# The New Normalcy under a Pandemic: A Real Options Approach

**by**

**Pasquale Lucio Scandizzo (scandizzo@uniroma2.it) and Odin Knudsen(odin.knudsen@gmail.com)**

A pandemic presents the authorities with stages of expiring options. In the initial stage at the first cases, the government has the option to react aggressively to stop the spread of the viruses. But initial uncertainty over expected infection rates, mortality rates, immunities etc presents the possibility that the government reacts prematurely and against a rather mild, perhaps flu like virus. The option to wait until more information is gathered and can be evaluated could result in the government hesitating to act with measures that could result in damage to economic growth and to its political credibility.

Once the option to act in this early stage has expired with now the pandemic expanding, the government in the second stage faces the option to expand the medical capacity to handle a surge of infections, that is, opt for treatment versus the other option of shutting down the economy to inhibit transmission, or "flatten the curve." These two related options--- the option to invest to expand the capacity for medical treatment and the more drastic option to shut the economy down – can be reinforced by the option to learn, through initiating research on the characteristics of the virus. Or the authorities could execute both options – expand medical treatment and attempt to check the growth of the virus.

In the next stage, the new normalcy, the economy has been released to function again but with restrictions. The government stands ready to again impose drastic shutdowns while imposing restrictions and constraints that are designed to mute the reoccurrence of the virus. Business can operate but under three forms of potential liabilities: (i) the possibility that the government could impose fines or restrict or shut down production if certain standards are violated, (ii) the public could punish the business through lower purchases or boycotts for not providing sufficient safety and health standards to protect workers and/or the public, and (iii) workers and/or the public who become sick could sue the business for damages. With these potential liability options, held by third parties, investment could be constrained as could revenue as the business operates below capacity for safety. In the face of these potential liabilities, the business could decide not to reopen, or could operate at lower capacity to ensure workers and the public maintain safe distances, or it could invest in protective measures, new technologies including robots to replace workers, or operate recklessly and take a chance that at least for a time workers remain healthy despite the working conditions and lack of safety.

For example, a restaurant could decide to remain close as these liabilities are likely to be imposed, could open but with distance between tables resulting in less revenue, or could invest in revamping the whole restaurant and automate serving and cooking including delivering food directly to customers at their homes.

In this paper, we explore the last stage, the new normalcy when the virus is still a significant threat, but businesses are allowed to open as long as they do not cause undue harm to their customers or staff. In this stage, the business can take on certain costs, C, that lower profits or make a significant investment in revamping production. A third party can deploy sanctions or penalties if a certain health or social standard of infections are exceeded. This third party has the option to enact penalties but not the obligation if the standard is exceeded as there are costs to imposing these sanctions, either in terms of enforcement costs or because the capacity of the regulator is limited. The firm is faced with uncertainty on the flow of profits in the future and whether infections will increase beyond the level where sanctions could be imposed.

To explore how uncertainty and the social standard affects the firm's decision we construct a simple model or a representative firm in an industry.

## 1. The real options of a pandemic with government intervention

Consider a pandemic characterized by a continuous random diffusion process X where contagion moves over time in proportion to an index of social density (e.g. number of workers and/or customers per unit of productive space) and this in turn is a proportion of an index of economic activity (output) Q generating damages at some rate *QX*, where *X* is the unit level of damages. However, if *QX* reached some critical social standard $R$, society would intervene and impose restrictive measures (e.g. lockdown, social distancing etc.) to arrest diffusion beyond this barrier. Following Brennan and Schwartz (1985) and Dixit and Pindyck (1994), assume that $X$ follows a Wiener process with drift:

(1) $$dX = \alpha X dt + \sigma X dz$$

where $dz$ is the increment of a Weiner process, $\alpha$ is the drift parameter and $\sigma$ is the variance. The term $dz$ is a normally distributed random variable such that $Edz = 0$ and $Edz^2 = dt$ .

With respect to the process considered, we assume that two decision makers are involved: (i) private business (embodied in a single representative agent), and, (ii) a public agent holding a contingent right to restrict economic activity of the private firms, if the damages from the diffusion of the infection following its normal operations exceed a threshold of social tolerance (i.e. a "social standard"). The private firms are assumed to be penalized by restrictive measures prescribed by the government on social distancing and other security and medical controls in proportion to revenue foregone from applying the social distancing and security regulations. In turn these restrictions are assumed for simplicity to reduce their expected output or to increase its costs. In addition to this proportional loss, the private firms are also faced with the threat of having to pay excess damages, if their measures to preserve social distancing fall short of the "danger level" corresponding to the social standard. This level and the right to extract compensations for excess damages are established by law, regulations or jurisprudence. We thus interpret the precautionary principle as a combination of the potential victim right and injurer liability, contingent to the attainment of a "threshold of danger", which makes a proportional fine insufficient to take into account the risks involved in raising the overall level of damages (Knudsen and Scandizzo, 2005; Pennisi and Scandizzo, 2003). Notice, in passim, that while we consider “flow” damages proportional to output, the threshold of danger after which excess damages can be paid may be assumed to depend on the accumulation of past damages (as in the “stock” of carbon dioxide in the atmosphere or the stock of the virus in circulation)). For the purpose of this paper, however, we will assume that the social standard is given exogenously.

As a decision maker, the firm (as a representative agent of the whole producing economy) faces the choice between two alternatives. The first alternative, which we may call the “contingent compliance alternative” consists in the faculty to abide by the restrictive rules (e.g. maintaining a minimum distance among workers and among customers, sanitizing with the required frequency ect.), by reducing the firm’s scale of operations (for example, by reducing labor intensity in manufacturing or by servicing a lower number of customers per unit of space in entertainment and restauration establishments), and/or by investing in measures that reduce the probability of violating the norms and incurring into the sanctioning domain of the public agency. Compliance would be however plagued by the liability option, e.g. the threat of being fined, restricted or locked down because compliance is judged unsatisfactory and/or the measures taken are, voluntarily or involuntarily, insufficient to prevent the spread of the virus. The second alternative, which we may call the “precautionary option”, instead, is the faculty to remove the threat by investing in a radical reorganization of the production processes, through the introduction of new technologies and modes of work (e.g. distance working) that drastically reduce the threat of contagion and essentially eliminate the possibility (and the need) of control on the part of the public regulator. Adopting this strategy, according to a protocol established by the government would also remove the threat of any fine or restrictive measure from the public regulator. Exercising the precautionary option thus implies an investment cost in reengineering the production process that can be considered equivalent to a once-and-for-all commitment of resources which would reduce at once the expected value of the threat that the same or a similar infection may spread in the present or future. The private adopter’s incentive to voluntarily pay these excess damage costs, in order to comply with the social standard, derives from a “liability option”, i.e. an option to proceed against it by third parties ( a regulator or the parties damaged) on the basis of government coercion power or the right to sue for damages through the court system.

The problem of the private firms is to choose between: (1) maximizing expected profit by maintaining a situation of business and usual and undergoing costs, which would involve some compliance, but also some risk of exceeding the social standard and being sanctioned for it (i.e. being forced to pay fines, to operate under restrictive measures, or to suspend business operations for some time, (2) exercising the option to switch to an entirely new mode of operation which would practically eliminate any risk to generate contagion and to exceed the social standard. This would imply reorganizing production at a cost, in order to comply with the precautionary principle:

(2) $$\underset{C}{Max}\,\Pi = \frac{Q}{r} - C - F(X|C)$$

(3) $$\frac{Q}{r} - C - F(X|C) + V(X) = \frac{Q}{r} - \gamma\left(Q\frac{X}{\delta} - \frac{R}{r}\right)$$

In expressions (2), $C$ is the cost to comply and/or to avoid the regulator’s fine, and $F(X)$ the liability option, i.e. the option of the regulator to sanction the firm in case of insufficient compliance. In expression (3), $X$ is the rate of damage per unit of output, $R$ the absolute level of the social standard, $V(X)$ is the option of the firm to switch, at the investment cost $I = \gamma\left(Q\frac{X}{\delta} - \frac{R}{r}\right)$ from compliance to a technology, which we assume is approved by the regulator, that eliminates the possibility of being sanctioned and drastically reduces the probability of giving raise to a significant level of contagion. Expression (2) defines the general problem of the private firm confronted with the threat of causing contagion through the crowding effects and the contamination opportunities of its operations and the attempt to reduce such a threat by undertaking an adequate cost. Note that here the regulator embodies in the form of a rational agent the threat that the spread of the infection constitutes for society. In other words, in the presence of an infection level linked to the intensity of the economic activity by private business, the contagion can be expressed as an externality that can be internalized by an appropriate level of penalty imposed on those who generate it. Expression (3), on the other hand, shows the condition that has to hold when the private firm decides to invest in the adoption of a technology that ensures once and for all that the social standard is upheld and no significant contagion can be generated. If this option is not exercised, the firm continues to face the prospect to pay fines in a given proportion of the excess damage (the difference between the damage inflicted, for example in terms of deaths caused and the social standard). The function $F(X)$ thus represents the option value of a liability, which can be exercised against the firm if the negative externality generated by the BAU situation reaches a critical value determined by an exogenously imposed social standard. The firm can ignore this threat or it can decide to remove it by engaging in costly innovations that are equivalent to a voluntary fine. In doing so, it would compare the disadvantage from removing the threat by paying a given cost (either a voluntary fine or any other cost of abatement), equal to a proportion $\gamma$ of expected excess damage, immediately against the advantage of not continuing to face a threat of uncertain magnitude.

Consider first the liability option $F(X)$. Its present value can be determined using dynamic programming. Starting at an initial $DX \leq R$, the condition for the optimum (the Bellman equation) prescribes that in the continuation region (i.e. where the option is not exercised) the option value be equal to the present value of its expected capital gains:

(4) $$F(X) = EdF(X)/r$$

where *r* is an appropriate social rate of discount.

Equation (4) states that, in order to maximize the present value of the option, the owner is to equate, in continuing time (that is, at the margin between holding and exercising the option), the value that he would obtain by exercising the option, to the expected present value of the future capital gains obtained by holding it. The expression $EdF(X)$ can be expanded using Ito's Lemma (see Dixit and Pindyck, 1994). Using primes to denote derivative yields:

(5) $$dF(X) = F'(X)dX + \frac{1}{2}F''(X)(dX)^2$$

Substituting for $dX$ , using (3) and noting that $Edz = 0$ gives:

(6) $F'(X)dX + \frac{1}{2}\sigma^2 X^2 F''(X) + \alpha X F'(X) - rF(X) = 0$

The solution to (6) is:

(7) $F(X) = AX^{\beta_1} + BX^{-\beta_2}$

where $\beta_i$, $i = 1,2$ are the roots of the characteristic equation:

(8) $r - \alpha\beta - \frac{1}{2}\sigma^2\beta(\beta - 1) = 0$

The first term on the right hand side of (7) $AX^{\beta_1}$ increases with the level of output, which is consistent with the expected value of the sanction increasing with output under non compliance. Thus this term is greater than zero. The second term, on the other hand, goes to infinity as the level of output grows without limits. The constant B*,* therefore, has to be zero.

A similar analysis can be applied to the option held by the firm to invest in the new contagion free technology, yielding:

(9) $V(X) = GX^{\beta_1}$

where the term with the negative root has been dropped because, as in the case of the liability option, the value of the option would go to zero as output grows without limits.

## 2. The social standard and the liability option

We can interpret the existence of a social standard $R$ as implying that if the damage $DX$ reaches $R$, a third party (either the government or a private party) has the faculty (through executive power, or by using the court system) to stop expansion of the pandemics by imposing a lockdown or selective measures of social distancing. We assume that, if this "liability option " (Knudsen and Scandizzo, 2003) is exercised, the agent moving the action can recover a proportion $\lambda$ of the excess of expected damage over the social standard, while the agents undergo avoidance costs equal to $C$ . These costs are not fixed, but can be determined by the firm in a way that maximizes its profits.

The value of the liability option can thus be established by using the following value matching and smooth pasting conditions:

(10) $AX^{\beta_1} = \lambda\left(\frac{QX}{\delta} - \frac{R}{r}\right) - \mu C$

(11) $\beta_1 AX^{\beta_1 - 1} = \lambda \frac{Q}{\delta}$

Expression (10) indicates that, at the exercise point, the value of the liability option is the expected value of the damage over and above the social standard minus a cost undertaken, with degree of effectiveness $\mu$, undertaken by the private agent to avoid the penalty. This cost represents the willingness to pay of the private agent to reduce her production, its contagion effects and/or by avoiding detection of any level of wanted or unwanted noncompliance. Expression (11), on the other hand, states the condition that, at the optimum, the marginal benefits for the regulator, and implicitly for society, from exercising the option should equal the marginal costs.

By solving the system of equations (10) and (11), we obtain the value of the threshold $X = X_L$ (corresponding to the value of expected social cost from the increased risks of the spread of the infection) at which the option of imposing the penalty may be expected to be optimally exercised by the regulator:

(12) $\frac{QX_L}{\delta} = \frac{\beta_1}{\beta_1 - 1}\left(\frac{R}{r} + \frac{\mu}{\lambda}C\right)$

Because of uncertainty, the value of the damage at which the penalty should be levied on non-compliant firms would not coincide with the social standard, but exceed it of an amount larger, the larger is uncertainty as $\beta_1$ approaches one with increases in the variance of X.

From (11) and (12), we can also obtain the value of the constant $A$:

(13) $A = \frac{\lambda Q}{\delta \beta_1}\left[\frac{\beta_1}{D(\beta_1 - 1)}\left(\frac{R}{r} + \frac{\mu}{\lambda}C\right)\right]^{1-\beta_1}$ ,

The explicit expression for the liability option is thus:

(14) $F(X|R, C) = \frac{\lambda Q}{\delta \beta_1}\left[\frac{\beta_1 \delta}{D(\beta_1 - 1)}\left(\frac{R}{r} + \frac{\mu}{\lambda}C\right)\right]^{1-\beta_1} X^{\beta_1}$

In order to maximize profits, the firm sets cost $C$ to a level that equates marginal revenues in expression (2). This implies differentiating equation (2) with respect to $C$, taking account of (14):

(15) $\frac{\partial \Pi}{\partial C} = -1 + \mu\left[\frac{1}{Q}\left(\frac{\beta_1 \delta}{\beta_1 - 1}\left(\frac{R}{r} + \frac{\mu}{\lambda}C\right)\right]^{-\beta_1} X^{\beta_1} = 0$

From (15), solving for $C$, we find:

(16) $C^* = argmax\Pi = argmax\left[\frac{Q}{r} - C - F(X|C)\right] = \frac{\lambda}{\mu}\left[\mu^{\frac{1}{\beta_1}}\left(\frac{\beta_1 - 1}{\beta_1}\right)\frac{QX}{\delta} - \frac{R}{r}\right]$

Note that willingness to pay to reduce the risk of infection on the part of the private agent will be declining with an increase in the social standard, in the index of cost effectiveness $\mu$ and in the level of uncertainty $\frac{1}{\beta_1}$ and will be zero at the threshold defined by the equality:

(16a) $\frac{QX_c}{\delta} = [\mu^{-\frac{1}{\beta_1}}\left(\frac{\beta_1}{\beta_1-1}\right)\frac{R}{r}]$

As Figure 1 shows, this threshold in turn will be larger the more restrictive the social standard, the lower the uncertainty and the lower the cost effectiveness of the measures that can be taken to contrast the infection by operating in the BAU environment. In the condition defined by (16a), in particular, the private agent will expect to be able to meet the social standard with no additional cost.

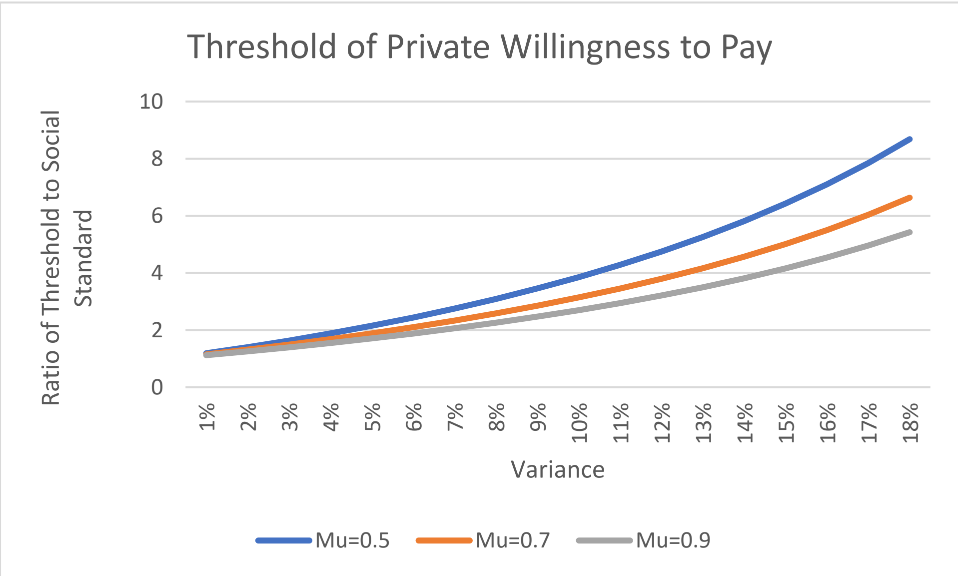


Figure 1

Substituting $C^*$ into (14), we obtain :

(17) $F(X|C^*) = \mu^{\frac{1-\beta_1}{\beta_1}}\frac{\lambda QX}{\delta\beta_1}$

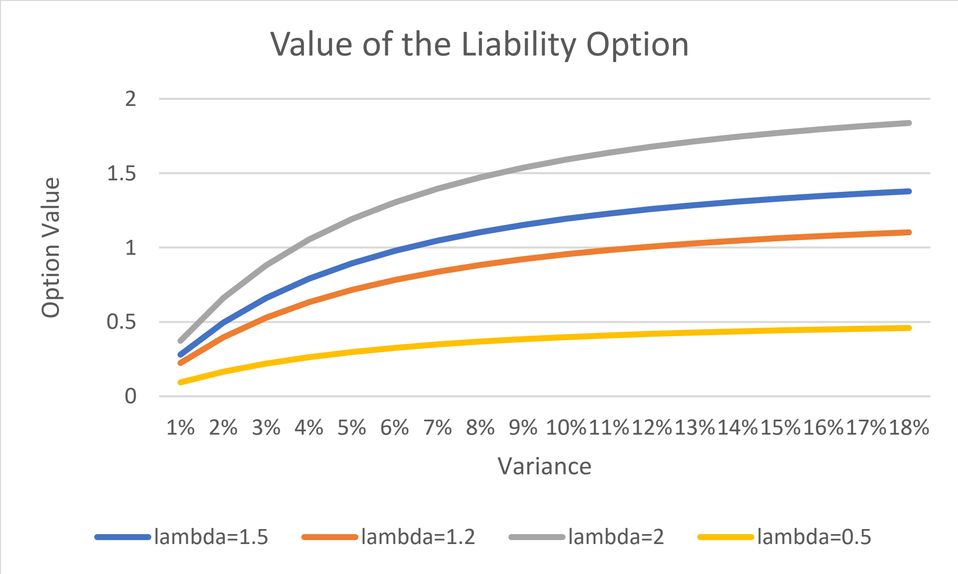


Figure 2

And substituting (16) and (17) into (3), we obtain the value of the maximum profit under the BAU situation:

(18) $\Pi((X|C^*) = [\left(Q/r - \lambda\mu^{\beta_1 - 1}Q\frac{X}{\delta}\right) + \frac{\lambda}{\mu}\frac{R}{r}$

Expected profit for the firm will be higher, the higher the social standard, i.e. the higher the tolerable degree of contagion that will not be considered as the firm's responsibility. Expression (16) and (18) can be interpreted as indicating the level of costs and profits that comply with the social standard in a way that minimizes the value of the liability option. Their values, however, vary from period to period with the stochastic movements of infection, so that costs and profits are higher and lower respectively, the higher the level of stochastic infection. Note also that expression (18) can be interpreted as a statement of Coase theorem. It implies that under the hypothesis of profit maximization, the introduction of the liability fully internalizes the externality if there are no transaction costs or other inefficiencies ($\lambda = \mu = 1$) and the social standard (the degree of tolerance for the damage inflicted ) is zero. In this case, in fact, expression (18) becomes simply the value of production net of the value of the damage, i.e. private benefits minus social costs:

(18a) $\Pi((X|C^*, \lambda = \mu = 1,\ R = 0) = Q\left(1/r - \frac{X}{\delta}\right)$

Substituting (17) and (18) into equation (3), we can thus impose the value matching and the smooth pasting condition to the firm's option to find at which level of infection the firm may find more convenient to switch to the new mode of production, taking into account of the uncertainty that this level will higher or lower in the future:

(19a) $V(X|C^*) = GX^{\beta_1} = \frac{QX}{\delta}\left(\lambda\mu^{1-\beta_1} - \gamma\right) + (\gamma - \frac{\lambda}{\mu})\frac{R}{r}$

(19b) $\frac{\partial V(X|C^*)}{\partial X} = \beta_1 G X^{\beta_1 - 1} = \frac{Q}{\delta}\left(\lambda\mu^{1-\beta_1} - \gamma\right)$

Solving for $X$ we obtain the critical value $QX_R$at which the firm will exercise the option to switch to the new risk-free technology:

$$(20)\ \frac{QX_R}{\delta} = \frac{\beta_1}{\beta_1 - 1}\left[\frac{\frac{\lambda}{\mu} - \gamma}{\lambda\mu^{1-\beta_1} - \gamma}\right]\frac{R}{r}$$

Note that, for $\mu$=1, i.e. perfect effectiveness of private costs to comply in the BAU situation, expression (20) becomes simply:

$$(21)\ \frac{QX_R}{\delta} = \frac{\beta_1}{\beta_1 - 1}\frac{R}{r}$$

Thus, the threshold at which the representative firm will switch to the minimum risk technology will be higher, the higher uncertainty (the lower $\beta_1$ ), the higher the effectiveness of avoidance costs, and the higher the social standard. A lower, stricter social standard, in other words, will act as an incentive to switch to structural security measures for the private firms and the more so the lower the uncertainty, the lower the effectiveness of firms' costs in avoiding the fines ($\mu$), the lower the cost of investment $\gamma X$ to perform the switching. Note that the threshold in (21) is identical to the level of expected damage requiring no action from the private agent in the BAU situation in (16a). With perfect effectiveness of private costs ($\mu = 1$), in other words, the representative firm will be indifferent between the BAU situation with no additional costs (but with contingent liabilities) and the switch to the new technology with investment costs, but no liability.

These results imply that any measure to contain the virus through social distancing or other ways to reduce infection by imposing social standards that impact business profits will tend to result into two distinct regimes, depending on the size of expected revenues as a share of the social standards. In both regimes, business profits will be reduced, with respect to the BAU situation, of a proportion of the expected damage over and above the social standard. In the first regime, however, uncertainty and a lax social standard will conspire to induce imperfect compliance on the part of the firms in the form of pro tempore costs that will include compliance as well as avoidance (elusion or evasion) actions. In this regime, compliance actions will remain in part confined to neutralize a contingent loss (the liability option), i.e. the risk that infection exceeds the social standard, if the measures imposed are not very costly (i.e. the standard is low). This will occur if the level of infection generated does not cross a threshold, which depends on the strictness of the social standard as well as on the costs of a technology that removes the risk of infection from productive activities. Once this barrier is crossed, a complete reorganization of the productive process is in order and the second, more persistent regime may prevail.

More generally, the results indicate that a possible measure of economic policy to promote security in the phase following a first lockdown could consist of a combination of hard standards of social distancing and other short term measures, such as subsidies and tax incentives to convert business procedures to new structural models that minimize the risk of infection. These could include, for example, smart working, wider spaces for economic activities and/or for service deliveries, and a general re-organization of the production process through self-contained and spatially separated modules.

**Endogenizing the Social Standard**

While the public agency and the private firm have different instruments to influence each other (the fine in the case of the regulator and the avoidance costs in the case of the firm), the social standard is a common variable whose level can be the object of bargaining. From the public point of view the social standard is a benchmark to assess the damage, in the sense that the public wellbeing can be quantified as the (positive) difference between the damage produced by private sector activity (e.g. the loss of lives and the other social costs determined by the infection directly and indirectly caused by it ) and the standard itself. In formal terms, this means that well being $W$ can be defined as the function:

(22) $W = W_0 - (D\frac{X}{\delta} - \frac{R}{r})$

For the private sector, on the other hand, profit is also a function of the difference between the damage and the social standard (see expression (18)).

(23) $\Pi = \Pi_0 - [\left(Q/r - \lambda\mu^{\beta_1 - 1}\frac{QX}{\delta}\right) + \frac{\lambda}{\mu}\frac{R}{r},$ where $\Pi_0 = Q/r.$

We can thus find the Nash bargaining solution to determine $R$, by solving the problem:

(24) $\underset{R}{Max} N = (W - W_0)^{\omega}(\Pi - \Pi_0)^{1-\omega}$

where $0 \leq \omega \leq 1$ is a weight representing the bargaining power of the public sector. The solution of (24) is:

(25) $\frac{R}{r} = \frac{1+\omega(\lambda\mu^{\beta_1}-1)}{1+\omega(\lambda\mu^{-1}-1)}\, Q\frac{X}{\delta}$

Expression (25) shows that if the public agency and the private firm are allowed to bargain over the size of the social standard, they would agree for it to be more stringent (i.e. smaller) than expected damage and the more so the higher is the bargaining power of the public agent $\omega$ , the lower uncertainty (the lower $\beta_1$ ) the less effective (the smaller is $\mu$) the firm is in complying within the BAU situation through temporary measures and/or avoidance costs.

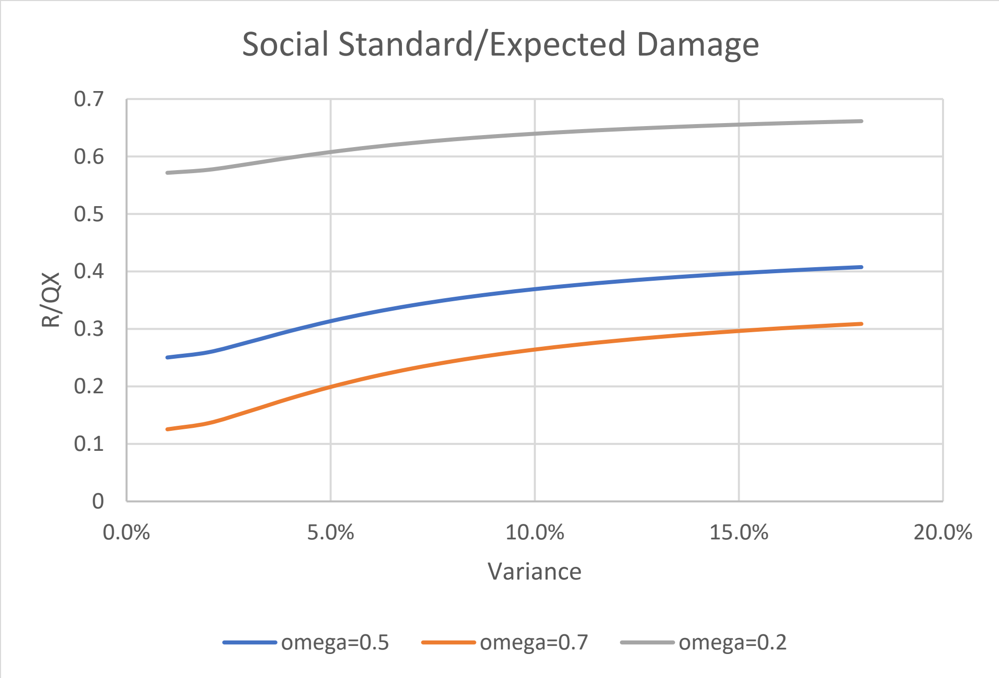


Figure 3

Substituting (25) into (17), we obtain:

(26) $$\frac{C^*}{\frac{DX}{\delta}} = \frac{\lambda}{\mu}\left[\mu^{\frac{1}{\beta_1}}\left(\frac{\beta_1-1}{\beta_1}\right) - \frac{1+\omega(\lambda\mu^{\beta_1}-1)}{1+\omega(\lambda\mu^{-1}-1)}\right]$$

This can be interpreted as the cost that would allow the firms (and that the firms would be willing to pay) to be compliant to the negotiated level of social standard. As Figure 4 shows, this cost is larger the higher is the public bargaining power in determining the social standard (and thus the more restrictive is the latter). It is also larger the smaller the uncertainty, falling below zero for values of the variance above a critical threshold (between 5 and 10%), which is higher the higher the bargaining power of the public party.

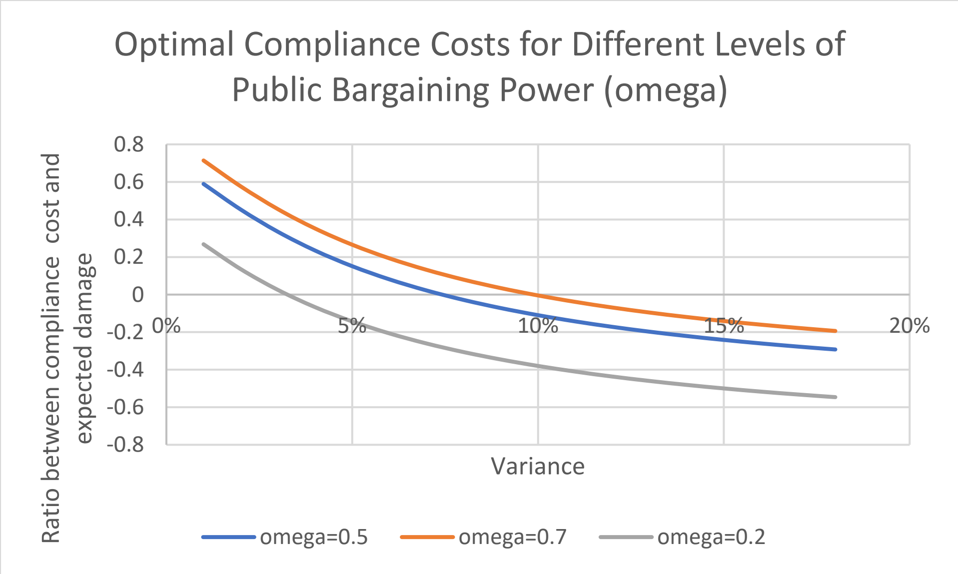


Figure 4

**Conclusions**

The degree of persistence of the changes in work processes due to the pandemic will be determined by several events that at this point in time are difficult to predict. The possible second wave of the virus as well as the successful search for an effective vaccine will be important factors for the return to normality. Somewhat independently of the behavioral changes in consumers and producers' habits, however, the experience of the pandemic is likely to induce important modifications in the behavior of business, consumers and regulators, simply as a consequence of uncertainty and the somewhat dramatic revelation of a new form of global risk linked to the diffusion of infectious diseases . Long term risk management to counter the unsuspected threat of deadly contagion in a hyperconnected world will cause a reorganization of business, especially in terms of space planning and management, with important consequences on the development of new social standards regarding hygiene, work and consumer distances and a whole set of new measures and precautions to respond to the public demand for safety.

In this paper, we have explored some of the characteristics of the new normalcy using the two concepts of liability option and social standard ( Knudsen and Scandizzo 2005, 2010 Scandizzo and Ventura, 2015, 2016) . The analysis shows that under appropriate conditions, a new standard of social distancing will prevail and be incorporated into permanent organizational changes on the part of the industry. It also suggests that a possible measure of economic policy to promote security in the phase following a first lockdown could consist of a combination of hard standards of social distancing and other short term measures, such as subsidies and tax incentives to convert business procedures to new structural models that minimize the risk of infection. These could include, for example, smart working, wider spaces for economic activities and/or for service deliveries, and a general re-organization of the production process through self-contained and spatially separated modules.

REFERENCES


Brennan, M. J., Schwartz E. S. (1985) “Evaluating Natural Resource Investments” *Journal of Business* 58, 2: 135-157.

Dixit A., Pindyck R. (1994) *Investment Under Uncertainty*, Princeton University Press

Knudsen, O. and Scandizzo, P.L. (2005) “Bringing Social Standards in Project Evaluation under Dynamic Uncertainty”, *Risk Analysis,*Vol.25, issue 2, pp.457-466.

Pennisi, G. and Scandizzo, P.L. (2006), *Economic Evaluation in the Age of Uncertainty*. 12: pp. 77-94.

Scandizzo, P.L. and Knudsen, O.(2010), “Risk and Regulation Compliance with Tradable Permits under Dynamic Uncertainty”, *European Journal of Law and Economics* (published on line, 27 February 2010) **.**

Scandizzo, P.L. and Ventura, M. (2010), “Sharing Risks through Concession Contracts”. *European Journal of Operation Research,* Vol.207, Issue 1, 16 November 2010, Pages 363-370.

Scandizzo, P.L. and Ventura, M. (2015), “Organized Crime, Extortion and Entrepreneurship Under Uncertainty”, *The European Journal of Law and Economics*

Scandizzo, P.L. and Ventura, M. (2016), “Innovation and Imitation as an Interactive Process”, *Economics of Innovation and New Technology*