A simple model of competing theories, with network externalities and adoption costs

Patrick Blanchenay*

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Abstract

This essay builds a simple model to analyse the dynamics of adoption between two competing ideas, when there are network externalities, and adoption costs. It shows that because of the externalities, the adoption path is very sensitive to the distribution of adoption costs in the population. It also shows that a benevolent "communicator" can take advantage of this by altering this distribution, and by doing so altering the final outcome of the adoption process and the speed at which it is reached.

1 Introduction

When a scientific discovery is made, its results can sometimes take a very long time to reach the laymen and become part of the "common knowledge", despite the fact that it might be have a direct impact on everyday's lives. For instance, how many people still think that gastric ulcers are caused by stress, whereas bacterial infection has been shown to be their main cause more than twenty years ago?[1] The problem of information diffusion can even be more patent in

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[1] Marshall and Warren suggested this hypothesis in 1983.

some developing countries, in which latest developments remains unheard of for even longer periods because of illiteracy and the lack of science journalism.

The discrepancy between quality and effective success has already been studied in the literature of technology adoption in the 1980s. Katz and Shapiro [1986] showed in their seminal work how, in a setting with network externalities, a technology might reach market superiority even though it is technologically inferior. If we think of ideas and discoveries as standards, the analogy with this framework might prove useful to explain the slowliness of new, better ideas and practices to gain popularity. Indeed, as Farrell and Saloner [1985] point out, network externalities can create "excess inertia" in the adoption of a new technology; this is the phenomenon that will be at work here to slow down the adoption of the new idea.

Contrary to the technology adoption literature however, I focus on the *dynamics* of adoption. This essay models in a very simplistic way the choice of a population between an old and a new idea or practice, each individual making the decision to adopt or not the new idea. Its main difference lies in the repeatition of this choice at every period (instead of a two-period model), and in the existence of a cost of adoption, whose distribution among the population can greatly alter the dynamics of adoption. Also it analyses the possible effects of public communication, i.e. a pedagogic or vulgarisation effort, in facilitating the adoption of the new idea.

The essay is organised as follows. Section 2 introduces the framework of individual decision that will be used. Section 3 focuses on the dynamics of adoption, and how it is affected by the distribution of adoption costs, the quality of the two competing ideas, and the degree of network externalities. Section 4 addresses the potential impact of a public campaign of information on the dynamics of adoption. Section 5 concludes.

2 Setting up the framework

2.1 Scientific discovery

Let's consider two competing ideas that we call O and N for old and new. Each one characterised by a quality parameter q_O for the old theory and q_N for the new theory. If we place ourselves in the context of a scientific discovery, O can be a historically adopted theory or practice[2], whereas N is the new theory or practice ; we may safely assume $q_O < q_N$, that is, that the new theory improves upon the old one.

This parametrisation of the quality of an idea might seem debatable. As the parameters q_O and q_N do not depend on the individuals, the quality of each idea can be said to be objective. And after all, it is often hard to assess the objective quality of an idea; as it is often the case, one can only do it retrospectively.

But in this model, I assume that individuals are able to derive some utility from the idea itself. One might think of this quality as the benefit a user has in believing in it. It might for instance be a practice related to hygiene, and believing in the idea (or adopting the practice) will improve individuals' health, and maybe life expectancy; or more figuratively, individuals might derive some utility from a better explanation of the phenomenon surrounding them, by statisfying their curiosity towards the world. These examples provide possible justification for an objective quality of an idea[3].

Moreover, I assume that each idea generates positive network externalities: the benefit of adopting one idea (or practice) is greater if the "network" size is great, that is, if a lot of people already adopt that idea. This allows for modelling the social influence that might substantially affect a personal decision because of peer-pressure, sanction on deviants, or an inner taste for conformism. Simply put, the externalities can be viewed as the social comfort derived from

[2]I use the words "theory" and "practice" indifferently, and with the hope that what is said in this essay can be generalised to both.

[3]See Popper [1963] for a more philosophical theory of objective quality or, as the author puts it, "their relative potential satisfactoriness" depending on their testability and empirical content.

believing the same things as surrounding people. The fundamental influence of conformism on individual decision-taking is well-documented in the literature, especially in sociology. On the economics side, Jones [1984] describes several examples including college students, soldiers and workers. Or, to stay within the medical field, the externalities can be used show that one's action may do little if it is isolated: the benefit for someone's washing her hands is greated if everyone around her also wash their hands.

It is noteworthy to mention that this model does not try to provide an explanation for conformism itself. Although the dynamics of the system will bring a state of the world in which the whole population might adopt the same theory, it is rather a consequence of the externality assumption, that is of the conformism assumption, rather than an explanation. An original, inspiring theory of conformism as a consequence of informational cascades can be found in Bikhchandani *et al.* [1992].

If the difference in quality of the theories is what may induce some individuals to adopt the new theory, the positive network externalities—associated with a cost of adoption—will create inertia, attraction to the more popular idea and provide dynamics. Therefore the population will not adopt the idea straight, that is, the system will not "jump" to its final level, but will *dynamically* reach it.

2.2 Specifying the individual's utility function

At every period, each individual decide whether or not to adopt the new theory, based on several considerations. As explained, each individual derives an objective utility from each idea, as well as a positive externality.

The positive externality is here captured in very simple way, to make the model tractable. Departing from Katz and Shapiro [1986], I assume that the marginal benefit of an increase in the network size (the subset of population with the considered belief) is constant. In other words, the externality for conformity is simply a fraction $\eta > 0$ of the network size.

However I make an additional assumption and, following Cabral [1990], I introduce an observation lag: each individual uses the *lagged network size* to make its decision. If we denote by N_t (resp. O_t) the share of the population having chosen N (resp. O) in period t, the positive externality received by adopting N in period t is therefore $\eta \cdot N_{t-1}$. This assumption is crucial to provide dynamics for the system. It can be motivated in different manners. Either by appealing to the bounded rationality framework, assuming that individuals cannot process information instantaneously. Or, within the rational expectations framework, by assuming that individuals do not access current information, and therefore (badly) have to assume $E(N_t) = N_{t-1}$, i.e. that the future network size to be the same as previously.[4]

On the other hand, the cost of adoption of N varies across individuals. This allows for heterogenous agents, some of them being more psychologically flexible than others, more open to new ideas, or better educated maybe, thus needing less efforts to grab and adopt the new idea. Let c_i be the cost of adoption for individual i ; I assume that there is a continuum of individuals, and that their characteristic cost parameter is distributed on $[0, 1]$.

In period $t \geq 1$, noting that $O_{t-1} = 1 - N_{t-1}$, the utility derived by individual i for either sticking to O, or adopting N, is:

$$\begin{cases} u_{it}(O) = q_O + \eta \cdot (1 - N_{t-1}) \\ \\ u_{it}(N) = q_N + \eta \cdot N_{t-1} - c_i \end{cases}$$

Notably, in this setup, individuals are not to go back to 0 once they have adopted N. The adoption choice is irrevocable.

[4] A more realistic expectation for individuals would be to assume, badly again, a given growth rate of network, so that $E(N_t) = (1 + \delta)N_{t-1}$. This only makes adoption faster by increasing the network externality, but does change the underlying adoption dynamics.

3 The dynamics of adoption

The model starts at $t = 0$; at the beginning all the individuals are on O, that is, using our notation: $N_0 = 0$. The new idea arrives at $t = 1$, which is effectively the first period at which agents can take decisions.

From the individual utility function, it is straightforward to see that individual i will adopt at period t if

$$c_i \leq q - \eta + 2\,\eta\,N_{t-1} \qquad \text{where } q = q_N - q_O \tag{1}$$

3.1 Corner cases

Because c_i is distributed between 0 and 1, let's first remark that if $q \leq \eta$, there will no adoption. Indeed, at the start, $N_0 = 0$, so that $q - \eta + 2\,\eta\,N_0 \leq 0$. Therefore, in period 1, there will be no c_i that verifies equation (1). This simply means that if $q \leq \eta$, the externality factor still outweighs the benefit of the new idea. The difference in quality between the old and the new idea is not enough to push the system from the low equilibrium to a higher; there is *excess inertia*[5], a phenomenon that has long been identified in settings with network externalities (Arthur [1989]). Instead of moving towards a new equilibrium in which more people would benefit from the idea, the system remains "stuck" because of high externalities.

Similarly, if the quality is very high compared to the weight of externalities, the adoption of the new idea N will be instantaneous. More specifically, if $q-\eta \geq 1$, then at $t = 1$, all individuals will satisfy the condition given by eq. (1). The benefit from changing the idea is significantly high to counterbalance the inertia towards the old idea. The system will jump from $N_0 = 0$ to $N_1 = 1$ (and stay there subsequently).

[5]This expression is found in Farrell and Saloner [1985] and highlights the deliberate similitude between technology adoption and theory adoption.

3.2 Non-trivial cases: sensibility to skewness

Let's now assume that the parameters q and η are such that $q-\eta \in [0,1]$. Then eq. (1) will not be trivially verified for all or none of the individuals. Instead, at each period, only a fraction of the population will adopt N. If the cost of adoption, c, is distributed according to the cumulative distribution F^c over $[0,1]$, then using eq. (1), the share of the population having adopted N is given by:

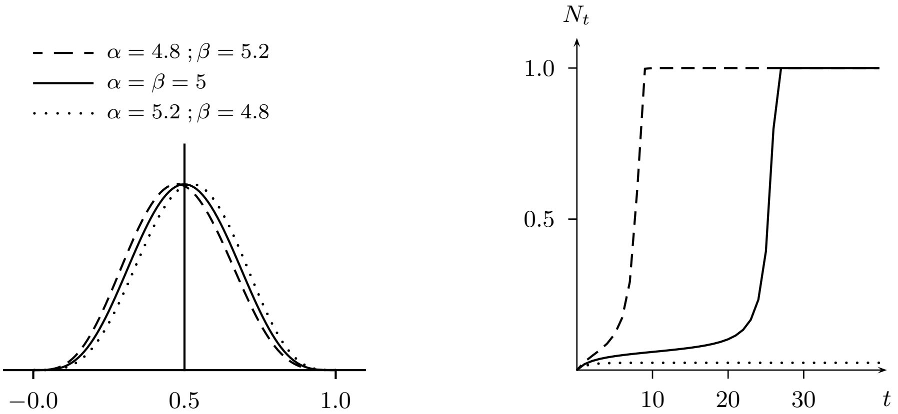
$$\forall t \geq 1, \quad N_t = F^c\left(q - \eta + 2\eta \cdot N_{t-1}\right) \tag{2}$$

The recursive nature of $\{N_t\}_{t\geq 0}$, the sequence of adoption, comes directly from the assumption that individuals only take the lagged network size into account. Equation (2) gives a clearer insight as to how this assumption provides dynamics for the model. Because individuals depend on the previous period state of the world, at a given period, the share of support for N will depend on its value the period before. Consequently, for a given set of parameters (q,η), it will be possible to deterministically infer the path of adoption for N.[6] Also, at a given time, the share of population that has adopted N is an increasing function of the quality premium of the new idea, captured by q. The impact of externalities, captured by η is ambiguous, and will be studied in a special case later on (section 3.3). Naturally, this path will highly depend, through $F^c(\cdot)$, on the distribution of the c_i.

Figure 1 shows how the path of adoption can be highly affected by the shape of the cost distribution, especially by its skewness. I used a beta distribution, which has finite support $[0,1]$, for its versatility: it allows for easy variation in the skewness of the distribution.[7] Using $q=0.75$; $\eta=0.55$, I plot the *adoption path*, i.e. the evolution of N_t, for slightly different distributions of cost in the population. For parameters $\alpha=4.8; \beta=5.2$, that is, when the population are

[6]However, individuals in this setting do not have enough information to determine the future path. For instance, they ignore the distribution of adoption costs.

[7]For beta distribution with parameters α and β, the skewness is: $\dfrac{2(\beta-\alpha)\sqrt{\alpha+\beta+1}}{(\alpha+\beta+2)\sqrt{\alpha\beta}}$. Therefore, the distribution of cost will be skewed to the left, that is, towards low-cost individuals, when $\alpha<\beta$.



(a) Three beta distributions of c_i, with slight variation in the skewness

(b) Adoption path: evolution of N_t over time

Fig. 1: Adoption path of N with beta distributions for c_i (no media). Fixed parameters for panel (b) are $q = 0.75$; $\eta = 0.55$. Adoption path is highly affected by small variations in the distribution of adoption costs in the population.

mostly low-cost adopters (distribution of cost slightly skewed to the left), the path of adoption is very fast. It only takes eight periods for the whole population to adopt the new idea. As a comparison, with symmetric distribution of cost ($\alpha = \beta = 5$) among individuals, it takes 27 periods for the whole population to settle on N (the uniform distribution studied in subsection 3.3 is a special case[8]).

On the other hand, when high-cost individuals are majoritarian in the population ($\alpha = 5.2; \beta = 4.8$), a very interesting phenomenon appears. *The new idea N never fully reaches the population.* There always remains a share of the population that will stick to O. In our example, $\lim_{\infty} N_t \approx 0.02407$, so the share of the population in that case is substantial (97.6%). It is therefore possible for the scientific discovery to remain confined to a very small share of the population.[9] More surprisingly: despite the increasing nature of N_t, this state of the world is stable in the long term.

[8]A beta distribution is uniform over $[0, 1]$ when $\alpha = \beta = 1$.

[9]The condition for this is that there exists an $x \in [0, 1]$ such that $x = F^c(q - \eta + 2\eta \cdot x)$, which is unfortunately very hard to solve for non-trivial distributions.

The main point of this estimation is to show that (a) the steady state of adoption is very sensitive to the distribution of cost in the population, and (b) there may only be a share (possibly small) of the population that adopts the idea, even in infinite time. Intuitively it is easy to understand that a society with a high proportion of low-cost (flexible) individuals is more likely to adopt the new idea. Conversely, in a "less flexible" society, the spread of the new idea will be blocked by the high share of high-cost individuals, because the size of N_t does not reach a critical mass soon enough to attract high-cost individuals. In our model, the importance of the media relies specifically on sensibility of adoption to the cost distribution (cf. section 4).

3.3 Uniform distribution for adoption cost

Let's now focus on a more neutral case, that will be easier to handle to assess the impact of the parameters q and η, by assuming that the adoption cost is distributed uniformely over $[0,1]$. Then, $\forall x \in [0,1], F^c(x) = x$. Transposing this to the general recursive equation (2) and using iterative substitution, we obtain the formula:

$$\forall t \geq 1, \quad N_t = \min\left((q-\eta)\sum_{j=0}^{t-1}(2\eta)^j \ ; \ 1\right) \tag{3}$$

For now, let's focus on the periods in which the idea has not fully been adopted, that is when $N_t < 1$. Then, as a geometrical series, N_t can be rewritten:

$$N_t = (q-\eta)\left[\frac{1-(2\eta)^t}{1-2\eta}\right] \tag{4}$$

As a first observation, at a given time, the magnitude of N_t depends positively on $(q-\eta)$; this is in line with the results from section 3.1. Intuitively, if the quality premium q of the new idea is really high compared to the weight of externalities η, adoption will occur very fast, because the force driving adoption is greater than inertia.

Using eq. (3), we can also study the *shape* of the adoption path, by noting that

$$\Delta N_t \equiv N_t - N_{t-1} = (q-\eta)(2\eta)^{t-1} \tag{5}$$

which clearly brings two possible cases, if we still assume that $q > \eta$.

Case 1 If $\eta > 1/2$, then ΔN_t is increasing over time, which means that every further step towards full adoption is bigger. The "snowball effect" created by externality is strong enough to counterbalance the fact that it is always more costly to convince people as we move towards the high-cost spectrum of the population. Therefore N_t will exponentially grow, until it reaches its upper bound 1. The time at which N reaches full adoption is given by:

$$t_f(q,\eta) = \left\lceil \frac{\ln\left(\frac{q+\eta-1}{q-\eta}\right)}{\ln(2\eta)} \right\rceil \tag{6}$$

where $\lceil\cdot\rceil$ is the ceiling function.

Case 2 If $0 < \eta < 1/2$, then ΔN_t is decreasing over time, which means that N_t is growing logarithmically, and therefore, N might not reach the whole population. Given that $\frac{q-\eta}{1-2\eta}\left[1-(2\eta)^t\right]$ tends towards $\frac{q-\eta}{1-2\eta}$ when $\eta < 1/2$, the condition for N to be fully adopted is that $q+\eta > 1$. Then, eq. (6) still gives the timing of full adoption. Otherwise, N_t will never reach its upper bound :

$$q+\eta < 1 \qquad \Longrightarrow \qquad \lim_{\infty} N_t = \frac{q-\eta}{1-2\eta} < 1 \tag{7}$$

In the special case where $\eta = 1/2$, eq. 5 indicates that N_t grows linearly, by $(q-\eta)$ at every period. Full adoption is reached in $\lceil (q-\eta)^{-1} \rceil$ periods.

Figure 2 shows how the shape, growth rate and limit values of N_t are affected by the quality premium q and the externality weight η, as explained above. In particular, for a given quality premium q, figure 2 shows how small changes in η

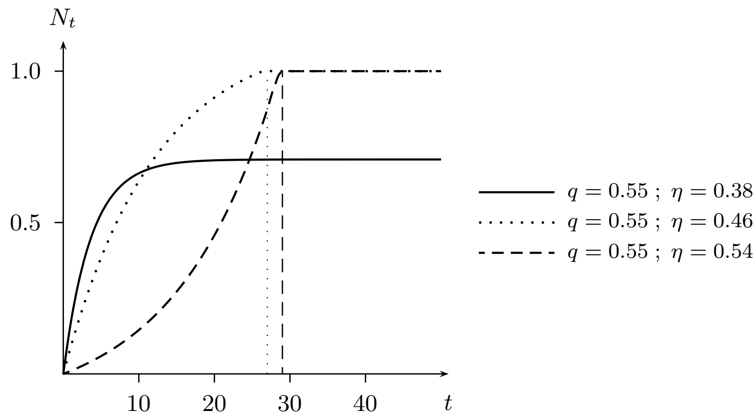


Fig. 2: Adoption path of N when c_i is uniformally distributed (no media). Note that for $\eta > 1/2$, N_t grows exponentially. When $q + \eta < 1$, N is never fully adopted.

can dramatically affect the shape of the adoption path for the new idea and possibly, its long term outcome. Several points are noteworthy:

1. Even though the inertia due to the externalities might be low, the idea will not spread totally if its quality is also low ($q = 0.55$; $\eta = 0.38$ in our example).
2. For a given quality, a more explosive path does not necessarily lead to earlier full adoption. This is because an increased η has a mixed effect on ΔN_t, as defined in eq. 5. In our example, when $\eta = 0.46$, full adoption is reach in 27 periods, wheras for higher $\eta = 0.54$ (exponential growth) it takes 29 periods.
3. In the case where $\eta < 1/2$ (logarithmic growth), the lower is the steady-state level that will ultimately be reached by N_t, the higher is the growth rate in the early period (in our example, compare adoption when $\eta = 0.38$ and when $\eta = 0.46$). This is because lower externality does not hamper adoption at the beginning, but in the same time it fails to give the dynamics enough momentum to convince high-cost consumers.

All these results tend to complement those from section 3.2. Instead of changing the distribution of costs in the population, I changed the quality premium and the externality factor, and looked at how it affected the adoption or partial adoption of the discovery. It is interesting to see that, in a way similar to section 3.2, the system evolution is very sensitive to small deviations. This sen especially when parameters q and η are close to critical values, i.e. when η is close to $1/2$, and to q.

4 The impact of public communication

The extra-sensitivity of the adoption path to the parameters involved imply that small changes may have a great impact on the final outcome of the adoption, and the speed at which it is reached. I now turn to the implications of this for public communication. Indeed, if a small change in the parameters can induce a substantial change in the outcome, a benevolent planner might choose to do so in order to reach a better outcome. I do not provide here a welfare analysis; however I study the potential impact of public communication on the outcome. More specifically I analyse situations in which public communication might be very effective, and which, on the contrary, where it has no effect on the outcome.

It would be hard to argue that media intervention could change the given parameters of the setting, that is the quality of the ideas, or the externality factor, which is specific to the population studied. However, by explaining in more simple terms the content of the discovery, and how individuals can benefit from it, public communication can make the adoption of the idea easier. In this setting, it acts as a pedagogic tool to facilitate the adoption of the discovery. In line with the previous section, I now investigate two ways of integrating public intervention in our initial setting.

4.1 Media intervention as cost reduction

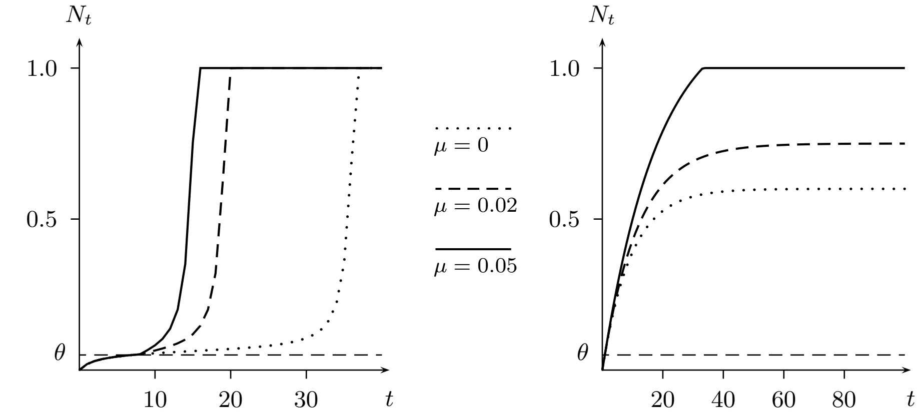
The most straightforward manner to model the benefit of public communication is to assume that it works towards the reduction of adoption cost. Public communication takes the form of an explanation or a promotion of the discovery, which is not target towards a particular part of the population, but instead reaches everyone. Thus, I assume that public communication reduces everyone's cost of adoption by a fraction μ. Instead of c_i, the cost for individual i to adopt N is now assumed to be $(1-\mu)\cdot c_i$. The condition for adoption by individual i , previously given by eq. (1), is now:

$$c_i \leq \frac{1}{1-\mu}\,(q-\eta+2\,\eta\,N_{t-1}) \tag{8}$$

Not much would be changed here, and we would roughly the same results as before, if it wasn't for the following additional assumption. I assume that public communication cannot occur at the very period beginning of the process. Instead, I assume that the communicator (be it the government, a NGO, a professional society, etc.) needs to assess the trend of the adoption path to see if it needs to communicate. A possible explanation could be that the communicator itself is not immediately aware of the adoption phenomenon. For instance, a government may have a bird's eye view and therefore might not be able to know about N and its importance unless a certain share of the population have adopted N, which makes its case visible to the government. Therefore, no public communication can occur until the share N_t has reached a critical threshold, which I denominate $\theta \in (0,1)$. This means that eq. (8) is only valid if $N_{t-1} \geq \theta$. Before that, the old condition (eq. (1)) is still used by individuals to make their adoption choice.

4.1.1 The consequence of different cost reductions

As hinted in the previous section, figure 3 shows how the reduction of adoption cost can dramatically affect the adoption path of N. In the case of a bell-shaped beta distribution of cost ($\alpha=\beta=5$), the full adoption is largely accelerated, as shows figure 3a. In our example, instead of full adoption in 38 periods when no communication occurs (if the benefit $\mu=0$, it amounts to no communication), it takes only 21 periods when the adoption cost is decreased by 2%, and 16 periods when it is decreased by 5%.



(a) Beta distribution of costs ($\alpha = \beta = 5$) $q = 0.74; \eta = 0.54$

(b) Uniform distribution of costs $q = 0.51; \eta = 0.45$

Fig. 3: The impact of different media benefits μ on the adoption path of N with beta and uniform distributions for c_i. The threshold of media intervention is $\theta = 5\%$.

Similarly, even a small diminution in the cost of adoption can considerably alter the final steady-state, as shows panel 3b in the case of a uniform distribution of costs. Here, when the discovery would not be fully adopted otherwise (in our example, when $\mu = 0$, N_t tends towards 0.6), the public communication can change this outcome. Depending on the level of benefit from communication, the outcome can change, either to higher steady-state (when $\mu = 2\%$, N_t tends towards 0.75.), or it can even reach its upper bound 1 (case when $\mu = 5\%$).

It is interesting to note that in the case of uniform distribution, eq. (4) can now be rewritten with media as:

$$N_t = \frac{q - \eta}{1 - 2\eta - \mu} \left(1 - \left[\frac{2\eta}{1 - \mu} \right]^t \right) \tag{9}$$

which, as in section 3.3, brings two cases. With media, adoption will be explosive if $2\eta > 1 - \mu$, and logarithmic otherwise (linear when $2\eta = 1 - \mu$). This means that with media benefit, the level of externality inertia needed for the discovery to be exponentially adopted is *lower*. So it might be the case (not pictured here) that the shape of adoption changes as the public communication takes place. If $1 - \mu < 2\eta < 1$, then before media intervention, the old dynamics still apply and N_t will be growin logarithmically, because $2\eta < 1$. But if the threshold θ is reached, then new dynamics prevail, and as $2\eta > 1 - \mu$, the system will now grow exponentially (and reach full adoption for sure). Therefore, a change in the curvature of the adoption path occurs if these conditions are met.

Also, using eq. (9), we can show that, provided that $q + \eta < 1$, and in addition that $q + \eta < 1 - \mu$ (that is: no full adoption), we have :

$$\lim_{\infty} N_t \approx \frac{q - \eta}{1 - 2\eta - \mu} \tag{10}$$

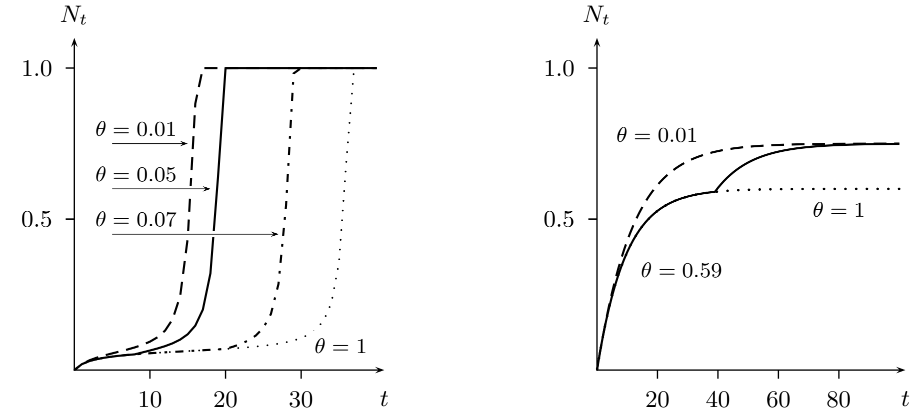
If we compare eq. (10) with eq. (7), the outcome reached when there is public intervention is approximately $\frac{1 - 2\eta}{1 - 2\eta - \mu}$, which is the case pictured in figure 3b for $\mu = 0.02$.

Note that the equality in eq. (10) would be strict if the benefit from public communication was felt from the very beginning, that is if θ was zero. In the case it is not, in the first periods (when N_t has not yet reached θ), the evolution that prevails is still the one without media, therefore creating a little difference in the limit that arises from this difference in the first term of the series N_t. However, if θ and μ are reasonably small, (a) this discrepancy does not last long, because θ will be reached fast, and (b) event if it does it will be quite small due to the fact that a small μ does not create much difference at the beginning, because N_t is still small.

This brings us to a second question. After showing that small differences in the media benefit can vastly affect the outcome, and the speed at which it is reached, I would like now to explore the impact of differences in the intervention threshold θ.

4.1.2 Does timing matter?

Figure 4 (p.16) shows the impact of different thresholds on the dynamics of adoption. Panel 4a clearly demonstrates that in the case of a bell-shaped beta distribution of costs, small changes in θ the threshold of sensitivity for the



(a) Beta distribution of costs
($\alpha = \beta = 5$) $q = 0.74; \eta = 0.54$

(b) Uniform distribution of costs
$q = 0.51; \eta = 0.45$

Fig. 4: The impact of different intervention thresholds θ on the adoption path of N with beta and uniform distributions for c_i. The benefit of media intervention is fixed at $\mu = 0.02$.

communicator greatly affect the speed at which full adoption would otherwise be reached. This result is particularly felt in small values of θ, that is, when public communication would occur on the flatter part of N_t curve. For instance, in our example, it takes 30 periods for full adoption when communication kicks in at $\theta = 7\%$ but only 21 when the threshold is slightly decreased, to $\theta = 5\%$. Therefore, in the case of a bell-shaped distribution of costs, a small improvement in θ can induce a much faster adoption of N.

On the other hand, figure 4b tells a different story. In the case of a uniform distribution, if N is tending towards a limit lower than 1 without media intervention (here, 0.6 when $\theta = 1$), then *the timing of the public communication has almost no impact on the final outcome.* Of course, as explained in section 4.1.1, the outcome will be different from the one without any media intervention. But the comparison between situations when the treshold is 1% and when it is 59% (more than half of the population!) shows that the huge difference in thresholds does not really alter the new steady-state level. This means that even if the communicator is not very sensitive to the adoption path of N and jumps in really late (when N_t has almost reached its limit), it can still lead a very effective communication campaign, that will quickly boost the adoption level to a higher steady-state.[10]

4.2 Media intervention as skewness change

Finally, I model the effect of public communication as a modification in the skewness of the distribution of costs. That is, I assume that when communication occurs, the distribution of costs shift slightly to the left, which amounts to a decrease in the skewness of the distribution. This is a macroscopic point of view and therefore does not specify how the cost change for a given individual. It is therefore less informative than the previous case. However, it still provides a justification for public communication.

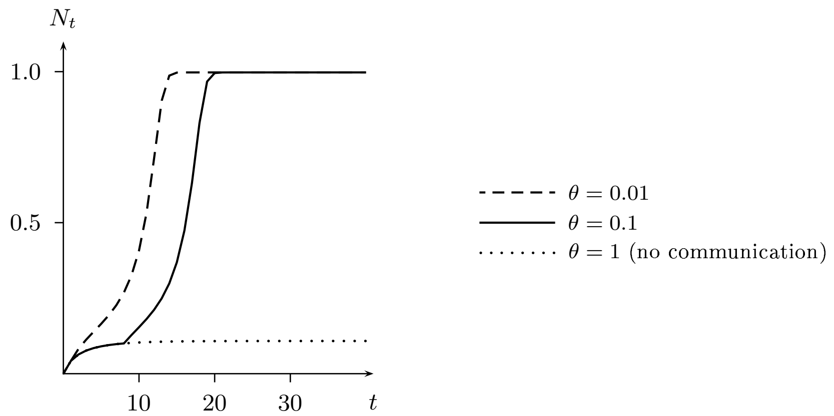


Fig. 5: Adoption path of N when c_i is beta-distributed, and when public communication changes its skewness. The original distribution parameters are $\alpha = 5.1$; $\beta = 4.9$. If public communication occurs, they become $\alpha^M = 4.9$; $\beta^M = 5.1$.

I have already show in section 3.2 how, in the case of a beta distribution of costs, different skewnesses can lead to very different outcomes in adoption. Figure 5 shows that this result still holds even when the skewness changes *during* the dynamics of adoption. The example pictured here demonstrates that the result are qualitatively similar to those of the previous section. More specifically,

[10]The condition is that θ is lower that the "natural" limit of N_t without intervention, so that intervention *does* occur.

if the threshold of intervention is low enough, a small change in the skewness can change the curvature of the adoption path, and can lead N to be fully adopted whereas it would not have been without public communication ($\theta = 0$). Note that the change of skewness used here is quite small: public communication change the distribution parameters from $\alpha = \beta = 5$ to $\alpha^M = 4.9$; $\beta^M = 5.1$, which means that the cost distribution changes from symmetric to slightly skewed to the left.[11] It nonetheless leads to full adoption, instead of a steady-state level of N_t around 10.9%.

Moreover, as already hinted in figure 4a, in the case of a beta distribution, a lower threshold can accelerate the full adoption: here for instance, the number of periods before full adoption goes from 21 to 15 when the threshold is $\theta = 1\%$ instead of 10%.

An advantage modelling the effect of public communication as a shift in the skewness is that it can more easily account for communication campaigns *targeted* towards a given part of the population, for instance towards middle-cost individuals in the peak of the cost distribution. This is not the case in the way I model it as a flat rate cost reduction, in section 4.1; then, media campaign is assumed to be universal and to reach everyone. However, a drawback of using skewness change is that it makes it hard to quantify the potential cost of the media campaign, because it is hard to make a precise quantitative link between the number of people targeted by the campaign and its target effect on skewness. In other words, it is hard to determine, for a given skewness change, how many people should be targeted, and how should their cost be changed.

5 Conclusion

This essay is a modest attempt to provide a possible explanation for the slowliness of adjustment after scientific discoveries are made. It shows how both strong positive externalities, and the distribution of adoption costs in the population—

[11] See fig. 1a for a graphical representation of the change implied, although the change here is even smaller.

or, in other words, the educational structure of the population—can greatly affect the outcome and timing of the adoption dynamics. The main point of this paper is to highlight the high sensitivity of the adoption path to those conditions. This in turn makes possible, under some conditions, the use of public communication, or vulgarisation, to facilitate the adoption of the new idea or practice, and reach a higher steady-state adoption level.

In my denominations, I have tried to stay as general as possible, so that this framework could be used to analyse topics as varied as the slow spread of hygiene practices in communities, *ideological stickiness* in philosophy, or the longlasting influence of deprecated theories in science.

The essay shows that a benevolent communicator can take advantage of the externalities to deeply alter the dynamics of adoption, using public communication to decrease the cost of adoption (or shift its distribution towards its lower end). Consequently, it shows the possibility to reach a higher equilibrium level, where a bigger share of the population actually adopts the better idea.

However, this simple model does not provide a cost/benefit analysis, that could help assess the "costs" involved for the benevolent communicator to take supporting actions towards the new idea; an extension of the model could therefore try to focus on the change in cost distribution to evaluate more precisely the costs involved and the expected benefits in social welfare analysis.

Also, the model introduced here relies heavily on the assumption of network externalities. Although there is supporting evidence for this assumption, this simple framework could be made more realistic by allowing for heterogenous externalities among agents (some caring less about what the others do); and possibly, by providing a rationale for this network externalities, for example by assuming greater cooperation in repeated games between players belonging to the same network, to the same ideology.

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