efficient way.
"Unfortunately, we live in a system, where every opportunity is generated, it must first be exploited by some important players (classically lobbies) before the mass can enjoy it" continues Gatto. That phenomenon has brought to a situation in which there are cases the Feed-in-schemes has been *dissipated* in photovoltaic plants (especially in the southern part of Italy) which today are characterized by management and maintenance problems.

Nevertheless, is important to bear in mind that for what concerns photovoltaic installed for private use, the situation is more positive. As stated by Gatto, "undoubtedly, getting a recurring bank transfer from GSE which buys electricity from you, is something very pleasing. Moreover, being able to pay the investment back, achieving at the same time a profit thanks to the sun, is very attractive."

According to this, the main regret is that these particular target, i.e. the private-users have not been sufficiently incentivized and it was worth it, because they represent the main business development source.
As I stressed the positive effect of this green technology diffusion, I should focus on the costs which photovoltaic technology represents for individuals as well, i.e. it's important to bear in mind the social costs coming from photovoltaic technology. These costs are obviously levied also to whom has not installed a photovoltaic plant.
These expense can be identified as part of the energy bill costs, nonetheless what is not taken into account are the lower fossil generation costs.

Was it possible to manage the funds in a more efficient manner?

The answer is yes. The point is that the system seems to work against the photovoltaic technology diffusion.
Anyway, as claimed by Luca Gatto, the energy produced - thanks to renewable sources - in two hours in June 2016 in Italy, was totally sufficient to fulfil the entire energy needs. As previously said, the grid parity has been almost reached, it's all about a politics issue.

As mentioned by Paolo Rocco Viscontini, Italia Solare association's president, the Italian electricity tariff reform, issued by the Italian Energy Authority - which has entered into force at the beginning of 2017 - encourages to use home electricity for any application, regardless of the damage this disinformation will cause to millions of households and to environment.
This reform will bring to an increasing of the energy bill from 10% to 30%. (www.autorita.energia.it).

What is important is that these incentives to increase the electricity consumption doesn't come along any measure intended to foster a renewable sources application.
That is an example of how big generating stations and, in wider terms, the Italian system, are struggling with photovoltaic technology diffusion, and more in general, with renewable sources spread.

CHAPTER 2.

THEORIES OF TECHNOLOGY DIFFUSION

2.1 Bass model application to green technology diffusion.

Green technology represents a particular range of technologies able to exploit environment-friendly production means, employing technical properties of generating electricity that sharply reduce or nullify polluting agents and carbon dioxide emissions produced by the refining of fossil energy sources and the like.
It's a kind of energy that is generated from natural processes that are continually replenished, and includes sources as sunlight, geothermal heat, wind, tides, water, and various forms of biomass.
This energy cannot be exhausted and is constantly renewed. (Ciolkosz, 2016)

An important field in which green technology is wide adopted is the renewable energy sources one. In that sense, we define as renewable energy all kinds of energies that are able to re-generate at least as fast as they are consumed. (Powers, DeWaters, 2008).
Considering the importance of these technologies - as we discussed in chapter 1 -, the fine point is to understand which are the ways to better spread them.

According to that, it's paramount to analyse which is the incentives' role on consumer decisions, behaviour and new green technologies adoption cycle.
To this aim, focusing on a mathematical theory of product innovation can help: I'm talking about the Bass curve. Even if it comes from 1970s, nowadays it's still useful when it comes to the analysis of such technological innovations.

Therefore, is interesting to observe incentives' effects from a dynamic point of view, comparing their evolution and development over time to the S-shaped Bass' curve.
Firstly, the aim of this predictive model is to somehow forecast - given leeway for interpretation, the adoption of a new technology or product.

In detail, the Bass diffusion model is efficient in analysing this process, taking into account time (x) and non-cumulative number of adoption (y).
That is, evaluating the adoption process of innovation in a dynamic, diachronic way.

The importance of this model lies in the fact that it provides the most relevant answers to uncertainty which a new technology innovation brings with it.

2.2 Bass model.

Basically, Bass model derives from a hazard function, that is the probability that an adoption will occur at time *t*, given that it has not yet occurred. (Mahajan, Muller, Bass, 1990).
The underlying idea behind this model is to figure out which are the communication channels through which information on the new technology is transmitted within the social system, taking into account two distinct types of influence: an internal influence, of the word-of mouth communication type - and an external one, represented by the mass media (Mahajan, Muller, Bass, 1990).

In our handling of this issue, I decided to extend that model, taking into account how the governmental incentives affect innovation diffusion as well, and which is their role within this diffusion model. (see chapter 3)
Bass forecasting model identifies three fundamental factors:

1) market potentiality: that represents the total number of people that are able to adopt that specific innovation;
2) external influence (or innovation) coefficient: in other words, the likelihood that someone is still a non-adopter, starts to make it under mass media or others external factors influence;
3) the internal influence coefficient: that is the likelihood that someone who is still a non-adopter, starts to make it thanks either to word-of-mouth effect, or to others direct-influence forms from who is already an adopter.

What makes this mathematical model so important and useful is that it is a predictive

one.
So its purpose is to forecast the number of future adopters within an established future time period, either on the basis of first pilot launch data of a new product - or from a managerial decision-based perspective, taking into account previously diffusion trajectories of analogue products and services.

Now, if we consider green technology diffusion, we clearly see how important is to predict such innovation cycle, especially for two main purposes:
1) to forecast which could be the adoption rate of a specific green innovation;
2) to set the right policies in order to promote this innovation spreading.

We know that Bass model addresses the market in an aggregate way, and its aim is to forecasts the total number of adopters in a given time period, rather than the adoption or non-adoption of individual costumers.

A similar approach was developed also in the sociological literature by Rogers, (see Rogers 1962.)

This diffusion model is based on two main entities:

- who has adopted because of external influence, called innovators that are driven by the coefficient of innovation, regardless of previous adoption, p;
- who has adopted thanks to external influences, also called interpersonal channels, that are called imitators. These influences depend on the imitation or learning coefficient q.

More specifically, the coefficient of innovation p is not linked to the influence of previous adopter, rather is driven by personal attitudes or willingness to pay (adopt).
On the other hand, the coefficient of imitation q it's directly connected to the likelihood that someone who is still a non-adopter, starts to convert thanks to the word-of-mouth or on others direct-impact forms of influence from who is already an adopter.

These effects are proportional to cumulative adoption, in other words, the number of adoptions at time t is proportional to the number of prior adopters.

Hence, the more word-of-mouth is spread, the more people talk about that innovation, the more other people within that social system will adopt.
We will see in depth the importance of a particular social system in section 2.6.
In any case, this situation can be graphically represented in figure 3, 4 and 5, where structures and conceptual ideas underlying Bass' Model are represented.

The innovation adoption process from a non-cumulative point of view is showed on figure 3; non-cumulative adoptions are on y axis and time on x axis, therefore we can appreciate a model that shows the number of new adopters per time unit.

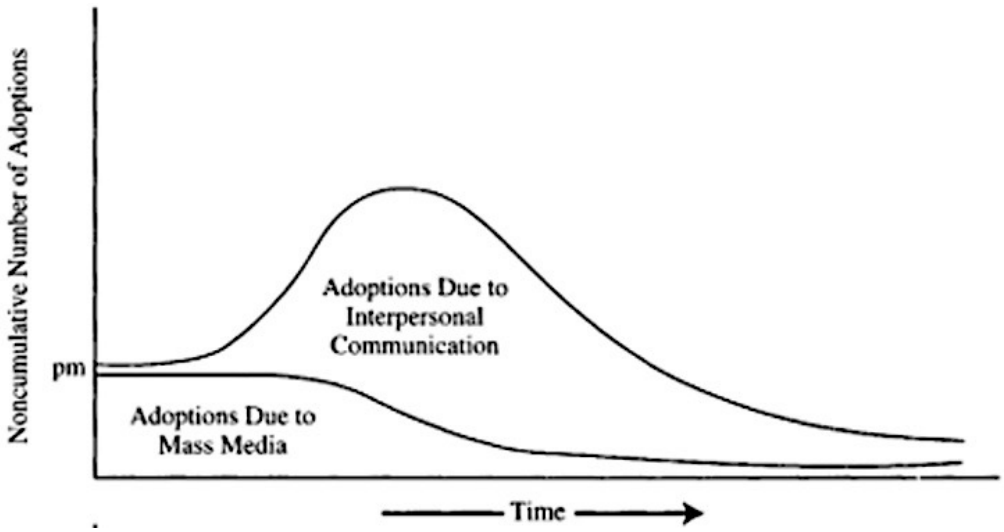


Figure 4. Adoption due to external and internal influences. Source: "New product diffusion Models in marketing: A Review and directions for research", Mahajan, Muller, Bass, 1990.

Bass model assumes that the ones called innovators or buyers, who adopt exclusively because of the mass-media communication or the external influence, are present throughout all the diffusion processes.

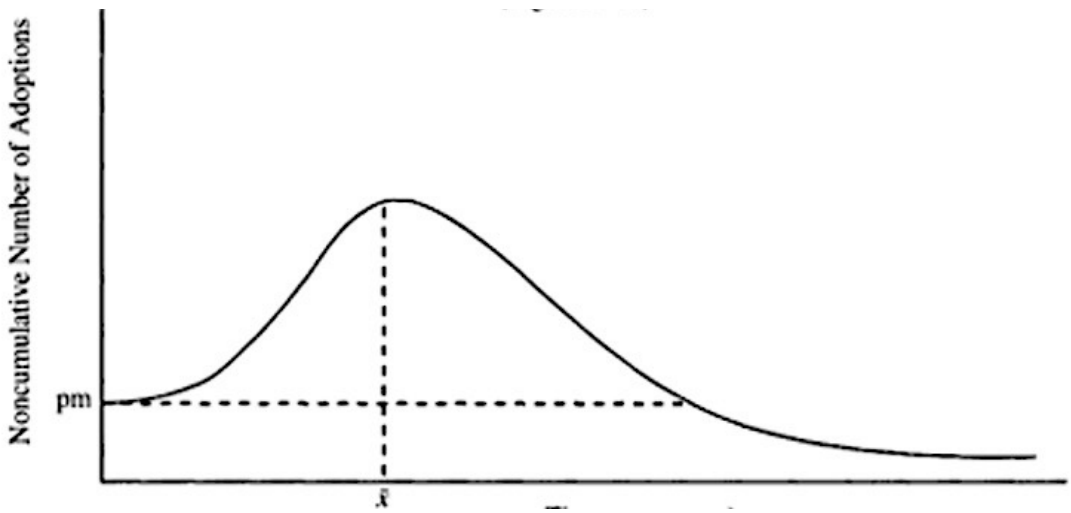


Figure 5. Analytical structure of Bass model. Source: "New product diffusion Models in marketing: A Review and directions for research", Mahajan, Muller, Bass, 1990.

Figure 4 shows that the non-cumulative adopter distribution peaks at time T*, which is the point of inflection of the S-shaped cumulative adoption curve (figure 5). Furthermore, the adopter's distribution implicitly assumes that an initial pm (a predetermined constant) level of adopters buy the product at the beginning of the diffusion process.

Once started, the adoption process is symmetric with respect to time around the peak time T* up to 2T*. That is, the shape of the adoption curve from time T* to 2T* is the mirror image of the shape of the adoption curve from the beginning of the diffusion process up to time T*. (Mahajan, Muller, and Srivastava 1990).

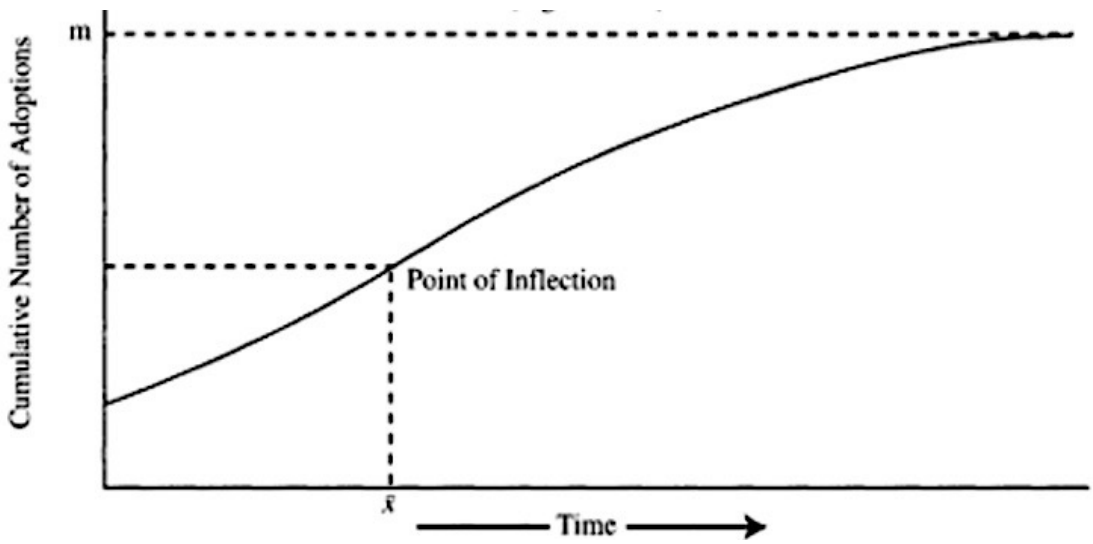


Figure 6. Analytical structure of Bass model. Source: "New product diffusion Models in marketing: A Review and directions for research", Mahajan, Muller, Bass, 1990.

Therefore, is possible to estimate the cumulative number of adopters due to the fact that if we consider the year of adoption, the S-Shaped diffusion curve - as underlined in figure 5, is symmetrical around the *point of inflection* at time $\bar{x}$.

Approaching Bass model mathematically provides a mathematical formula that take into account three fundamental parameters, partly introduced and discussed in the previous chapter:

a) M, that represents the maximum potential market demand;
b) p, innovate coefficient of innovation;
c) q, coefficient of imitation.

$$\frac{\boldsymbol{f(t)}}{\boldsymbol{1-F(t)}} = \boldsymbol{p} + \frac{\boldsymbol{q}}{\boldsymbol{M}} * [\boldsymbol{A(t)}]$$

This formula can be interpreted as "The portion of potential market that adopts at time t, given that they have not yet adopted, is equal to a linear function of previous adopter". (Bass, 1969).

The maximum potential demand market (M) represents the number of people that lives within the social system in which word-of-mouth process created by previous adopters, is the main driver of new adoptions.

Furthermore, the adoption rate is measured according to the following three variables:

- f(t), that represents the portion of potential market that adopts at time t;
- F(t), that is the portion of potential market that has already adopted at time t;
- A(T), cumulative number of adopters at time t.

2.3 Italian photovoltaic adoption curves.

Focusing on time of innovation adoption is possible to draw two types of diffusion curves: the cumulative number of adopters (blue line in graph 2) and the frequency distribution of the number of brand new users per year (red line in graph 2).

Usually, the adoption of an innovation follows a normal, bell-shaped curve when plotted over time on a frequency basis. (Rogers, 1962).

Furthermore, according to Rogers' theory, there are five types of subjects that takes part in the innovation adoption process (figure 6):

- Innovators: have a high-risk tolerance, financial good availability, excellent technical skills and a strong willingness to try new technologies. They have a key role in the early adoption phase, due to their solid underpinning behavior within the innovation process.
- Early Adopters: they are more integrated into society than the Innovators, however they have a strong influence on potential users. In fact, they are considered as Opinion Leaders. The role of the Early Adopters is to decrease the widespread uncertainty of the innovation process.
- Early Majority: they are a category of persons which is distinguished by the fact of adopting the technology on average before the rest of the population. They require a longer period to weight the decision.
- Late Majority: they are characterized by a scepticism toward innovations, adopting only after the majority of the population. They need more security, even because of their lack (on average) of financial means.
- Laggards: they are the last to adopt innovation in the social system. Often they adopt innovation when it has already been overtaken by new technology considered by the Innovators. They need the certainty that innovation can not fail because of limited financial resources.

As mentioned before, the adoption process is not a linear one, that's why we are taking into account a S-shaped diffusion curve. (Mahajan, Muller, Bass, 1990) During this S-

shaped mechanism, innovation diffusion reaches a Tipping point (Gladwell, 2000). Basically, that is the point where innovation turns out to be widespread.

Gladwell's central argument is that the number of patterns and factors are paramount in virtually every influential trend forecasting, ranging from the spread of communicable diseases to the adoption of a new technological innovation.
Three key components typically determine whether a particular trend will "tip" into wide-scale popularity.
First, the new thought or advancement needs some persuasive early adopters or champions.
Second, the innovation needs a quality or characteristics that individuals find convincing.
Third, the physical and more extensive social environment can be immensely persuasive (Gladwell, 2000).
Therefore, the tipping point represents a situation where the rate of reception takes off.

The domino effect that occurs during this part of the diffusion process continues, notwithstanding for the individuals who are prudent, or have specific misgivings and pratical (such as financial, cultural and social) difficulties with the advancement.

Eventually, the innovation adoption turns into a need, as the usage of the development choices of earlier adopters result in a overall advantage, so it follows that individuals who have not embraced it will lose their status or monetary feasibility.

These relevant consequences - that includes social, cultural and financial relapse, propels a further adoption, even among laggards.

Rogers' spread of innovation

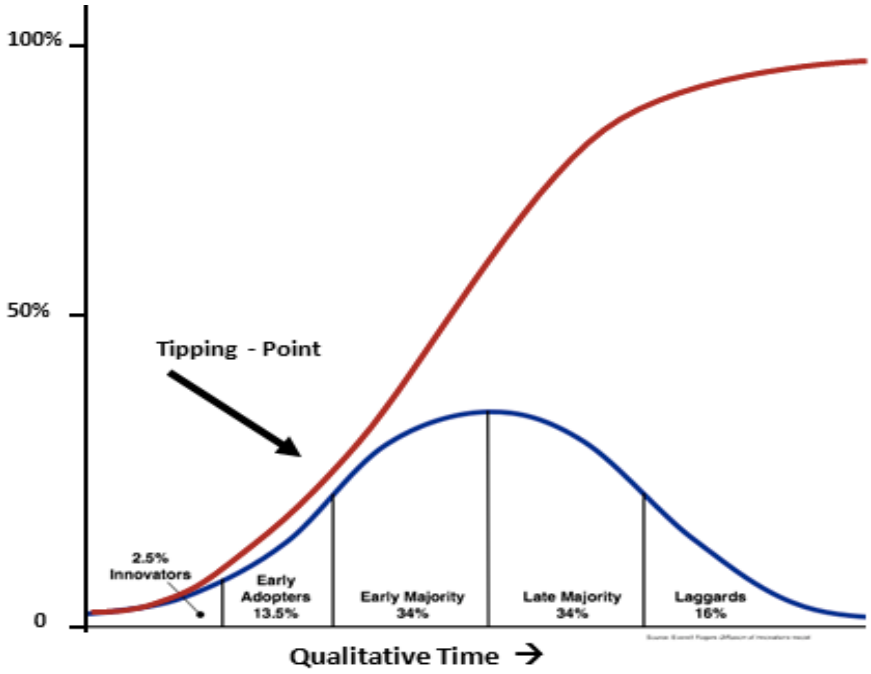


Figure 7: Source: www.onhealthtech.com

According to Figure 6, when a cumulative adoption of innovation rate is plotted, what comes out is a S-shaped curve.

Considering the small number of early adopters at the very beginning of the process, the curve will rise slowly. But consequently, the more the adopters' number, the more the adoption curve slope will increase over time.

As we said in Chapter 1, we are witnesses of a high photovoltaic adoption rate in Italy, therefore I decided to merge and adapt the adoption curve of this green technology to what has been theorised by Bass and Rogers.

This is why in Figure 7 I've plotted data from cumulative plants power of Italian photovoltaic. The increasing adoption rate from 2009 to 2011 - for instance, is due to a variety of reasons.

First of all, its arises manly because of the attracting incentives provided during Second and especially Third Feed-in schemes period (see chapter 1 for details on the Italian photovoltaic market).

According to Rogers, the curve then reaches a maximum, until half of persons within the whole social system have adopted the technology.

Then it starts increasing again, but at a slower rate since fewer individuals adopt the innovation.

Considering the Italian photovoltaic technology adoption process, this conclusive mechanism has been backed by the end of the Feed-in schemes that made the photovoltaic adoption less economically favourable.

As showed in figure 6, the Tipping Point has been reached between 2010 and 2011, indeed, during that period has been registered a stark acceleration in the diffusion process, with an increasing of 9,3 GW of operational power during 2010-2011 period. (GSE statistical report 2011).

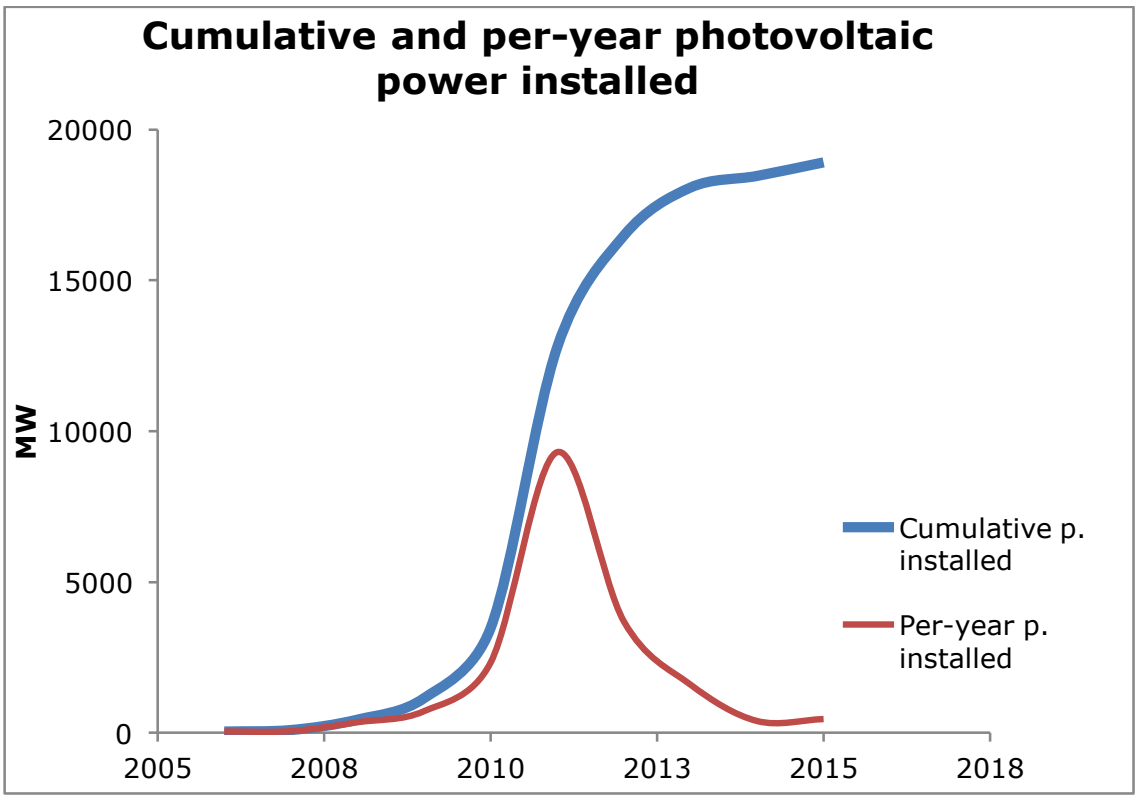


Figure 8. Cumulative and per-year photovoltaic power installed in Italy. Source: www.gse.it

Another reason of such a large growth, has to be attributed to the reduction of uncertainty, and increasing information available on the matter.

As can be seen from Figure 7, the cumulative power of photovoltaic systems began to

rise faster during 2010-2012 period, then slowing down after 2013 and finally reaching a plateau in 2015.
The fact that this growth process started slowly is due to an initial scarce photovoltaic knowledge and an unprofitable incentives' policy for costumers (as showed in Chapter 1).
In Figure 7 is also clear that to this day we are witnessing a stabilisation phase. This is happening because investors and private costumers are waiting to see whether there will be or which will be the next governmental policy related to photovoltaic diffusion.
As mentioned before, the fine point is that political strategies are almost impossible to forecast, and so the uncertainty of adopters thrives.

Going back to period 2010/2011, the information regarding photovoltaic technology was good and the uncertainty regarding the same has been adequately reduced.
This period corresponds to the time when even Late Majority and Laggards have begun to make use of photovoltaic technology, somehow reassured by the increasing users number occurred during the previous period.

The process can be also appreciated looking at the frequency distribution (red line in graph 2) of the number of mean adopters per year, which loosely approach a normal, bell-shaped curve. Italian photovoltaic distribution reached its maximum around 2011 especially because of the reasons mentioned before.

Furthermore, the fact that the adoption rate follows a bell-shaped distribution is also due to the cumulatively increasing influences upon an individual to adopt or reject an innovation, resulting from the activation of peer networks in the social system.
This influence results from the increasing rate of knowledge and adoption (or rejection) of the innovation in that specific system.

As we will see in next section, interpersonal networks play a crucial role when an technological innovation is spreading across people.

For instance, if the first adopter of an innovation discusses about it with two other persons, it's likeable that both these two adopters will transfer the brand-new idea

along to other peers and so forth and so on.
The resulting distribution will be a mathematical function that follows a normal shape when plotted over a series of successive generations. (Rogers, 1962).

Certainly, is not so easy to fit this mechanism perfectly with real life dynamics, especially because it is due to several assumptions and simplification.
For example, individuals from a given framework don't have totally free access to communicate with every single other part.
Status differences, geographical barriers, and different factors deeply influences who communicate with whom about technological development.

The S-shaped dissemination curve starts to take off after a considerable portion of people in a given social framework have embraced the innovation.
Consequently, because of each new adopter finds progressively harder to spread the new thought to a peer who has not yet embraced it, for such non-knowers turns out to be progressively more difficult to adopt the new technology.

However, this network-diffusion process will be analysed more in details in the next section. Now, we are going to take a deeper look into how innovation spreads in a given social framework.

2.4 Innovation diffusion as infection. SI model.

The spread of an infection during an epidemic represents a biological pattern able to explain and well describe the diffusion of an innovation.
In order to compare these two entities, I decided to analyse two most common epidemic models, i.e. susceptible-infected also known as SI model and susceptible-infected-recovered, also known as SIR, model.
Starting from the most basic situation, two states live together during an epidemic: susceptible and infected.
A person in the susceptible state, is a person who doesn't have the infection yet, but could catch it if comes into contact with an individual who does. An infected individual

has the infection and could pass it on if he/she comes into contact with a susceptible person. (Newman, 2010).

According to this, considering an infection-spreading across a population of individuals, we'll define as S(t) the number of susceptible individuals at time t, and X(t) the infected individuals number.

Evidently, the number of infected individuals will increase when susceptible individuals contract the disease from the infected ones.

Let's say that β is the random per-individual rate through which people meet and have contacts sufficient to result in the spread of disease entirely.

Following this, each individual has, on average, β contacts with randomly chosen others per unit time.

As we said, the infection is transmitted just when an infected person has contacts with a susceptible one.

Considering the total population of *n* people, we can define the average likelyhood of a person you meet randomly being susceptible, that is $S/_n$.

Therefore, an infected person will have contact with an average of $\beta * S/_n$ susceptible people per unit time. Considering X infected individuals in total, the total average rate of new infections will be $\beta * S * X/_n$ (Anderson and May, 1980, 1981).

It's possible to write a differential equation for the rate of change of X, that is: $\frac{dX}{dt} = \beta \frac{SX}{n}$.

Simultaneously, the number of susceptible individuals goes down at the same rate: $\frac{dS}{dt} = -\beta \frac{SX}{n}$. This represents the SI model.

Moreover, if is convenient to write variables as the fractions of susceptible and infected individuals, so: $s = \frac{S}{n}$ and $x = \frac{X}{n}$.

Considering apart the entire population of susceptible or infected, thus eliminating s from the equations and substituting it with *1-x*, we'll get $\frac{dx}{dt} = \beta(1 - x)x$.

This equation is known as the logistic growth equation and can be represented in figure 7.

The classical logistic growth curve of the SI epidemic model.

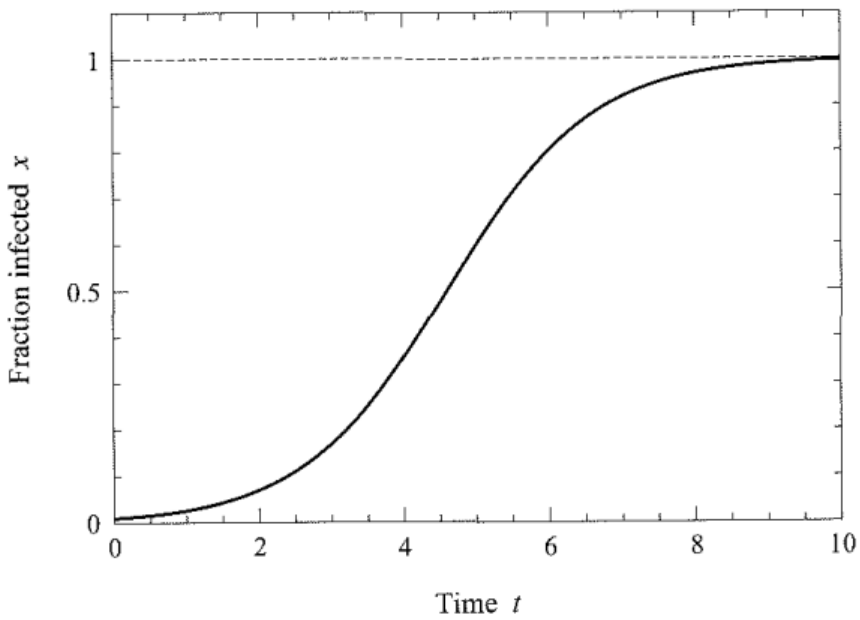


Figure 9. Source: Networks, an introduction. Newman, 2010.

According to figure 7, a small initial number of infected in an SI model (in this example 1%) will at first grow exponentially as they infect others, but eventually saturates as the supply of susceptible individuals is exhausted, and the curve levels off at x = 1. (Newman, 2010).

2.6 Time-dependent properties of epidemic on networks

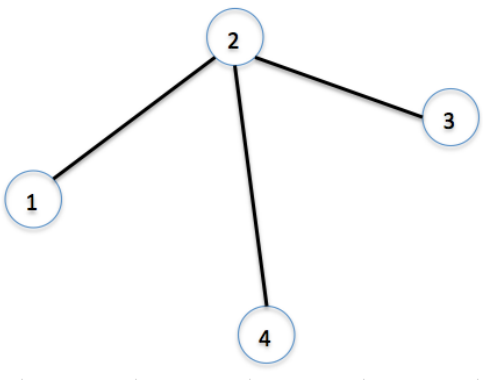
These two epidemic models presented takes into account the fact that during an epidemic, the contacts between infected and healthy ones happens among all the population, assuming that any two people could potentially have contact with one another.

Even though, the chance of a meeting between two people chosen at random from the population of the entire world, is probably small enough to be negligible. (Newman, 2010).

Most of the people meets and talks mostly with peers in their contact network (as neighbours, friends, and folks included in their social system).
Therefore, each person are likely to have more contacts with one another within his/her social sphere, ranging around 100-250 individuals.
The fine point is that the interaction system on which the epidemic diffusion is based on, is represented by a network, that plays a fundamental role in outbreak spread through the population.

The transmission rate within this realistic situation is commonly denoted, that is different from the parameter used in the SI models, because in the fully mixed case it represents the rate of contacts between an infected and all others in the population, whereas in the network case it is the rate of contacts with just one other. (Bokharaie, Mason, Wirth, 2010).
The transmission rate depends both on the kind of disease and on the social and behavioural parameters of the population.
There are diseases more easily to transmit and there are countries where a disease transmission is more likely.
The two models previously described - in this respect, are well adaptable to the contact network issue.

In the network version of this model we have n individuals represented by the vertexes of our network, with most of them in the susceptible state at time $t = 0$ and just a small fraction Xu - maybe even just a single vertex, in the infected state.
With probability β per unit time, infected nodes spread the disease to their susceptible neighbours and over time the disease spreads across the network. (Newman, 2010).
Focusing on the timing of spread in the networks, there are several approaches to analyse the progression of an outbreak; all of these take dynamics into account.



$$A = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}$$

Figure 10: an example of network with 4 vertexes and the adjacency matrix A linked to it.

If, for instance, we take into account the time-dependent properties of the SI model, is possible to investigate the time evolution of the probabilities for vertices to be in specific disease states. (Newman, 2010).

The main difference in network theory - compared with the ones previously described, is that a SI epidemic begins with a single arbitrarily picked vertex somewhere, which spreads to all individuals of the network containing that vertex.

In order to treat in an analytical way the time component of the model, I'm going to focus on the outbreaks occurring to the giant component of the network, especially because during in actual epidemics, who is infected will only come in contact with a small component of the networks and then die out.

So, let's consider a vertex *i*. If the vertex does not belong to the giant component, then by hypothesis $s_i = 0$ at all times, since we are assuming the epidemic to take place in the giant component. (Newman, 2010).
That is logical: if an individual is not susceptible of an epidemic, because is out of the contact network, he/she will be not affected by the disease at all.
Instead, considering *i* within the giant component, is possible to write a differential equation taking into account the probability that *i* becomes infected between times *t* and *t+dt*. First of all the probability that *i* is susceptible is defined by s_i .

Moreover, as said before, in order to become infected, a susceptible individual must come in contact with an infected individual, *j*.

Obviously, *j* must be already infected, and the disease diffusion happens with a probability of $x_j = 1 - s_j$. The infection spread will happen at a given time *t* with the odds at βdt. Now, by calculating these probabilities and summing over all neighbours of *i*, the total odds of *i* to become infected is:

Prob (agent i being infected at time t)= $\boldsymbol{\beta\, s_i \sum_j A_{ij}\, x_j}$ (Newman, 2010.)

Here, A_{ij} is an element of the adjacency matrix.
As showed in figure 8, an adjacency matrix, (given any graph) is a square matrix of order equal to the number of vertices of the graph, that indicates the "adjacency" of its vertices, namely the whose element $A_{i,j}$ is 1 (or true) if there is an edge connecting vertex *i* to vertex *j*, otherwise 0 (or false).
In other words, starting from the assumption that an individual can not have an edge with himself/herself (this is why the main diagonal is composed by zeros) the matrix elements will have value 1 if there is a contact between the two entities considered, and 0 if there is not. The adjacency matrix of a simple graph is a symmetric matrix.
Therefore, the differential equations for s_i and x_i are:

$$\frac{ds_i}{dt} = -\beta s_i \sum_j A_{ij}\, x_j = -\beta s_i \sum_{j} A_{i,j} * (1 - s_j);$$

$$\frac{dx_i}{dt} = \beta s_i \sum_j A_{i,j}\, x_j = \beta (1 - x_i) \sum_j A_{i,j}\, x_j.$$

In the first equation is shown that the probability of being susceptible goes down when vertices become infected. Moreover, it's important to remind that x_i and s_i represent to the entirety of population, therefore: $s_i + x_i = 1$.

Note that the standard SI model corresponds to an adjacency matrix A, where $A_{i,j}$=1 for all *i, j.*

2.7 Applying epidemic models to innovation adoption.

This kind of analysis can be referred to several fields, like medical and biochemical issues, but it could be also used to represent - economically speaking, how a brand new product or service drives the consumers' adoption growth, influencing (with the same pattern of an infection) other customers, therefore spreading the innovation.

It can be used especially with the aim to analyse consumers' adoption growth during the innovation process.
What creates this sort of infection, is the contact between who has been already infected by that innovation and who has not been infected yet.

In this way, is clear how a thick network could be created. This kind of process is sequential: if the products is really useful, reliable and satisfying for customers, a positive feedback will be generated.
So the infection creates a imitation mechanism that - in the case of positive feedback, produces growing number of adopters (therefore people infected) and thus increasing the product diffusion.
This diffusion trend will keep going until the number of potential adopters has been exhausted. As previously discussed, just within the connected component it's possible to observe this kind of "infection".

Therefore, just a limited cluster of potential adopters will be affected by the positive feedback provided by early technology adopters.
What identifies this specific group is represented by who as has been defined as contact network (Acemoglu et al. 2010).
Contact network fosters the innovation spreading, because who are involved in it will have contacts with infected people on a regular basis.

We are not just talking about physical proximity, people within a certain social sphere also shares habits, proclivities, opinions, belonging and beliefs, and so forth and so on. For instance, the epidemic effect played a very important role within who purchases using mobile.

That kind of information spreading gave rise and facilitated social learning to drive consumers' purchasing decisions.

An analysis directed to understand which is the role of word of mouth in consumers' purchase decisions, shows the relevance of word of mouth in customer choices via mobile in US.

Half of all shoppers who used a mobile device prior to purchase are influenced by search results. 50% of mobile shoppers said search results via smartphones influenced their purchases, followed by 42% who said they were influenced by ratings & reviews. (Benjamin, 2014)

Therefore, we can assume that this epidemic process within networks is becoming an established pattern nowadays, and social interactions are something that can not be underestimated when analysing the diffusion of an innovation.

Given that, I will focus on word of mouth as the main tool to foster this process in chapter 5; here instead, I'm going to focus on the link between SI model described above and the innovation spread, as showed in figure 9.

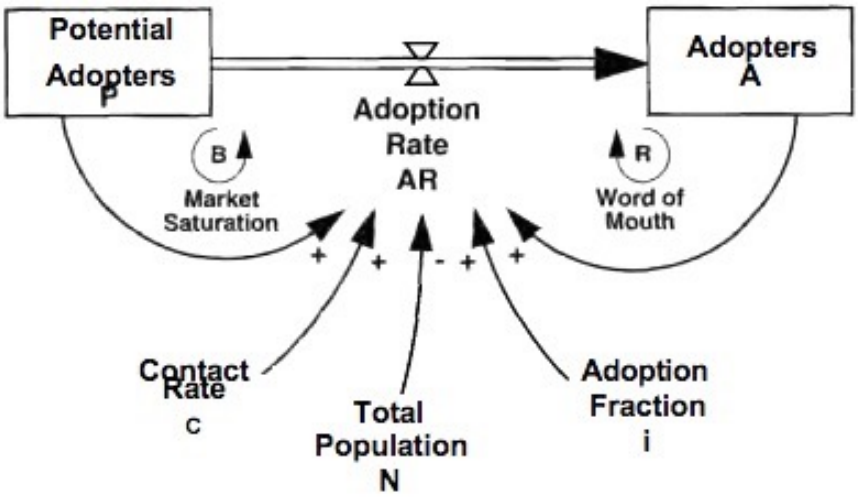


Figure 11. Source: Business dynamics. J. Sterman 2000.

Through social interactions, potential adopters and adopters will come into contact - as showed in section 2.6, within their social network.

Consequently, some of the former will be affected, fostering the new product diffusion among them. Part P represents potential adopters, who are, within the SI model, called susceptible, that is, who is more prone to be infected.

The contact rate shows how many people will come into contact with the infected adopter; the ratio between total number of adopters and population $\frac{A}{N}$ represents the very probability of how many infected people will spread the diffusion through word of mouth.

So we can assume that the adoption fraction *i*, represents the likelihood of adoption, given a contact with at least a single adopter within the network.

Furthermore, this percentage indicates - conversely, the very fact that not every adopters will be able to have a positive influence among potential adopters into their network.

The entities presented in figure 11, can be described as:

- Potential adopters, will be adopters following a process driven by contact rate, that affects the model in a positive way, i.e. the higher the contact rate, the higher the likelihood of adoption;

- The total population number, that is a decreasing function of the adoption rate, in other words the more people adopt, the less is the potential adopters within the population;
- Adoption fraction, that increases its value following the increasing number of individual adopters.

As shown in figure 11, this model is driven by two loops:
a) firstly, we know that the more is the adopters number, the less are potential adopters in the market, a phenomenon of saturation (that is, market saturation), that causes a negative loop (identified as "B" in figure 11);
b) secondly, the word of mouth effect can be considered as a positive, counteracting loop. The more is the adopters number, the higher is the likelihood that word of mouth process will develop, especially because the contact network expansion (identified as "R" in figure 11).

Summing up the whole figure, we can identify the fundamental role performed by SI model within a new technology innovation process, that underlie the infection spreading produced by adopters; nevertheless, we are still missing something.
That's because we are considering a system in which adopters already exist, but we know that the innovation curve must start from a zero point, which represents a situation in which no one is aware of the innovation and no one has adopted the innovation yet.
It's clear that we can't talk about positive feedbacks at the beginning of the innovation process, clearly because it takes time to create and spread them too.

This is defined as the start-up problem. Obviously, there are different ways in which customers' awareness can be stimulated, the most important of these is advertising. Anyway, is paramount to understand how this early diffusion processes are considered within a product's innovation diffusion curve.
Who has been able to overcome the start-up problem was Frank Bass, claiming that what makes aware the potential adopters of an innovation are external information, that stimulate customers' minds and inform them about new products and services.
The intensity of external information diffusion is approximately constant over time.

As previously said, Bass model takes into account the epidemic (or word of mouth) effect described before, and the advertising one - considering social exposure, imitational behaviour and other external effects of awareness,.

Hence, the adoption rate will be the sum of adoption obtained from advertising and adoption from word of mouth. Adoption from advertising will be a function of advertising effectiveness while adoption from word of mouth will be a function of contact rate and adoption fraction.

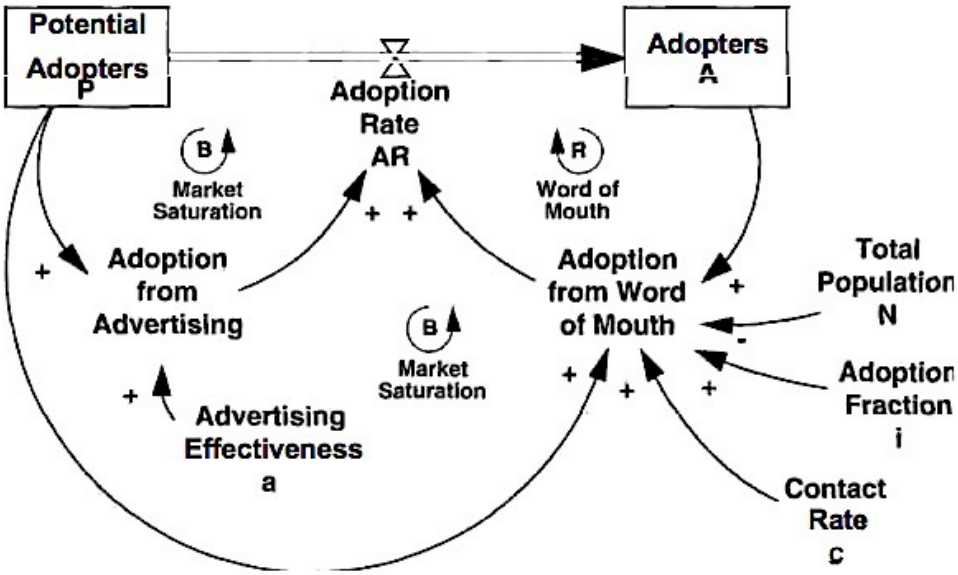


Figure 12. Contact network structure within Bass diffusion model. Source: Business Dyniamics, J. Sterman, 2000.

Figure 10 schematise the interdependence of the elements that affect the adoption rate in the Bass innovation model. The AR (that is, adoption rate) is considered as the sum of people embracing the innovation that comes from two main sources:

a) word of mouth activities;
b) advertising contents.

Adoption from word of mouth are formulated exactly as in logistic or infective models on which they are based on. (Ostojic, 2010)

Bass diffusion model is able to overcome - and in a sense resolve, the start-up problem og the logistic models, basically because AR coming from marketing sources - or advertising one, doesn't depend on the adopter population.
During the starting phase of adoption process, the AR consists only of people who heard about the product or technology from external sources via advertising content through their network; subsequently, whose that already adopted it - that is, innovators - will give a initial start to the epidemic process.

The process of spreading that I've described in this chapter is driven by an underlying mechanism, that is word-of mouth. This can be seen as the milestone on which epidemic models become the leading force within innovation adoption cycle, and so for the viral diffusion of products amd services.
However, due to the need to explain properly this process of adoption, I deliberately limited my analysis in this chapter, focusing on a theoretical approach to it.
I will provide a tangible, in depth perspective on word-of-mouth and on peer to peer interactions in chapter 5.

In summary, it's obvious how ideas that underpins the Bass model are still meaningful nowadays. The fact that innovation is supported by social interactions, is relevant even within other fields, as for sociology, medicine and biochemistry.

According to this, models which better describe this phenomenon are epidemic models, which in spite of the fact that are employed on different fields other than innovation technology, have the same fundamental idea, i.e. outbreaks or innovation adoptions are spread across people within a determined social system, also known as contact network.

In the next chapter, I am going to apply theories described by Rogers and Bass to green technologies adoption cycle, that represent the central point of my dissertation.

CHAPTER 3.

A MATHEMATICAL MODEL TO FORECAST CONSUMERS' DEMAND IN SOLAR POWER MARKET.

Solar energy is the only source of electricity that can be used in a decentralised way, wherever people need it. It is also virtually inexhaustible, while fossil sources of energy are slowly running out and every day are getting more expensive, in terms both of financial burdens and environmental damage.
Nevertheless, climate change and energy supply struggles are steadily driving us towards new technology solutions, that allow exploiting green source of energy - that is, durable, renewable clean energy sources, which means decreasing the expenses and so granting an improved quality of life for us and generations to come.

Green technology adoption process is also incredibly fast. Thinking about 20 years ago nobody would have ever image such a level of green technologies' development, new processes and products that are little by little getting suitable almost for all.
During the last 15-20 years, what has promoted this particular and - in a sense, unavoidable state of affairs worldwide is the very fact that people's choices have been driven by an ethic and economic desire that is quite shifted toward a conscious, responsible adoption of green technologies.

In addition to this, due to an increasing popularity and relevance of green economy, both among consumers' governments' stakeholders, it's clear how this kind of technology have been taking into account the public and private sector.

Keep on fuelling our production using gas, carbon, nuclear energy sources is just unthinkable. We are damaging our environment exploiting resources that are already running out at ever-increasing speed, not to mention climate changes.
So, this shifting - rather than a mere moral obligation - it's the only viable railroad to go.
Considering the improvement of green technology concerning renewable sources of energy, and the increasing consumers' awareness about the topic, it could be very interesting to analyse and understand how costumers behave within this specific scenario. In order to do this, I've developed a demand model as in Ruben Lobel and Georgia Perakis (2011), that is able to describe and analyse perspective consumers' purchase decisions about energy solutions.

3.1 Underlying components of the model

What has prompted this super-fast growth in clean energy installations - that is, photovoltaic panels -, was primarily the government's support, but since facilitation cuts, that green source of energy became hard to afford.
Obviously, several other variables play a major role within this thorny situation, nevertheless, subsidies are the most important one.

In particular, Italian governments' aim is to maximise network externalities by growing the adoption level throughout subsidies, in order to reach a specific target - following the National Renewable Energy Action plans, that is moving from 2505 MW in 2010 to 8600 MW no later than 2020.
Now, with that in mind, it's time to focus on the fine point of my thesis, that is a mathematical model that describe the adoption process of Photovoltaic technology.
I'm going to do this forecasting the demand of a technology that seems to not have ended its growing process yet.
We can assume that a suitable way to define costumers' utility function is creating a model, as in Ruben Lobel and Georgia Perakis (2011).
This approach is called "Consumer choice model for forecasting demand and designing incentives for solar technology".
Nevertheless, before describing how can be depicted a consumer's utility function, it is quite necessary to explain which are the underlying idea of the model at the stake here.

First, we have to consider the cost of components.

According to historical data and technological progress, due to economies of scale and an increasing competition between producers of modules and solar panel installers, the photovoltaic plants' installation is currently characterised by a dynamic, steadily cost reduction.

Besides these two main factors, another mechanism is influencing the Photovoltaic purchasing costs reduction, that is the learning-by-doing effect.

I will focus on it in sub-chapter 3.2, demonstrating how cost decreases thanks to the use of work techniques and material in a better and more efficient way.

Secondly, as mentioned in chapter 2, another process affects the solar power technology diffusion, i.e. information spreading among costumers, and its bringing to a reinforcing, steadily demand process. Graphically, it can be demonstrated that even if information spreads by Word-Of-Mouth mechanism - described in detail in chapter 5 -, thus increasing the adoption rate, maybe it makes them to wait longer for information gathering (Lobel, Perakis, 2011). Anyway, I'm going to analyse this side effect graphically using Matlab in sub-chapter 3.4.

Thirdly, as said in chapter 1 and 2, government is a fundamental actor in this process. Given a positive network of externalities, the aim of the incentives' strategy process is to make solar power technology competitive with other traditional sources of energy, in order to overcome one of the main problem regarding green technology adoptions, brought to light during IPCC 2014 annual report by Vona and Verdolini. (see chapter 1).

Before starting with the model description, is important to bear in mind that different types of incentives are provided in order to foster solar power adoption.

The three main incentive' structures implemented by governments for renewable energy source are:

1) installation rebates;
2) feed-in tariffs;
3) subsidised loans.

In Italy, the first two types of subsides have been embraced by government. From 2005 to 2013 was in effect the Feed-in-Scheme, largely described in chapter 1. Indeed, the future is going to be characterised by installation rebates policies that still allow to return the investment in the near future.

A part from this consideration about incentives and WOM effects, the fine point here is to figure out when this technology will definitely take off and the adoption curve behaviour according to changes in main variables of the model.

3.2. The model

Considering the fact that we are taking into account the two main entities of the photovoltaic adoption process - that is market demand and policy-maker strategies, I decided to focus on the first one, as I believe it is paramount to capture what is the right mix of variables that allows to reach the maximum level of utility perceived by costumers, therefore what will drive consumers' decision and so the market evolution.

As previously said, the main strategy following this approach is to understand which is the role of incentives and WOM effect in solar power technology adoption, analysing and so assessing how consumers' behaviour modifies as rebates level and information spreading varies.
Basically, I identified two fundamental players in this sector. From a model point of view, government can be considered as the "Supplier", bearing in mind that it has the right resources and the capability to dispense incentives.
On the other hand, the demand side is composed of the ones who this policy will be directed toward, hence the costumers. Following this, if we consider every household as a potential costumer, we consider that he/she has two possibilities:

- to adopt
- to not adopt

Now, let's define the variables involved in the model.

$\boldsymbol{M_t}$= represents the market size, namely the total number of households (potential costumers); it's important to bear in mind that we consider the adopters' fraction as percentage. Hence, in our model will assume the value of 1.

$\boldsymbol{x_t}$= the number of customers at a time t that have already adopted the technology, in this case solar photovoltaic panels. When M_t= 0, $x_t = 0$. Otherwise, $x_t = M_t$ if every household in the market has adopted. Theoretically, x_t can assume value 0 at the beginning of the adoption process, but because of mathematical simplification, we have to assume a value close but different from 0. This is due to the fact that logarithm of 0 is undefined, and so its misleading for calculation.

As previously mentioned, government plays a paramount role and it can be seen as the supplier within that model. It's policy is defined by variable r_t. It represents the rebate level offered by government. In my model application I have considered it as a constant at the beginning, in order to better understand which is the adoption curve behaviour when rebate level varies.

$\boldsymbol{q_t(x_t, r_t)}$ represents the demand function, depending on costumers that have already adopted and the rebate level provided by government.
Formally, the adoption or diffusion rate (Mahajan, Muller, Bass, 1990) is defined by $q = x_{t+1} - x_t$. In our case, the number of costumers that adopt at time *t+1* is defined as = x_{t+1}= x_t + $q_t(x_t, r_t)$.
In other words, it represents change in x between *t* and *t+1.*

So the point of interest in this model is the utility level that an average costumer need to perceive to purchase a photovoltaic system, thus embracing the innovation.
This is a function of the current state of the system and the rebate level (Lobel, Perakis, 2011), and it can be written as $\boldsymbol{V_t(x_t, r_t)}$.
In order to adapt the model to our purposes and to calibrate it in a more realistic way, we need to set some basic assumptions:
a) at each time period t, a customer will either buy a single average sized solar installation (denoted AvgSize) or not buy at all;

b) after the purchase, this customer is out of the market: no depreciation, resell or additional purchase options;
c) the solar yield - that is, electricity output, and installation costs are homogeneous across the entire country;
d) the demand $\boldsymbol{q_t}$ for solar panels at time *t* is a function of the utility that consumers gain from purchasing a solar installation at time *t*. (Lobel, Perakis 2011)

Furthermore, we can not underestimate the heterogeneity of consumers' utility, therefore we need a random variable **ε** to take into account all the different values perceived by customers. Consequently, according to what mentioned before, the consumers' perceived utility in purchasing and installing solar power system is:

$$= \boldsymbol{U_t} = \boldsymbol{V_t(x_t,r_t)} + \boldsymbol{\varepsilon_t}$$

Consequently costumer's choices will be driven by this utility function and more specific by its value:

- if it is > 0, they will decide to purchase and install solar panels;
- if it is <= 0, they will decide to give it up.

By assumption d), the demand has the following shape:

$$\boldsymbol{q_t(x_t, r_t) = (M_t - x_t) * \frac{e^{V_t(x_t,r_t)}}{1+e^{V_t(x_t,r_t)}}}$$

It's clear how the term $\boldsymbol{(M_t - x_t)}$ describes the number of consumers that have not installed solar panels yet, while the second term $\boldsymbol{\frac{e^{V_t(x_t,r_t)}}{1+e^{V_t(x_t,r_t)}}}$ represents the likelihood of adoption.
As previously said, that function represents the utility perceived by costumers in purchasing a solar power plant and it depends on several variables and parameters.

First of all it has a monetary value which is not represented by its mere economic value, but rather by the Net Present Value, (NPV), defined as the incremental costumers' wealth generated by solar panels installation over time.

So, we model this value using NPV of an average solar installation purchased at time *t,* defining it as:

$$\boldsymbol{NPV_t(x_t, r_t) = (-k_t\,(x_t) + r_t + d_t)}\textbf{Avg Size}.$$

Where $\boldsymbol{k_t}$ represents the installation costs as a decreasing function of the number of panels sold $\boldsymbol{x_t}$**.** (Lobel, Perakis, 2011). As we said, $\boldsymbol{r_t}$ indicates the subsidy level provided by government and $\boldsymbol{d_t}$ represents the discounted cash flows.

In other words, it is the present value of cash flow that consumers' will receive after having installed solar panels, so it is given as constant, and we consider the Feed-In tariff subsidies as data and the government can further subsidise only by introducing upfront rebates ($\boldsymbol{r_t}$). (Lobel, Perakis 2011).

Finally, AvgSize indicates the size of an average household installation.

Therefore, Net Present Value will be represented by the sum of rebates and the discount rate given as constant, deprived by the implant costs and multiplied by the number of costumers that have already adopted the innovation.

As mentioned before, we refer to solar panels of average size, in order to not take into account a variable linked to different kind of solar panels on the market.

Moreover, a further clarification is necessary: even if variable $\boldsymbol{k_t}$ includes several component costs, we gather in it the total installation costs of solar panels. (Lobel, Perakis, 2011).

Another process that is important to keep in mind is that the more panels are sold, the less is the installation cost.

For instance, as shown in figure 11, where is taken into account the evolution of photovoltaic plants overall cost in Europe, just during 2012-2016 period - within the residential segment -, it has been registered a cost reduction of 13%.

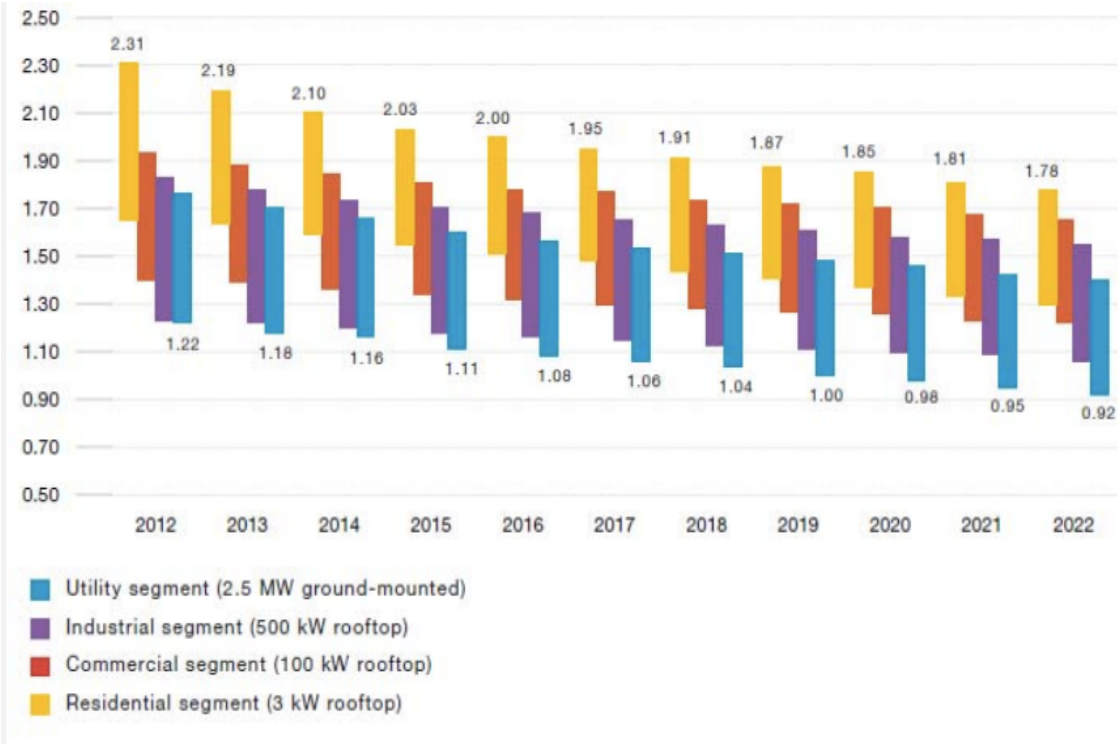


Figure 13. Pv plants cost evolution in Europe. Source: Global market outlook 2016, EPIA.

This mechanism is mainly driven by the learning-by-doing phenomenon, an ever-increasing improvement in know-how and practice which allows exploiting technology advancements to better the efficiency of the whole process - that is, lowering the cost of production and fostering the diffusion of the technology at the same time.

Within such a dynamic sector, a great importance is fulfilled by the experience and by minor, incremental technologies discoveries.
Learning how to use work techniques and material in a better and more efficient manner, allows decreasing costs, thus increasing the cumulative output.

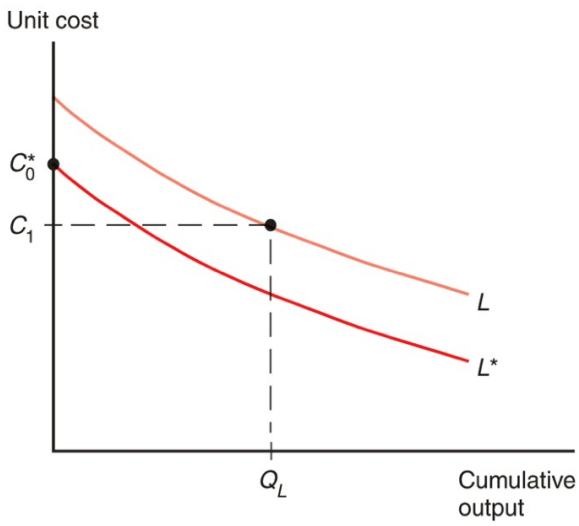


Figure 14: learning curves. Source: http://oregonecon.blogspot.it/

This effect is also due to improved techniques developed by installers, driven by practical experience and a pragmatic approach on the field.

This refinement process could be graphically explained. In figure 13, a company which already operates in a determined sector will have a learning curve defined by L.
L* represents the learning curve of a firm that comes inside this specific market at a later time. In spite of higher starting production costs for the first operating company, it will reach a more efficient cumulative output with lower unit costs compared to the second-operating company.

That is due to the cumulative experience previously described - i.e. the learning-by-doing process, that allows maintaining lower unit costs, improving cumulative output.
Log-log learning curve represents the standard model in the learning-by-doing literature (Lobel, Perakis, 2011).
Therefore, the learning-by-doing effect, according to this model, can be described as:

$$\log(k_t) = \alpha_i + \beta_i \log(x_t),$$

where α_i and β_i are installation costs parameters.

In addition to the learning by-doing-effect, there is another fundamental variable that will influence consumers' behaviour and their purchasing decision, namely the peer effect, or **word of mouth effect (WOM)**.

As we stressed before, in this essay the central assumption is that solar panel technology will be spread due to a viral communication effect between who has already adopted the innovation and who has not installed the plants yet.
This spreading communication effect will cause a sort of chain mechanism of influencing; consumers' choices will be positive affected by other consumers' choices and advices and so forth and so on. For instance, if my neighbour has solar panels, it will be more likely that I will do the same.

This behaviour is explained by the fact that somehow I trust him and I suppose that he has already calculated that his welfare will improve thanks to that choice.
"In particular, we model this effect as a penalty function on the proportion of adopted customers $\frac{x_t}{M_t}$ which lies between 0 and 1.

We propose the following limiting conditions for this penalty function: if nobody has adopted the new technology, consumers are generally unaware of the product and their perceived utility of purchase should go to $-\infty$; If everyone has adopted the technology, $\frac{x_t}{M_t}$ = 1, then this penalty should go to zero." (Lobel, Perakis 2011)

Hence, taking into account monetary parameters, component costs, dissemination and spreading of information and costumers' heterogeneity as well, we are finally able to write the utility function:

$$U_t = a_d * NPV_t(x_t, r_t) + b_d * \log\left(\frac{x_t}{M_t}\right) + c_d + \varepsilon_t$$

where a_d ; b_d ; c_d are demand parameters and $\frac{x_t}{M_t}$ represents the percentage of who has already adopted the innovation on the total number of households.

3.2.1 Comparing the model to the Bass diffusion model

This effect can be easily compared to the Bass model of innovation adoption:

$$\frac{\boldsymbol{f(t)}}{\boldsymbol{1-F(t)}} = \boldsymbol{p + qF(t)}$$

Now, taking into consideration the Bass model, coefficient $\boldsymbol{q}$ **-** that is the coefficient of imitation- can be compared to the word of mouth effect within the Lobel and Perakis model. Coefficient q is also the parameter $\boldsymbol{b_d}$ present in the final utility function**.**

Particularly, in our model the installed base fraction is represented by $\frac{\boldsymbol{x_t}}{\boldsymbol{M_t}}$, while in Bass model this formulation is represented by $\boldsymbol{F(t)}$**;** indeed, the denominator of the first term represents who has not yet installed the innovation - i.e solar panels.
Also, market size is not defined as in Lobel Perakis model as $\boldsymbol{M_t}$, instead is defined as 1; this variation is due to the fact that Bass innovation diffusion model considers the market as percentage.
Hence, the first term of Bass model, represents the ratio between the variation of who has installed the technology and who has not installed at a given time t.
Translating this expression according to Bass model, we'll get this ratio: $\frac{\boldsymbol{1-F(t)}}{\boldsymbol{1}}$ considering total market size = 1.

3.2.2. A comprehensive model for demand

Eventually, we are able to explicitly write down the demand model:

$$q_t(x_t, r_t) = (M_t - x_t) * \frac{e^{a_d NPV_t(x_t,r_t)+b_d \log(x_t/M_t)+c_d}}{1 + e^{a_d NPV_t(x_t,r_t)+b_d \log(x_t/M_t)+c_d}}$$

Bearing that in mind, now we can define a clear set of equation that drives and underpins the demand model, namely:

a) Diffusion process: $x_{t+1} = x_t + q_t(x_t, r_t)$.

b) Logit demand: $q_t(x_t, r_t) = (M_t - x_t) * \frac{e^{a_d NPV_t(x_t,r_t)+b_d \log(x_t/M_t)+c_d}}{1+e^{a_d NPV_t(x_t,r_t)+b_d \log(x_t/M_t)+c_d}}$.

c) Net present value: $NPV_t(x_t, r_t) = (-k_t(x_t) + r_t + d_t)$**Avg Size**.

d) Learning-by-doing effect: $k_t = e^{a_i + b_i \log(x_t)}$.

As showed in section 3.4 is possible apply this demand model on Matlab.

3.3 Conclusions

Considering at the demand model above-mentioned, we came to the conclusion that in order to estimate the most likely customers' utility function, a lot of variables have to be taken in consideration.

I preferred not to weight all the variables considered by Lobel and Perakis, in order to obtain a more simple and immediate model and define an equation able to generally describe consumers' perception and behaviour within solar panels adoption.
I've looked into some variables that I consider explanatory of what drives a client during its photovoltaic purchasing process.

I firmly believe that word of mouth effect and learning by doing effect are the very network externalities that affect most consumers' choice, and so are the ones that had to be taken in consideration analysing the subject of this issue.

Despite it's quite clear how a huge role is exercised by governments' incentives as well, it is not an easy task at all to predict governments' different subsidies rate because of a huge variable that determine it.

Finally, I can state that consumers' choice will depend on:

- the perceived Net Present value, that has been calculated based on the number of customers that have already adopted the innovation and the governments' subsidies, considering a different perception of the financial burdens necessary to adopt photovoltaic technologies among the population;
- the cost function connected to learning by doing effect, that allows a steady reduction in costs;
- the standard utility for installing a photovoltaic system, defined by the parameter c_d;
- the word of mouth effect, conveyed by b_d parameter.

In the following chapter, I will analyse incentives and word of mouth effects on the adoption rate of solar power technology, in order to show how the adoption S-curve modifies according to changing in peer effect rate and rebates level.
Firstly - using Matlab - I decided to make a preliminary quantitative analysis, comparing data obtained from photovoltaic diffusion in Italy, (see chapter 2 for more details) to the diffusion S-curve derived by that model.
Thereafter, I'm going to elaborate a comparative statics, in order to analyse how the diffusion curve varies, taking into consideration different parameters $\boldsymbol{b_d}$ (word of mouth process) and $\boldsymbol{r_t}$ (rebates' level) and values within the model.

CHAPTER 4.

QUANTITATIVE ANALYSIS OF THE MODEL.

To get a consistent interpretation of the model previously described, I used Matlab to trace the S-curve trajectory representing the adoption rate of photovoltaic technology.
Starting from a comparative statics analysis - in order to assess how the adoption rate change when word of mouth effect and in rebates level varies- I calibrated data about solar power technology from the Italian photovoltaic market.
In this way, it is possible to apply the mathematical model described in chapter 3 to realistic data, allowing a better understanding of the theoretical approach on the stake, and how it can be compared to reality accordingly.
In order to carry on these two analysis, I made some assumptions about the model, to made it easier to be translated into Matlab codes.

4.1 Developing the model using Matlab

Considering the comprehensive model for the demand as in chapter 3, it's clear how several parameters have to be estimated in order to get a realistic demand model.
Basically, what we need is an estimate of cost function - represented by parameters a_i and b_i -, and of the consumer perceived utility model - represented by parameters a_d, b_d and c_d.
In particular, in section 4.2 I focus on the specific behaviour of parameter b_d and constant r_t within the model, which respectively describe the word of mouth effect and the rebate level offered by governments.
By the way - in order to avoid complication with the system' endogeneity- it is not possible to estimate these two parameters together.
Following a log-log relationship between k_t and x_t it is possible to estimate the cost improvement function parameters (Lobel, Perakis, 2011) represented in table 15.

	Estimate	Std. Error
a_I	3.05^{***}	(0.0635)
b_I	-0.127^{***}	(0.0065)
R^2	0.907	
$\bar{R}^2$	0.893	

Table 15: installation costs parameters' estimation. Source: Lobel, Perakis 2011.

"The significance level for the estimates in table 15 are satisfactory, as indicated by a p-value less than 0.1% (marked *** on the table). "(Lobel, Perakis 2011).

Furthermore, those parameters concerning demand model have been estimated following the same approach, as can be seen from table 16.

"The significance level for estimates in table 16 are indicated by a p-value less than 1% for b_d (marked ***) and less than 10% for a_d and c_d (marked *). "(Lobel and Perakis, 2011).

	Estimate	Std. Error
a_D	0.164^{*}	(0.112)
b_D	0.657^{**}	(0.240)
c_D	-2.891^{*}	(1.592)
R^2	0.957	
$\bar{R}^2$	0.950	

Table 16. Demand model parameters' estimation. Source: Lobel, Perakis 2011.

Given that, parameter estimation is paramount in order to properly calibrate the model. Nevertheless, we still miss some assumptions to explain how we chose to deal with model estimation.

Bearing in mind the time component, I decided to take into account two different time periods: one that is able to fit into the comparative statics analysis, and one another able to properly compare the Italian data about solar power adoption rate, and so the diffusion curve obtained by the model.

In the first instance, I decided to exploit a long-time range, in order to describe the diffusion trajectory of photovoltaic and so forecasting a possible future scenario.

In order to better understand the diffusion curve behaviour to changing rebates level and word of mouth effects, I used a 30 years' time duration. That made possible to analyse a reliable diffusion trajectory.
In the latter situation, I have considered the time period linked to Italian photovoltaic diffusion - i.e. 10 years, from 2007 to 2016.
The reason justifying this choice of time period is that I think it represents the better way to compare a realistic data analysis to the diffusion trajectory estimated by the model.

Anyway, some further considerations on the number of customers that adopt photovoltaic innovation, are needed. First, I assumed that they range in the interval [0; M_t]; therefore, the zero-scenario in which nobody has adopted the innovation yet, should be represented by x_0= 0.
Nevertheless - as mentioned in chapter 3 - this assumption is not consistent because of the presence of a logarithmic function. We therefore rate $x_0 = \varepsilon$, for $\varepsilon = 0.001$ without any loss of generality.

Moreover, after an estimation of the cost function and consumer perceived utility parameters, I need to define which variables of the model are constant.

In order to do this, I assumed as constant:

1) the average size of photovoltaic plants, denoted as $Avg\ Size$, calculated as the very mean of photovoltaic plants size of Italian photovoltaic market in terms of power installed;
2) the discount rate d_t , calculated considering the Feed in Tariff at time t (FIT_t) and the operation and maintenance costs at time t (OM_t) (Lobel, Perakis 2011). "For simplicity we've decided to consider the discounted cash flow of the panel only for the duration of the Feed-in-Tariff contract. Let (in €/kWp) be the revenue earned at each year for a panel bought at time t. This is the value of the Feed-in-Tariff contract times the average annual electricity output of a 1 kWp nominal capacity solar panel." (Lobel, Perakis 2011).

Furthermore, I've assumed a discount rate of δ_c approximately equivalent to the Italian interbank interest rate which is worth around 0.3% (tradingeconomics.com). The resulting equation is represented by:

$$d_t = \sum_{\tau=1}^{T} \frac{1}{(1+\delta_c)^{\tau}} [FIT_t - OM_t]$$

What is crucial to bear in mind from Chapter 3, is that I consider d_t as constant. This means that we consider the Feed-in Tariff rebates promoted by government as representative data, and the government can further subsidise only by introducing upfront rebates.

- Finally, I've assumed r_t as constant ($\bar{r}$) the level $\bar{r}$ has been chosen in order to make it comparable with k_t and d_t. I took this decision primarily because I am interested in adoption rate variation due to changing in rebates level. Moreover, this assumption makes the model reliable to almost every incentive type, because it does not depend on a specific value.

In light of these assumptions, it is now possible to translate the model into Matlab code. (For Matlab code details, see appendix).
The idea is that starting from a zero-scenario, taking into consideration all the components regarding the demand model - such as monetary component, information spread, cost component and demand function) at time 0, is then possible to iterate the function using a while cycle in order to analyse how the consumers' adoption rate evolves.
Basically, the outputs are time t and the technology adoption x_t . In this way, it is possible to describe the evolution of adoption rate during a time frame t.

According to this - taking into account what previously said, the zero-scenario can be described as follows:

- $\mathbf{x_0 = 0.001}$ that represents the starting adoption rate;
- $\mathbf{k_0 = e^{a_i}}$ that represents the cost function at time 0;
- $\mathbf{NPV_0 = (- k_0 + \bar{r} + \bar{d}) * AvgSize}$ that represents the monetary component at time 0;
- $\mathbf{q_0\ (x_0, \bar{r}) = (M_0 - x_0) * \frac{e^{a_d NPV_t(x_0,\bar{r}) + b_d \log(x_0/M_0) + c_d}}{1 + e^{a_d NPV_0(x_0,\bar{r}) + b_d \log(x_0/0) + c_d}}}$ which describes the demand function at time 0;

Since $x(t) = x(t-1) + q_t(x_t, \bar{r})$, we can update the slope variables up to a final date T_{fin} (see Appendix for Matlab code details).

4.2 Results

Plotting the iterated function previously mentioned into Matlab, what I obtained is - as expected, an S-curve.
The result of the iteration explained above is plotted in Figure 14.
I deliberately decided to use a time frame of 20 years, starting the assessment in the early 2000's and then making a forecasting over the few next years.
Plotting time and the number of customers who have already adopted at time t, what results is.

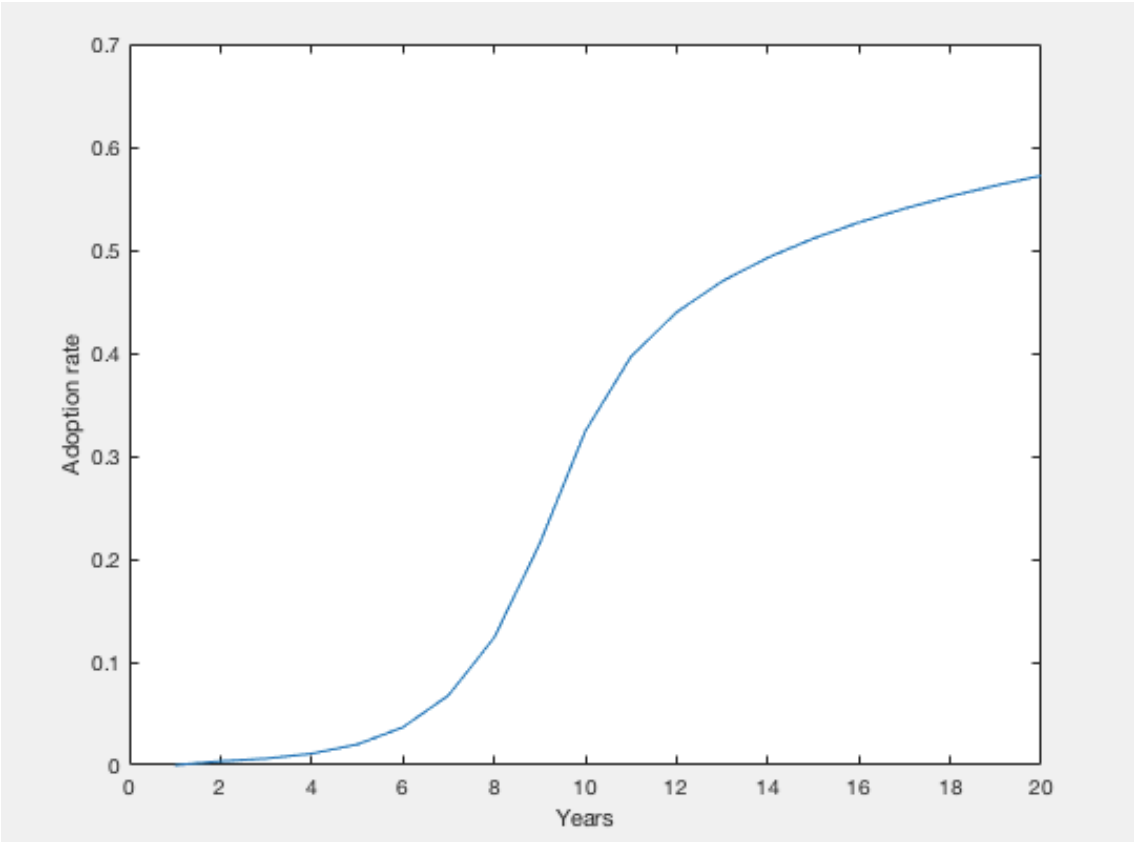


Figure 15: The S-shaped adoption curve obtained plotting on Matlab the model adoption function.

As expected, the adoption rate follows an S-curve, with a slow increment during first six-eight years. A tipping point (for more details see chapter 2) can be observed after eight years: during this period, the photovoltaic innovation turns out to be widespread.

Ten years since- then, the adoption rate seems to stop its incremental growth; interestingly, the curve doesn't seem to stop its growing after 20 years, with a tendency to get flatter but still increasing.

This condition can be explained by the fact that photovoltaic technology has not yet reached its maturity, especially because of the continuous technological process which underlines its diffusion.

It is worth to note that this effect validates our conjecture posed in chapter 2, that is the reduction of uncertainty is directly consequential to the increased number of information available.

In addition, considering the tremendous leverage effect of Internet on word of mouth process within this sector, it's easier for people to get informed and to gather information about photovoltaic.

What is interesting is that this S-shaped curve has been obtained maintaining the incentives' level constant, i.e. not considering a subsidies' variation, as happens. I focus on this changing in section 4.2.2.

Anyway, a way to analyse the adoption curve reaction to a decreasing incentives' quota, as happened in Italian incentives policy analysed in chapter 1, is possible to obtain a different S-shaped adoption curve, as showed in figure 15.

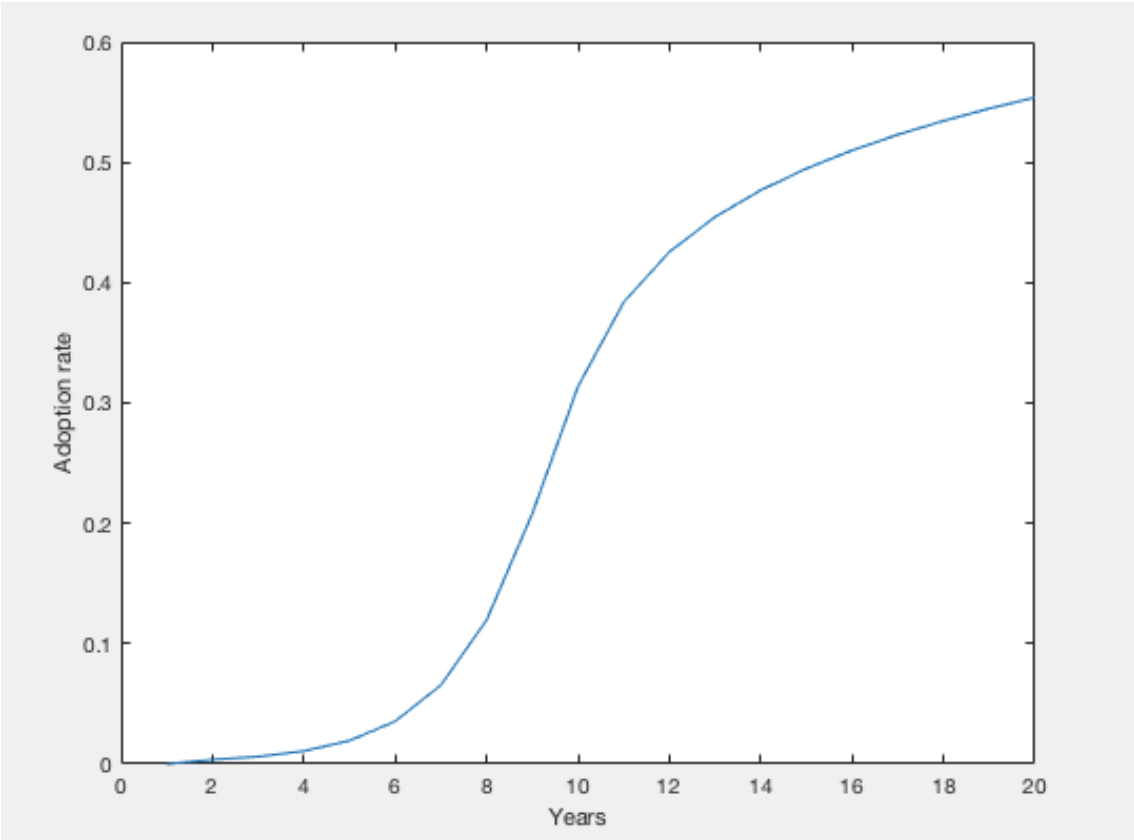


Figure 16. S-shaped curve obtained with a decreasing level of incentives.

Mathematically, the S-shaped adoption curve depicted in figure 15, has been obtained modifying the rebate levels offereb by governments, in Net Present Value formula showed in chapter 3. In other words, the rebate level decreases the more individuals adopt the photovoltaic technology, i.e. $r_t = \frac{r_t}{1+x_t}$.

This assumption makes the model more adaptable to reality incentives' policies.

Anyway, to figure out if the model could be coherent with a real scenario, I decided to compare it to the empirical analysis of the photovoltaic Italian market, already analysed in chapter 2.
In order to do this, I need to calibrate the model to the Italian solar power diffusion over a ten-years-period.

4.2.1 Calibration

In order to adapt the model iterated for twenty years to the photovoltaic Italian diffusion during a time interval of ten years - i.e. between 2007 and 2016, some of the parameters involved in the diffusion curve function have to be re-calibrated.
The idea is that accelerating the diffusion process described by the model, its is possible to compare the two adoption curves.
That assumption gets interesting for two main reasons:

1) it lets us prove whether the Italian solar power diffusion rate is related to the theoretical assumptions which comes from the model and which allows to obtain a S-shaped diffusion curve;
2) as a comparison methodology, it allows us to understand and analyse which parameters have to be changed to compare the two curves.

The result of this re-calibration can be seen in figure 15, where the blue line represents the adoption curve obtained by the calibrated model, while the red curve represents the Italian photovoltaic adoption curve during the 2007-2016 period.

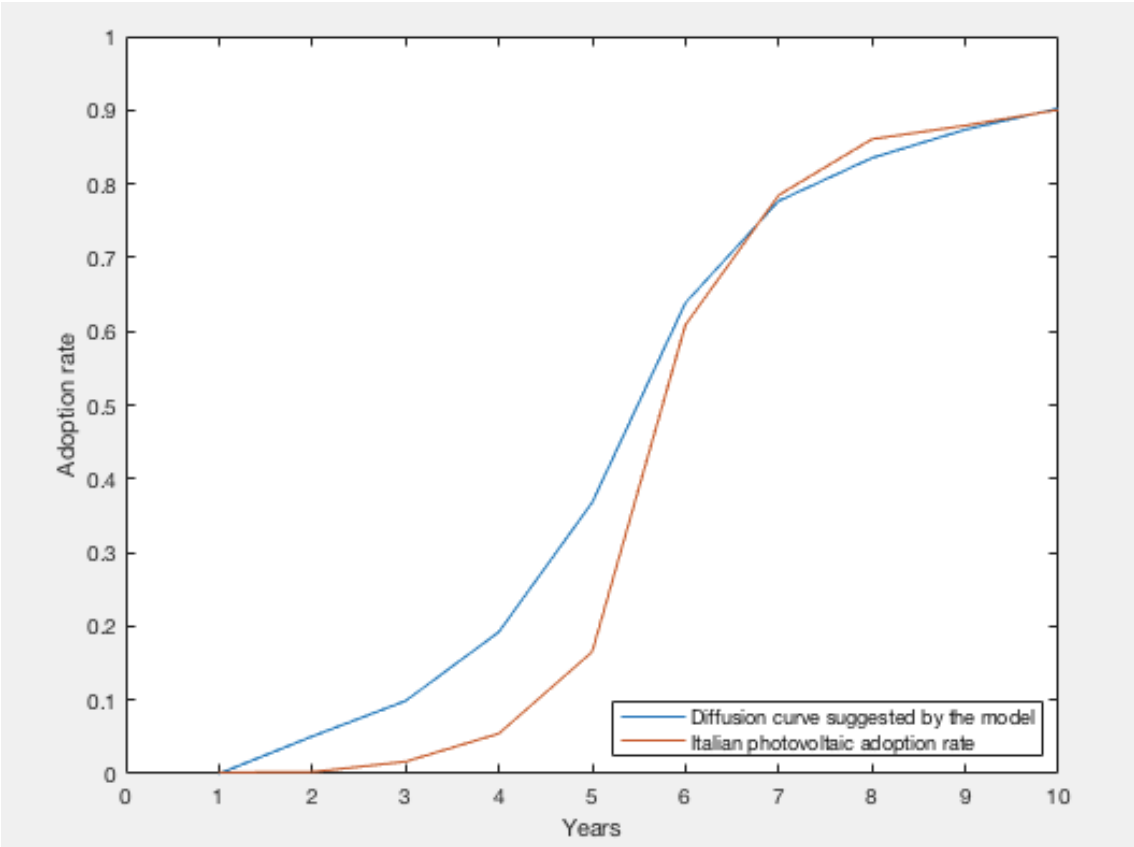


Figure 17: comparison between Italian photovoltaic market adoption rate (red line) and diffusion curve suggested by the model (blue line).

Using Matlab (for Matlab coding in details, see Appendix), I found out that in order to compare the two curves, two parameters have to be re-calibrated: the installation costs parameters and the parameter which describes the information spread in the consumers' utility. In particular, I decided to decrease the latter and increase the formers.

Firstly, we can say that the more time passes, the more frequent are the contacts between people (who I've called market size in chapter 3) and so the more likeable is the spread of information.

Therefore, reducing the value of information spread parameter, it is possible to obtain a diffusion curve that fit within a period of ten years.

More in details, starting from an information spread parameter's value of $b_D = 0.650$, in order to compare the two curves I reduced the parameter value of 7.7%, therefore obtaining a new value for parameter $b_D = 0.600$.

Secondly, if we reduce the time period from twenty years to ten, cost parameters have to be increased too.

This can be explained considering two issues: first of all - as shown in chapter 3, learning by doing process get more efficient as time went on. Furthermore, considering the incremental improvements that bring cost reduction within this specific sector, it is clear how the whole process is strictly linked to the time issue.
In other words, the more time passes, the more technology improvements will be obtained, and so the cost reduction due to more efficient technologies that allows exploiting photovoltaic innovations in a cheaper way.
In details, increasing the two cost parameters a_i and b_i of respectively 14.75% and of 84% has been possible to obtain a significant comparison between the two adoption curves.
Furthermore, from this parameters' variations can be inferred that calibrating the model adoption curve on a ten years' basis, brought to a substantial variation of the costs related parameters, along with a less significant change of parameter related to word of mouth. That probably means that costs parameters are more sensible to a diffusion time reduction, whereas word of mouth effect seems to have been less influenced by the time variation.

Moreover, considering the blue line of figure 15, it is clear that the adoption process has not reached its maturity phase yet, in sharp contrast with the Italian photovoltaic market adoption rate which - according to figure 15, doesn't seem to provide a clear diffusion process in the immediate future.

One possible reason of this discrepancy, is that the future of Italian photovoltaic market will be driven by other not foreseeable mechanisms.
On one hand, it's not an easy task to forecast how much the information spread will affect the diffusion of this technology during these years in Italy.
On the other hand, the incentives' level provided by government is not possible to be calculated right now, as discussed in chapter 1.
The future situation seems to depend on the legislator choices and policies which will strongly affect the adoption curve of solar power technology.

4.2.2 Comparative statics

According to the model above-mentioned, I decided to run some comparative statics in order to try to develop the main point of my dissertation, i.e. understanding which are the effects of word of mouth and incentives' systems mechanisms in the adoption of photovoltaic technology.

So, if we take into account the model described in Chapter 3, it is possible to assess the influence of the information spread process varying the parameter which describes the incentive value - initially given as constant.

In this way, it is possible to figure out which would be the more efficient rebate level able to assure a higher adoption rate, and consequently, forecast the consumers' behaviour according to changing rebates level.

What is paramount to bear in mind now, is that I'm not trying to define an equal or "right" specific incentive level.

In other words, I will not focus on a specific value of incentives, because it depends on several variables linked to different countries' economic situation and legislative policies.

Instead, I want to focus on incentives' variations, in order to try to forecast how consumers react to that and how much these affect consumers' decisions.

Therefore - following the model described in chapter 3 - I will keep in mind the parameter which describes information spreading b_d, and so the constant which represents the incentives level r_t.

In that sense, it should be reminded that I run this analysis maintaining the S-shaped adoption curve measured on a 20-years basis as a fixed time period, then comparing to it the new curves obtained, varying the duration of the period and so the b_d and r_t values.

I have decided to consider a time period of 20 years for two main reasons: on the one hand, to analyse the life-cycle of photovoltaic technology (around 15 years) - and on the other hand, to forecast the effects of the two variables considered in the next 5 years.

Consumers' reaction to information spread variation.

In order to analyse the word of mouth process influence in the adoption of photovoltaic technology, I've taken into account three different scenarios.
Assuming the initial value $b_d = 0.675$, I've analysed the adoption curve behaviour following these parameter variations:

- b_d= 0.5 therefore decreasing the parameter value of 35% represented by the red line in figure 16 ;
- b_d= 0.7 therefore increasing the parameter value of 3.57% represented by the yellow line in figure 16;
- $b_d = 0.80$ therefore increasing the parameter value of 18.5%, represented by the green line in figure 16.

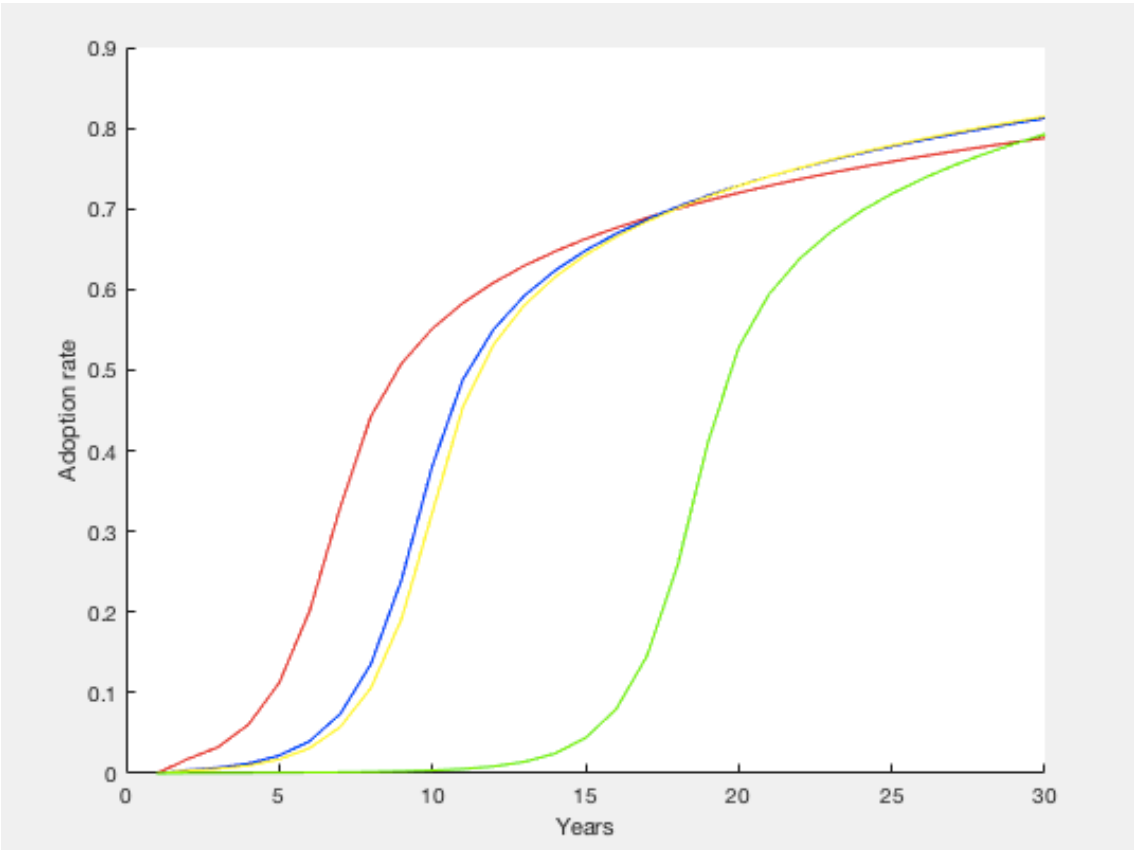


Figure 18: adoption curves obtained by information spread parameter variations.

Figure 16 shows four different adoption curves. As said, the blue line shows the initial scenario described by the model analysed.
Now, it can be noted that the yellow line seems to follow the behaviour of the diffusion curve described by the model: the reason for this is that a small variation of the information spread parameter doesn't affect strongly the adoption rate.
Given that, I decided to focus on two scenarios that provides an important parameter variation, i.e. red line and green line.
This is the way to analyse the consequences in consumers' behaviour that follows a strong parameter variation pattern. Red line represents the adoption rate with a 35% decreasing of information spreading parameter.
The adoption curve seems to be higher during the initial part of the innovation diffusion, while it crosses the other diffusion curves after about 15 years.
At this pivotal point, it is clear that the diffusion rate is lower than other three diffusion curves'. So, we can state that reached a critical point, a stronger information spread between costumers reinforces the adoption process.
In general, with a decline of the word of mouth effect, the costumers' adoption rate is higher (compared to the zero-scenario) at the beginning of the S-curve, while after a period of 15-20 years the situation is inverted.
This is exactly what we were expecting: in the long term, with a decreasing of the information spread effect - and consequently of the adoption rate, the willingness to purchase for customers decrease sharply.

The effects of an increasing in word of mouth effect are visible in the green adoption curve. Despite a slower initial adoption rate, after a critical quota around 20-25 years, the willingness to purchase of customers increases over the long term.

How can we explain such a behaviour? According to Ulu and Smith, the reason is the fact that the more the information available for costumers about that technology, the more the time they get to gather all the information. (Ulu and Smith, 2009).
This explain why at the beginning of the adoption curve - with a sharp increasing of the word of mouth effect (green line in figure 16), the adoption rate is lower compared to the others curve, where the peer effect is less strong.

Nevertheless, in the long term the adoption rate it seems to affect the curve in a stronger way, increasing costumers' willingness to purchase solar panels accordingly.
Another reason that can explain this mechanism is the fact that within this specific sector, the decision to install solar panels does not lead to an immediate installation, therefore the social interactions have an effect only when solar panels have actually been installed, or rather, when a customer has experienced the benefits of the panels.

Bollinger and Gillingham (2012) have showed that this effect is significant in the adoption of solar panels in California.
In particular, they showed that an additional solar installation increases the probability of another solar installation in the same zip-code by 0.78 percent.
This effect happens because consumers become increasingly more aware about a new technology as more people buy the product.
In our case, the more rooftop panels are adopted in a block, the more other consumers in the neighbourhood will become prone to adopt the technology as well (see Goolsbee and Klenow (2002). (Lobel, Perakis 2011).

Consumers' reaction to rebates' level variation.

Another effect that we should take into account is the consumers' reaction - in terms of adoption rate - to a given variation of rebates' level.
As mentioned several times during my dissertation, incentives play a fundamental role in the spreading of this kind of innovation.
Given that - starting from a zero scenario with a level of incentives defined by the model described in chapter 3 -, now I am going to measure the effects of a variation of the incentives' quota in costumers' purchasing decisions.
My purpose here is to understand to what extent the incentives provided by governments affect the diffusion curve during the adoption process.
Using Matlab, I decided to analyse the effects due to a variation of the constant r_t.

Note that it's paramount to keep in mind that my analysis on Matlab does not take into account an incentive policy decreasing year by year - as it appears in reality.

I made this decision in order to focus my analysis on how incentives' quota variations affect the technology diffusion curve.

As before, I lined up this analysis to the zero-scenario in order to make some comparisons - graphically, which are possible to observe in figure 17.

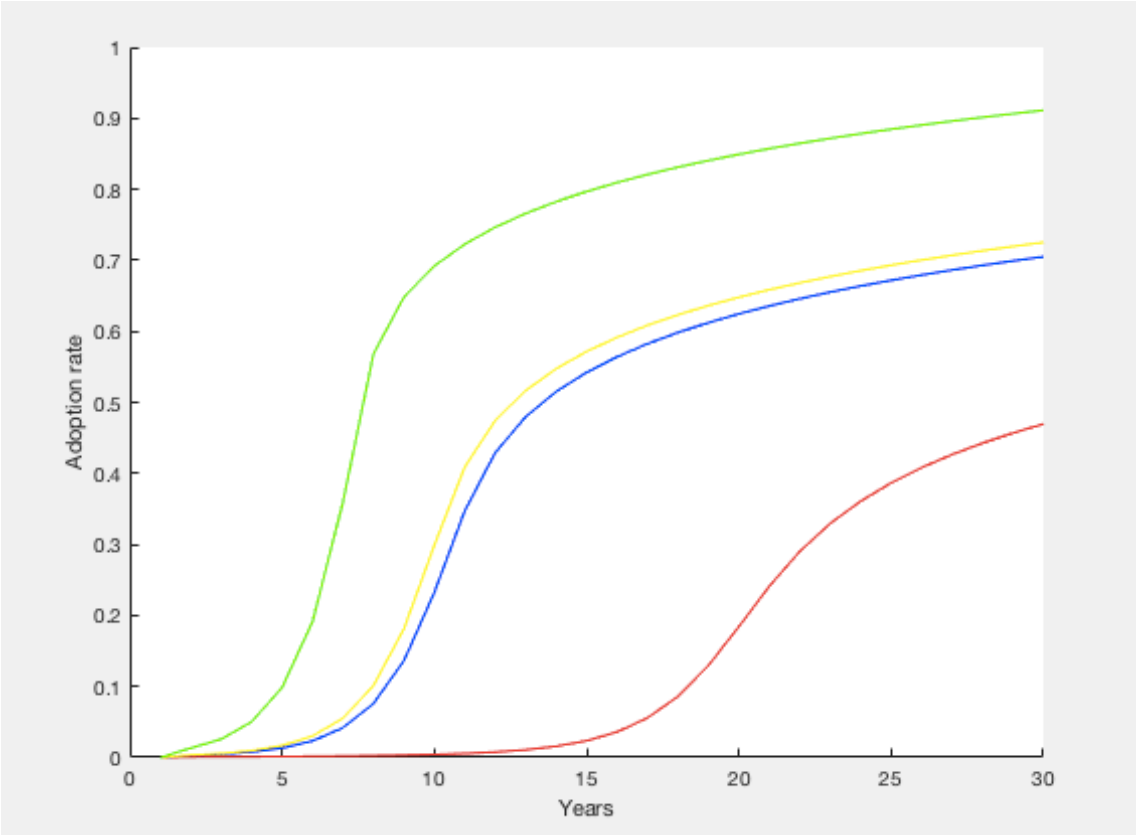


Figure 19: adoption curves obtained by rebates' level variations.

The red line in figure 17, represents an incentive policy obtained by a rebates' level reduction of 25% compared to the zero-scenario (blue line).

The yellow line represents a small variation in incentives level provided to customers, i.e. a reduction of 2% compared to the zero-scenario.

It means that a small incentives level variation, do not affect consumers' purchasing behavior.

Finally, the green line represents a diffusion curve corresponding to an incentives level increase of 25% in comparison with the zero-scenario.

So what can we infer from figure 17? Firstly, if we consider the model analysed in chapter 3 as a pretty good and reliable representation of what is like, taking into account the new diffusion curves obtained varying the rebates' quota, we can assume that an incentive policy turns out to be very important in photovoltaic technology adoption.
With a reduction of 25% in incentives' quota within the zero-scenario, it is possible to notice an innovation spread delay of 10-15 years, that continues - with lower adoption rate, throughout all the diffusion process analysed (30 years).
Moreover, if big variations do not occur in the rebates' level (see yellow line in figure 17), it is clear the positive influence that an increase of the rebates' quota provides to the consumers' willingness to adopt the solar power technology.
For instance, I compared the three curves evolution at specific intervals, i.e. at 15th year, at 20th year and at 25th year of diffusion process.
In details, a reduction of the incentives level of 25% (red line) causes a reduction (I've always compared data with the zero-scenario) in the adoption rate of 98% after 15 years, of 70% after 20 years, and of the 38% after 20 years.
Also, with an increase of the incentives' level of 25% (green line) causes a rise in the adoption rate of 85% after 15 years, of 40% after 20 years and of 32% after 25 years.
Therefore, comparing those data - in terms of adoption rate, with the zero-scenario ones, I found out that the most significant variations in terms of adoption rate occurs during the first 10-15 years of the adoption process.
In order to study it, I've considered an initial time period of 15 years, and that is because otherwise the adoption rate that follows an incentive reduction of 25% would not have been measurable. (see red line in figure 17).

Given that, it is clear how an incentive policy during the first years of the technology spread sector fed a stronger willingness to embrace the innovation among customers.
As showed by the red line in figure 17, that "delay" of the adoption curve influenced by a reduction of the incentives' quota, slow down the spreading of the innovation.
Therefore, I can state that the best strategy is to encourage with a high rate of rebates the early adopters, stimulating the early phases of the innovation diffusion.
Then, during the mature phases of the process, the quota of subsidy could be gradually reduced, considering that the adoption rate will be strongly supported by the word of mouth process carried out by the early adopters.

CHAPTER 5.

THE IMPORTANCE OF PEER EFFECTS IN TECHNOLOGY DIFFUSION: TESLA'S 0$ MARKETING BUDGET.

From a theoretical point of view, word of mouth process (or peer effect) plays a crucial role in technology diffusion.
As showed in section 4.2.2. this concept can be relevant also when we talk about photovoltaic technology and its diffusion process.
On one hand, the peer effect seems to delay the innovation diffusion, given that for consumers it takes time to gather all the information available.
Nevertheless, on the other hand it fosters the dissemination of innovation, therefore producing effects in the long term.

Focusing on green technologies, the issue is very interesting both for policy makers and for marketers, taking into account the fact that this process can arouse social spillovers which foster the adoption process. (Bollinger, Gillingham, 2012).
In general, as said in chapter 3, during the renewable energy technology adoption process, this mechanism reinforces the positive loop process claimed by Bass (1969). In other words, potential adopters are affected by the pressure that early adopters carried out, thus initiating the diffusion of photovoltaic technology. This causes that some of these potential adopters get persuaded to adopt the technology.
Thanks to this fact, the number of adopters increases, and this leads to greater take-up through the peer effect. (Mutingi, Matope 2013).
Undoubtedly, other effects accompany the adoption rate evolution, as for example promotional efforts done by photovoltaic technology providers, governments and interested stakeholders (Mutingi, Matope 2013).
By the way, unlike these effects, word of mouth process is hard to be measured, because it concerns qualitative data that sometimes are not possible to directly correlate to the innovation adoption curve.

Therefore, the limit of this issue, is that this mechanism is not easy to measure, hence is not easy to understand which has been the word of mouth specific role in innovation spread.
There are no many companies which base their marketing strategy on word of mouth, directing their marketing campaign towards the creation of advertisements.
The exception is represented by Tesla, which thanks to the "0$ marketing budget" strategy is revolutionising the way to do business, not only within the automotive sector but also in the field of renewable energy.

5.1. How to measure peer effects. The case of Californian photovoltaic diffusion.

As said, social interactions between costumers may result in social spillovers i.e. a marketing action which indirectly affects an agent to whom it was not initially directed.
However, social spillovers are anything other than random effects; instead, they are caused by causal social interaction effect.
This is an issue that should be taken into account by companies, because it strongly affects their marketing activity.
Basically, social spillovers foster the adoption curve evolution because they allow to spread the technology towards a wider audience.

As a consequence, it's clear that there is a tie between social interactions and the diffusion process.
One way to measure this kind of connection - i.e. between the word of mouth process and social spillovers - is to take into account the geographical proximity of new installations. In other words, how a new photovoltaic installation in a given place – designated by its zip code - affects the probability of an additional installation in the neighbourhood.
It's clear how this process is nurtured by peer effect. (Bollinger, Gillingham 2012).

Considering the peer effect influence on the adoption rate evolution, every stakeholder within green industry should take into account that process of dissemination.

In particular, policy makers have to establish the right policies in order to maximize the positive externality - greenhouse gas emission reduction - backing at the same time the technology adoption rate.

As said, word of mouth process is as important as hard to measure, because consumer's decision to purchase a solar power system, is not immediately followed by the actual installation.
Rather, it will come after having been completed the necessary paperwork and, after the lead time required to complete the installation. Moreover, the adoption of regulated or incentivized products will delay further the real installation.
In that sense, the installation of a solar power system in the same zip code is not necessarily correlated to peer effect.
This fact proves that - as discussed in chapter 4 - the installation lead time delays the word of mouth process, making harder to establish a direct correlation between two installations within the same zip code.
Social interactions do not have a clear effect until the photovoltaic system has been installed. More specifically, social interaction effect will be felt once neighbours would be able to notice the benefits of this technology talking with the adopters.
In order to reduce the error due to the installation lead time, we can take into account the adoption phenomenon according to different photovoltaic installation in different zip codes areas.
As showed in an analysis conducted in San Francisco Bay area, in California, it's not obvious that more densely populated zip codes tend to have more installations, while less densely populated ones have few installations.

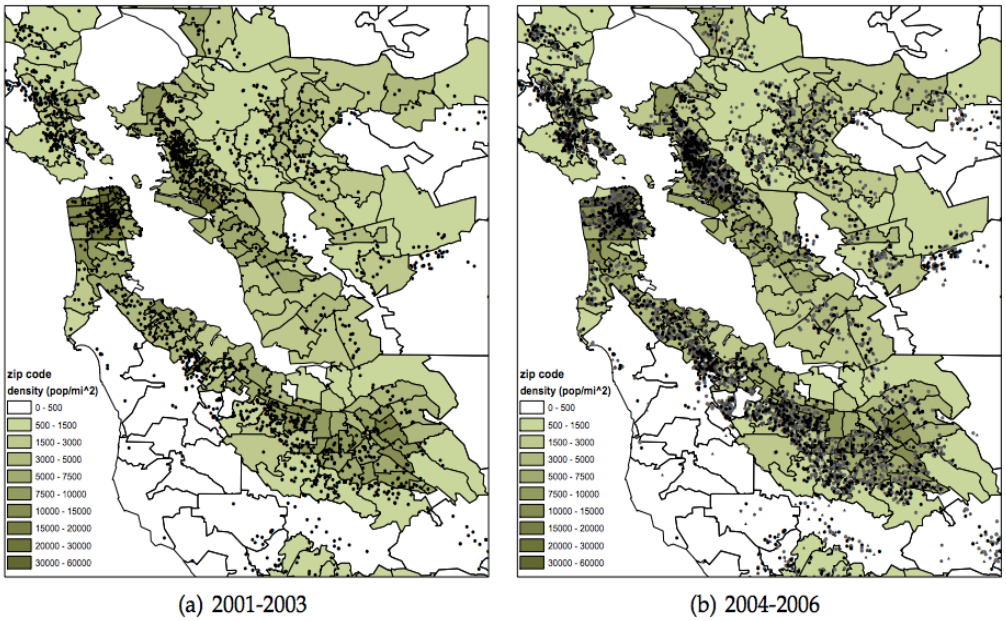


Figure 20: clustering in solar power installations in the San Francisco Bay Area, California, between 2001-2006.
Source: "*Peer effect in the diffusion of solar photovoltaic technology";* Bollinger, Gillingham, 2012.

Indeed, considering photovoltaic installation between 2001 and 2006 in California (figure 18) it becomes clear how there are densely populated zip codes with few installations and less densely populated ones with many installations.
What does it mean? Either it is indicative of peer effect or spatially correlated preferences, "perhaps due to clustering of environmental preferences" (Kahn and Vaughn 2009).

From figure 18, it is possible to identify another evidence of the existence of peer effects: the adoption process accelerates in regions with more installations.
The fact that new installations imply an increasing adoption effect can be explained by the marketing efforts to leverage peer effects, with the aim of induce a more rapid dissemination of the new technology.
This is why several companies try to focus their marketing efforts to foster the word of mouth effect. One of this is Tesla (I focused on its marketing strategy in section 5.2) and it's not by chance that Tesla's CEO, Elon Musk, is also the co-founder and chairman of Solar City, the largest solar panels installer in California.
This company's strategy is efficiently described by Bollinger and Gillingham.

“It involves finding one or two vocal solar advocates in a neighbourhood and giving the entire neighbourhood a slightly lower price if enough adoptions are made within that neighbourhood. Some firms commonly increase the visibility of new installations by putting up a sign indicating that a solar PV panel has been installed at that location”.
Accordingly to Bollinger and Gillingham, having analysed the Californian photovoltaic market, it has been showed that an extra installation in a zip code increases the probability of an adoption in the zip code by 0.78% points when evaluated the average number of owner occupied-homes in a zip code.

Word of mouth effect can also reduce the uncertainty related to the installation.
This process can be fostered by the transfer of opinions and ideas about what concerns photovoltaic installation (rebate level, tax incentives, pay-back time..). As seen in chapter 4, whilst this mechanism encourages the adoption rate increasing, it also delays the technology adoption time, because the stronger is the word of mouth effect, the more time to gather all the information is needed. (Lobel, Perakis, 2011).
Therefore, peer effects have a positive impact on the adoption rate of photovoltaic installation. It can be seen as an instrument able to overcome the higher barriers in adoption of this technology, i.e. consumer uncertainty.
As a matter of fact, in order to expand the market companies such as Solar City are trying to cope with this critical issue leasing solar panels to consumers.
They take care both of installation and maintenance; moreover, they guarantee to refund the costumers if the system will not perform as guaranteed.

SolarCity's community is a group of 200,000 solar ambassadors promoting photovoltaics in the neighborhoods, in the office, or on Facebook and Twitter and widely and tirelessly explaining the benefits of renewable energy, also because they receive $ 200 for each new customer that the PV they can convince. (greenreport.it)
That is the referral mechanism which I will describe in section 5.2. accounting for Tesla’s Referral program.

Undoubtedly strategic actions like these allow to win consumers’ confidence, thus reducing the uncertainty barrier, increasing costumers’ and ultimately, rising the possibility of referral.

Again, it is no accident that Elon Musk, the co-founder and chairman of Solar City is the co-founder, CEO, and product architect of Tesla Motors, where gave rise to a marketing strategy, almost completely based on word of mouth effect, named "$0 Marketing budget".

5.2 Tesla's 0$ marketing budget

"Tesla motors has no advertising, no ad agency, no CMO, no dealer network, and that's not a problem." – Advertising Age.

Is it possible to entirely base your marketing strategy on word of mouth process? Is it possible to make your costumers become your products' sellers, almost without paying them? For Tesla Motors, Inc., an American automaker and energy storage company, the answers are "yes".

As said, the marketing strategy of this multinational company is almost entirely founded on peer effects, i.e. exploiting customers' positive experiences to build a network of satisfied customers, who throughout word of mouth can expand the demand for Tesla's vehicles.

This allows the company to avoid advertising investments and so set aside these financial resources for enhance its products, taking care of bottleneck issues and investing in R&D.

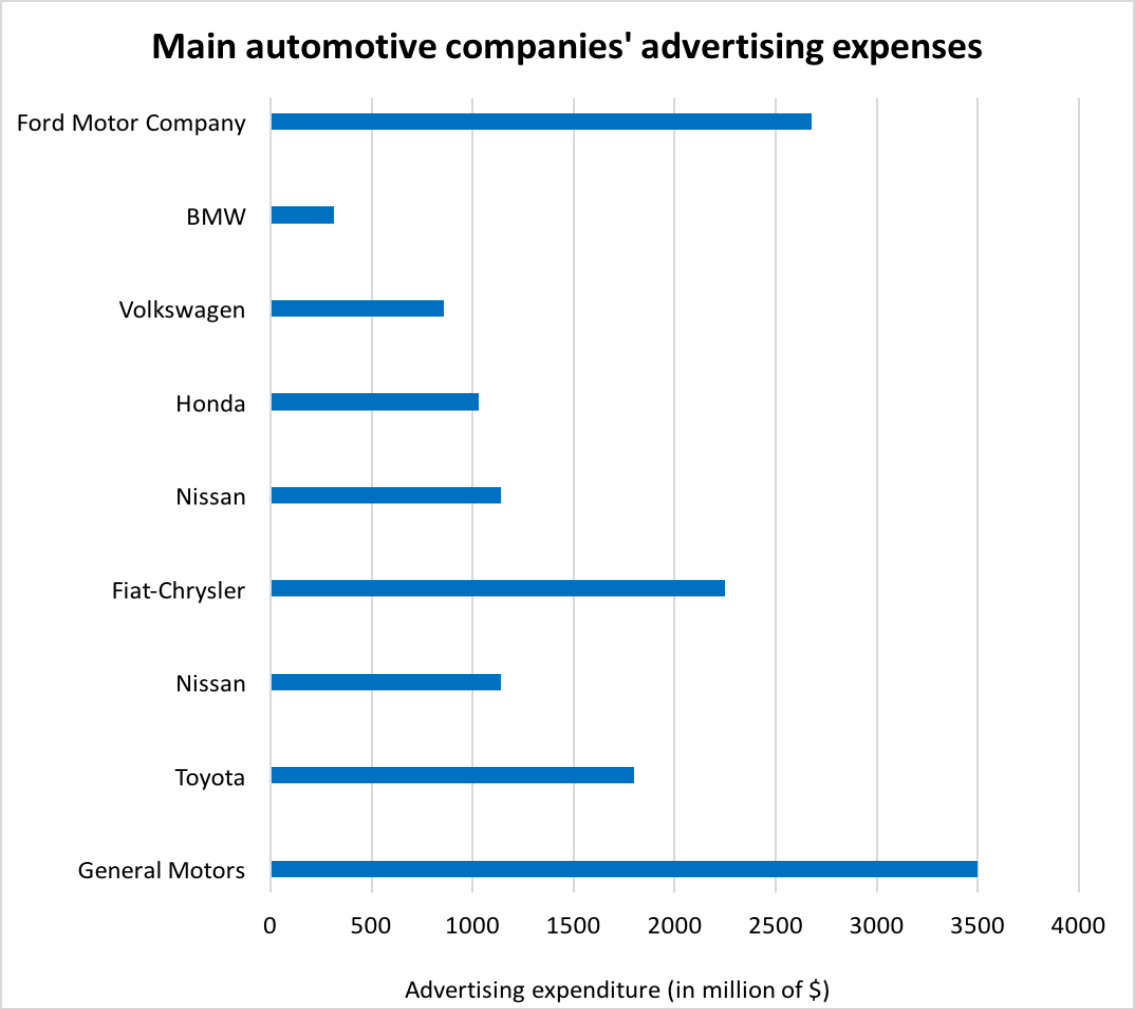


Figure 21. Main automotive companies' advertising expenses in 2015. Source: AdvertisingAge.com

If we compare Tesla's spending in advertising with the money committed by other main competitors to establish their marketing campaigns, (as showed in figure 19) it's immediately clear what is the savings' size.

I'm talking about huge figures, considering that the automotive sector is ranked as the second category for advertising expenses in a rank which took in consideration Advertising expenses in US during 2015. (AdvertisingAge.com).

In order to have an idea of the expenditures' size, is sufficient take a look to figure which shows that for instance Ford Motor Company's advertising expenses are in order of size of $4 billion.

Undoubtedly, this strategic move is not for everyone; i.e. it is earned, not bought. Selling an innovative, cutting-edge, newsworthy product allows you to catch the consumers' and medias' interest.
These are two fundamental actors when we talk about word-of-mouth strategy. In fact this is the case of Tesla.

Tesla's co-founder, CEO and product architect Elon Musk, has showed to firmly believe in this kind of strategy, as showed in solar panels diffusion throughout Solarcity, described in section 5.1.
He decided to not advertise Tesla's product (from Model X to Tesla Powerwall) on posters, TV commercials, nor on newspapers' advertisements, creating a real disruptive marketing strategy.
Certainly, the way in which Musk interacts with the Tesla's community helps to create this kind of social interaction effect.
He incentives communication through Tesla's blogs, providing his costumers continuous updates about the company, taking advantages of social medias as Twitter — where he has followed by almost seven million of people — in order to keep his community up-to-date about everything is new about the company.

These are many ways to foster the word of mouth process and so expand the social interaction network, which represents the main Tesla's marketing goal.
This strategy — namely "0 marketing budget" — which leverages on a $0 investment in advertising policy, rely on Tesla's CEO, Elon Musk, who is intended as the vertex of an imaginary word of mouth pyramid.
Immediately below there are customers, who are the very advocates on which this word of mouth strategy is clearly based on.
This kind of pyramidal structure can be related to Rogers' theory described in section 2.3. According to it, Elon Musk represents the innovator *par excellence*, with a high-risk tolerance, financial good availability, excellent technical skills and a strong willingness to try new technologies; while early adopters are to be intended as top influencers.

In order to move towards the early majority and beyond, Elon Musk realised he has to invest not only in his product, but also to foster the fine social interactions that are at the bottom of the diffusion process.
In other words, he has to invest to create a market.

In particular, a clever use of Elon's Twitter and Tesla' Youtube channel — which counts millions of followers and views, respectively — are two of the main ways exploited by Tesla to reach its goal (See TED talks, "Elon Musk, the mind behind Tesla), that is to spread the word of mouth process between costumers.
Anyway, in order to reinforce and accelerate peer effects, Tesla established a referral program, capable of expanding the demand for its products and to increase the social interactions network.

5.2.1. Tesla's referral program

The main goal of Tesla's referral program is to turn its costumers into company's advocates. They motivate people — early costumers first — to spread the word, thus expanding the demand for their products within their circle of friends and close acquaintances.
An example of Tesla's referral program is represented by the member-get-a-member formula, which rely on the costumers' gratification to obtain new adhesions to a specific service or a greater number of purchases of a given good.

The underlying idea of the referral program is that the strongest source of new customers are the current ones.
This mechanism can be sustained with an incentive, which can be distributed either to the new customer or to the product's advocate.
Undoubtedly, to maximise the peer effect — as in Tesla's case — it should be distributed to both the actors.

How do Tesla's referral program work?

One of the main Tesla' competitive advantage over traditional OEMs is its incredibly effective referral program. "Tesla treats advocates like heroes and give them unique rewards only it can offer". (Extole.com).
The company is letting its customers to make the job that an advertising campaign should perform, that is reach potential consumers, engage them successfully and eventually perform a conversion.
A Tesla review found that the cost of selling a car through its stores costs about $2000. (bloomberg.com). "Saving that amount would let the company give that money to customers". (Elon Musk).

However, marketing campaign based on positive customers' experiences doesn't represent something totally new. This innovative communication technique has been already used within the marketing strategy of another Musk' company, PayPal.
The ruse in that case was to offer $10 of deposit if a brand new client referred the online payment service to a friend, who wuold have gain the same amount when the registration is completed. Following Luke Nosek, another Paypal co-founder, at least 1 million people took up the offer. (Bloomberg.com).
The fine difference here is that convincing someone to buy a car sold for around $60,000 - $80,000 it's definitely harder than persuade him to submit some personal details into a sign-up sheet. This is why Elon Musk stated "What worked for PayPal may not work for Tesla, but it is worth trying".

According to what mentioned in section 5.1. about Solarcity, the solar provider company uses a similar referral program to foster the photovoltaic technology diffusion. This marketing strategy is coherent with what has been demonstrated by Bollinger and Gillingham and with what I asserted in chapter 4, i.e. peer effects can foster the photovoltaic technology adoption.
As showed in figure 20, company's strategy is awarding with $200 the "solar ambassador" and with a first full month of solar power offered by SolarCity, the new costumer.

Figure 22. SolarCity's referral program showed on company's website. Source: mysolarcity.com

Different Referral program steps.

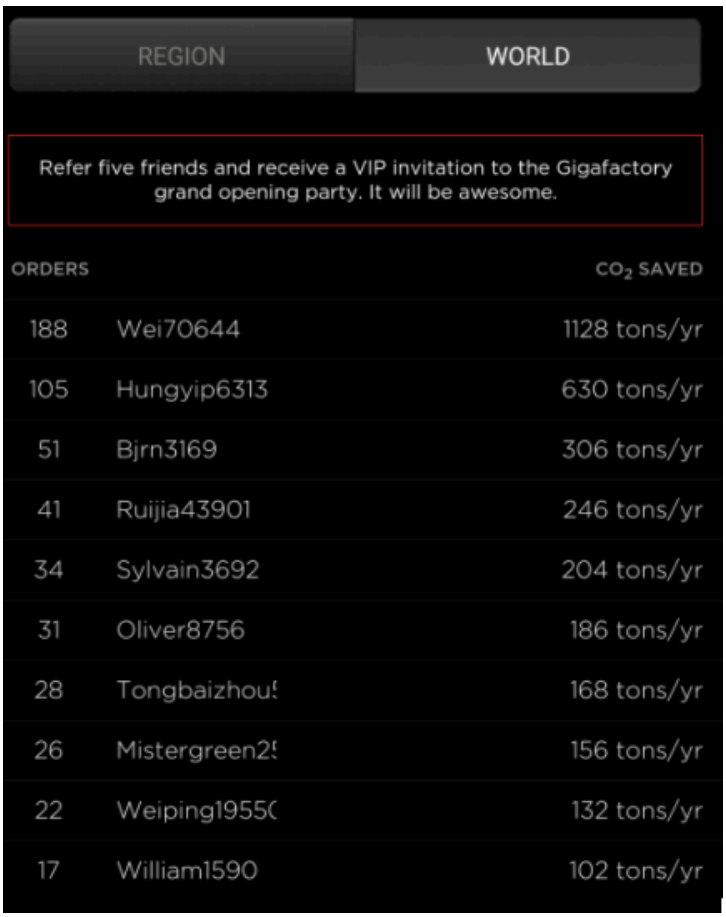
Tesla' referral program has been articulated as an evolving process, based on different strategic goals. They had modified and improved it through time, exploiting some innovative ideas developed within the company.

In the first phase, the program envisaged a $1000 in "Tesla credit" both for new referred customers and advocates. It was primarily used as a testbed to see how consumers would have responded to the initiative.
Rewarding both costumers and advocates allows to avoid the fact that incentivized only the advocates could be perceived as a selfish move.

During the second phase of the referral program, Tesla decided to implements the program itself, rewarding the most influent advocates for each region — i.e. North America, Europe, Asia) — with a new Tesla P90 model, a home wall-charger and a ticket to the grand opening of Tesla's Gigafactory in Nevada.

An order of magnitude of Tesla's economic advantage obtained by the referral program is showed in figure 21.

The top overall advocate, with the nickname Wei70644, referred 188 people, bringing about 16 million in sales for Tesla, at a cost of around $135,000 for his prizes. (Tesla.com).



REGION | WORLD

Refer five friends and receive a VIP invitation to the Gigafactory grand opening party. It will be awesome.

ORDERS		CO_2 SAVED
188	Wei70644	1128 tons/yr
105	Hungyip6313	630 tons/yr
51	Bjrn3169	306 tons/yr
41	Ruijia43901	246 tons/yr
34	Sylvain3692	204 tons/yr
31	Oliver8756	186 tons/yr
28	Tongbaizhou!	168 tons/yr
26	Mistergreen2!	156 tons/yr
22	Weiping1955(	132 tons/yr
17	William1590	102 tons/yr

Figure 23. Results coming from the second Tesla's referral program step. Source: electrek.com

Given this data, it is possible to summarily calculate how much Tesla has earned from this word of mouth action.

First of all, let is calculate the incentives cost provided by Tesla. Basically, the company has payed $1000 both for the advocate's action and as a "Tesla credit" to the new customers. Therefore, it payed an amount of $2000 for each order obtained by referrals, along with the expenses linked to the top-advocate-rewards, i.e. less than $100,000.

Taking into account the top overall advocate, who brought about 188 orders, it is now possible to calculate how much Tesla obtained with that referral action: $85,000 for every model S sold, therefore around $16 million. (tesla.com).
Despite its rough approximation, this simple calculation allows to figure out how much Tesla's has earned just from the top overall advocate word of mouth, i.e. around $15 million. So, what is absolutely sure here is that the benefits are exceeding the costs related to the referral program.

The 3rd phase of the referral program brought about another disruptive idea: along with a $1200 of incentive for new customers, advocates were entered a raffle to win a tour at Space X (whose CEO is Elon Musk) headquarters in Los Angeles.
That allows Elon Musk to "sell a vision of the future in which everyone zips around in zero emissions cars and can travel to other planets at will." (Extole.com).
This move obviously reinforces the engaging process exploited by Musk, that is the creation of a visionary-innovative community of advocates.
The final steps of Tesla referral program were based on advocates' rewards, according to the referrals number, along with a $1000 in Tesla credit.

In conclusion, we can state that referral marketing is the cornerstone of Tesla's marketing strategy and it can be said that it is generating an extraordinary outcome.
As previously said, it's a resultant that is earned, not given. So, we can argue that without a cutting-edge, innovative and newsworthy product it is extremely hard to take advantage of the word of mouth process.
First with PayPal and with Tesla, Elon Musk has demonstrated that this is a mechanism which can allow your company to spend money in a more efficient way, as for example in R&D development, instead of using that money for advertising expenses.
He showed that it works, although the referrals are made on a high-priced, cutting-edge product and services.
Talking about this, as appears in the "Secret Tesla Motors Master Plan" Tesla's CEO' idea is to start selling luxury cars, expanding then over time, so that is possible to reach a broader consumer base. (Tesla.com)

Certainly, the success of such a strategy depend upon of the the very perception about the product that you are able to build up inside consumers' minds.
A great product concept allows you to create a larger social interaction network around it, and so the demand of it.

As previously mentioned, the advantages of this strategy are not just in the increased number of orders. It also helps to raise people awareness about Tesla's products, services and corporates' culture.
Perhaps, the company will reap the benefits of this mechanism in a near future, during which the company will be able to produce and sell low priced-high volume cars, increasing its target market and consequently, its customers' network.
Another important perspective about referral program, is that it is useful to understand which are the geographic areas in which Tesla's cars are more sold, and which are the areas where a different marketing effort is needed.

I've stressed several times during my dissertation the importance of word of mouth process in innovation technology diffusion.
Tesla's case seems to validate this thesis, having made the referral program as a key part of its brand and its growth strategy.

CONCLUSIONS

The main goal of my thesis has been the identification and characterization of the drivers of green technology adoption, specifically, photovoltaic technology adoption.
Regarding this, I found that consumers' choices are mainly driven by two components.
On one hand, consumers' purchasing choices are influenced by an economic and financial component fostered by incentives' policies, whereas on the other hand individuals' purchasing actions are in part driven by peer effects, which are able to create social spillovers aimed to nurture the information spread.

Taking into account the economic component, incentives' policies influence costumers' purchasing decisions because are able to overcome the high economic expenses which concern photovoltaic plants installations.

In my thesis, I tried to analyse the importance of incentives in technology adoption rate, that is corroborated by the difference in installed plants in Italy - in the amount of 32% - from 2014 to 2015, exactly the period which registered the end of the Feed-in-Scheme, the most important incentives' policy issued by Italian governments.
The rebates' relevance in the adoption of this kind of technology has been proved from a mathematical point of view as well. Indeed, thanks to the model developed, it has been possible to demonstrate how much an incentive policy affect consumers' decisions.
With regards to this, it has been shown how a reduction of 25% in incentives' quota, delays the adoption process of 10-15 years.
This rebates' reduction also influences in a negative way - i.e. reducing the adoption rate - the entire adoption process all along its duration.
On the other hand, has been demonstrated how an increase of the incentives' level of 25%, considerably rises the adoption rate – and in the same way, costumers' willingness to purchase a solar power system - of 85%. This growth happens especially during the first 15 years of the diffusion process, decreasing progressively its effectiveness as time goes on.

Therefore, this analysis provides a measure to understand how much the adoption process can be affected by governments' policies.

Along with an effective incentives' policy, it has been demonstrated that also the information spread plays a fundamental role in the photovoltaic technology diffusion.
In order to understand in what measure these affect the innovation curve, I run a comparative static analysis, which allowed to figure out the real importance of information spread within the diffusion process.
According to this, it has been demonstrated that an increase in word of mouth effect, is more effective, in terms of adoption rate, in the long term.
In other words, a stronger peer effect has more pronounced effects on the second part of the curve, i.e. after 10-15 years from the beginning of the diffusion.
This mechanism is probably due to the fact that the more information is available for costumers, the more time they will get to gather all of the information.
Another probable reason for this, is that within this specific sector, the decision to install solar panels doesn't lead to an immediate installation. Therefore, the social interactions have an effect only when solar panels have actually been installed, or rather, when a customer has experienced the benefits coming from the solar power installation.

Anyway, what is important is that the word of mouth effect is more effective after a critical time quota, i.e. around 15-20 years. After this span of time has passed, has been showed that the customers' willingness to purchase increases.

This theory, related to the mathematical model, has been confirmed in reality as well.
Indeed, it has been shown that an additional solar installation increases the probability of another solar installation in the same zip-code by 0.78%. This mechanism happens because consumers become increasingly more aware about a new technology as more people buy the product, i.e. solar power systems.
That is another evidence of word of mouth – and, more broadly, of peer effects - importance within the photovoltaic technology adoption.

In addition to this, Tesla's case provides an interesting example of how a company can base its marketing strategy almost entirely on peer effects, obtaining profits from positive customer experiences.

This study can provide interesting sparks to governments in order both to set the right incentives measures and to leverage on word of mouth effect when designing policies aimed to increase the adoption rate of a specific technology.

As said, an incentive policy provided during the first years of the technology spread sector fed a stronger willingness to embrace the innovation among costumers.
In light of this fact, the best policy would be the one which encourage the early adopters with a high rate of rebates, stimulating the early phases of the innovation diffusion. Then, during the mature phases of the process, the quota of subsidy could be gradually reduced, considering that the adoption rate will be strongly supported by the word of mouth process, carried out by early adopters.

The conjectures proposed at the beginning of my dissertation has been proved, bearing in mind that incentives policies issued by governments and word of mouth effect are two of the main drivers of the sector.

The key point is that we should stop seeing these reforms as useful only from the environmental point of view, and begin to explore how to make them acceptable to interest groups which are mainly involved. In other words, investments should be oriented to increase costumer awareness and engagement.
To this aim, it is essential to make customers aware also of the financial advantage which comes from the solar photovoltaic technology, i.e. savings related to the electricity autonomy.

Undoubtedly, just focusing on these two aspects will not guarantee a rosy future to photovoltaic technology, especially, as mentioned by Luca Gatto, because of fossil fuels lobbies.

It is no secret that these companies struggle to limit customers' awareness of the advantages coming from photovoltaic technology. Nonetheless, this phenomenon seems just to decelerate the green technology adoption, without stopping it.
Therefore, governments' task will be double: on one hand, it should foster solar power technology adoption through effective incentives' policies, whereas on the other hand, it should economically protect the main actors, i.e. thermoelectric companies, which at the moment play a lead role in the sector.

In conclusion, the photovoltaic technology diffusion process seems to not have yet reached its maturity phase, i.e. the grid parity, even if it seems that it will be reached soon, especially because of the decreasing solar module costs.
As shown, two drivers can accelerate the diffusion process, even if it is still limited by thermoelectric lobbies which pushes towards a future based on fossil fuels.
It's very likely that the automotive sector will drive this change. For instance, Tesla - one of the main competitor within the electric cars sector – is one of the main innovators of this process. As claimed by Elon Musk, its aim is to provide an electric car not only able to be fuelled by electricity but also exploiting the electricity which comes from renewable sources.
This "electrical circle" can really represent an effective push to foster photovoltaic – and green - technology diffusion.

"Obviously, Tesla is about helping solve the consumption of energy in a sustainable manner, but you need the production of energy in a sustainable manner. "
Elon Musk

APPENDIX

Adoption rate obtained by the model, Matlab code.

```
a_d= 0.164;
b_d=0.657;
c_d=-2.981;
a_i=3.05;
b_i=-0.127;
r_t=80;
d_t=0.95;
AvgSize=0.45;
x_0=0.0001;
k_0=exp(a_i+b_i*log(x_0));
NPV_0=((-k_0)*x_0+r_t+d_t)*AvgSize;
q_0=1*(exp(a_d*NPV_0+b_d*log(x_0/1)+c_d)/(1+exp(a_d*NPV_0+b_d*log(x_0/1)...
   +c_d)));
i=1;
T=20;
x=x_0;
q=q_0;
NPV=NPV_0;
k=k_0;

while (i<=T-1)
 x(i+1)=x(i)+q(i);
 k(i+1)=exp(a_i+b_i*log(x(i+1)));
 NPV(i+1)=((-k(i+1))*(x(i+1))+r_t+d_t)*AvgSize;
 q(i+1)=(x(i+1))*(exp(a_d*(NPV(i+1))+b_d*log((x(i+1)))+c_d))/(1+exp(...
 a_d*(NPV(i+1))+b_d*log((x(i+1)))+c_d));
 i=(i+1);
end;

time=(1:1:20);
plot(time,x/12.1);
axis ([0 20 0 0.7]);
```

Adoption rate obtained by the model, calibrated on a 10 years' basis, Matlab code.

```
a_d= 0.164;
b_d=0.650;
c_d=-1.281;
a_i=3.5;
b_i=-0.020;
r_t=80;
d_t=0.95;
```

```
AvgSize=0.45;
x_0=0.0001;
k_0=exp(a_i+b_i*log(x_0));
NPV_0=((-k_0)*x_0+r_t+d_t)*AvgSize;
q_0=1*(exp(a_d*NPV_0+b_d*log(x_0/1)+c_d)/(1+exp(a_d*NPV_0+b_d*log(x_0/1)...
   +c_d)));
i=1;
T=10;
x=x_0;
q=q_0;
NPV=NPV_0;
k=k_0;

while (i<=T-1)
 x(i+1)=x(i)+q(i);
 k(i+1)=exp(a_i+b_i*log(x(i+1)));
 NPV(i+1)=((-k(i+1))*(x(i+1))+r_t+d_t)*AvgSize;
 q(i+1)=(x(i+1))*(exp(a_d*(NPV(i+1))+b_d*log((x(i+1)))+c_d))/(1+exp(...
 a_d*(NPV(i+1))+b_d*log((x(i+1)))+c_d));
 i=(i+1);
end;

time=(1:1:10);
plot(time,x/3.75);
axis([0 10 0 1]);
hold on;
```

Adoption rate obtained by the model as a function, Matlab code.

```
function[time,x] = P1(b_d,r_t)

a_d= 0.164;
%b_d=0.657;
c_d=-2.981;
a_i=3.05;
b_i=-0.127;
%r_t=80;
d_t=0.95;
AvgSize=0.45;
x_0=0.0001;
k_0=exp(a_i+b_i*log(x_0));
NPV_0=((-k_0)*x_0+r_t+d_t)*AvgSize;
q_0=1*(exp(a_d*NPV_0+b_d*log(x_0/1)+c_d)/(1+exp(a_d*NPV_0+b_d*log(x_0/1)...
   +c_d)));
i=1;
T=30;
x=x_0;
```

```
q=q_0;
NPV=NPV_0;
k=k_0;

while (i<=T-1)
 x(i+1)=x(i)+q(i);
 k(i+1)=exp(a_i+b_i*log(x(i+1)));
 NPV(i+1)=((-k(i+1))*(x(i+1))+r_t+d_t)*AvgSize;
 q(i+1)=(x(i+1))*(exp(a_d*(NPV(i+1))+b_d*log((x(i+1)))+c_d))/(1+exp(...
 a_d*(NPV(i+1))+b_d*log((x(i+1)))+c_d));
 i=(i+1);
end;

time=(1:1:30);
%plot(time,x);
```

Comparative static analysis, rebates' level variation, Matlab code.

```
bb=0.5:0.01:0.80;
rr=60:1:100;
b_d=0.675;

for i=1:length(rr)

   r_t=rr(i);
   [time,x(:,i)] = P1(b_d,r_t);

end
 hold on
plot(time,x(:,1),'r');
plot(time,x(:,18),'b');
plot(time,x(:,20),'y');
plot(time,x(:,40),'g');
```

Comparative static analysis, information spread effect's variation, Matlab code.

```
bb=0.5:0.01:0.9;
rr=70:5:90;
r_t=80;

for i=1:length(bb)

   b_d=bb(i);
```

```
    [time,x(:,i)] = P1(b_d,r_t);
    end
 hold on

x2=x/9.5;
 plot(time,x2(:,1),'r');
plot(time,x2(:,18),'b');
plot(time,x2(:,20),'y');
plot(time,x2(:,40),'g');

 axis([0 30 0 0.9]);
```

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