F.O.G. and Teleworking :
Some Labor Economics of covid-19

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Abstract

FOG (« fear of going back to work ») is a new acronym reflecting workers stress to become contamined by covid-19. In response, firms have been offering protections, extending teleworking as a way to continue to work during the pandemics. Leveraging a classical epidemiologic SIR model, we study how pandemics such as Covid 19 affect labor market, when the labor productivity is tied to the value of interactions, and under wage negotiations.

Despite relatively schematic, our modelling highlights that workers participation during pandemics is dependent on reservation wages, and that the final dynamics are also critically dependent on a mix of health and wealth factors such as age, work interactions, workers power, and productivity of interactions. In general, teleworking may be a way to restore work participation, even if teleworking may be less productive, to the extent that the productivity gap can be compensated by a much higher protection of workers.

Keywords: pandemics, covid-19, labor participation, teleworking

JEL codes: I12, J22, J23, J33

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1. Introduction

With million records of infected, the covid-19 pandemic has been a major health shock to date.

The subsequent lockdown that has been adopted by a large share of countries to flatten the curve of the disease diffusion, has however brought extra social and economic challenges. A survey recently conducted by Neurohm in France[2] has looked at the consequence of the lockdown. It shows that for one person quoting worries about her health, another 1.3 also expresses concerns of not being able to meet with family or friends, and another 0.7 is slowly getting afraid of her financial situation.

But companies, trade unions, and workers are said to be equally wary about lockdown exit. The fear of going to work at covid-19 time is big enough that it has its own acronym (« FOG »). This fear may be not misplaced, as those who have kept working on site (a segment in France of another 21% of the population in the Neurohm survey referred to above), have been infected up to 4 times more than the average population (see Figure 1).

Even Silicon Valley, a champion for pushing for back-to-work, has witnessed some workers' reluctance ; in fact, FOG has been said to be prevalent among 70% of the tech professionals in the US[3]; hence, a large response of Silicon Valley firms have been to push for teleworking, - a strategy that indeed has become

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[2] https://neurohm.com/#covid

[3] See https://spectrum.ieee.org/view-from-the-valley/at-work/tech-careers/coronavirus-is-triggering-fear-of-going-to-work

widespread at covid time, with close to 40% of workers in the European Union to have started teleworking during the lockdown period (Eurofound, 2020).[4,5]

If those interactions between health and markets (and in our case, the labor market) are of relevance, they only are being integrated in epidemiologic models (see McAdams, 2020; Eichenbaum et al., 2020; Garibaldi et al., 2020), and demonstrate that people choice may indeed impact how pandemics may unfold.

To see why, let's consider the classical S-I-R model ("S" for susceptible, "I" for infected and "R" for recovered) which defines the epidemic reproduction rate as $R_0 = \beta_{0.}\, \alpha.\nu./\psi$. In the seminal contribution by Kermack and McKendrick (1927), where all contacts have same probability to infect, β_0 is known at the rate of effective transmission per contact between the infected and the susceptible, ψ is the rate at which infected individuals recover, ν is the number of contacts per person, and α is the portion of connections that are contagious. The law of motion of infected through times t, $I_t\text{-}I_{t\text{-}1}$, is thus guided by $I_t\text{-}I_{t\text{-}1} = \beta_0.\alpha.\nu.\ I.S.\text{-}\psi\ I$.

In the case of the covid-19, the median of studies suggests that $R_0 = 2.5$, with $\beta_0 = 0.3$ and $\psi = 0.12$ (see Arroyo Marioli et al., 2020). This means that, in case the pandemic is free to diffuse with same equiprobability among the population, the infection flow would peak at $1\text{-}(1/R_o)$, or, at 60%.

Only a *structural* decline in the number of infectious contacts, $\alpha.\nu$ may thus make the infection spread lower than the one induced by the epidemiology of the disease. Ways to have such shift includes exogenous factors, such as the discovery of a vaccine, or the imposition of containment measures. The «Great Lockdown »

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[4] As result of covid, for instance, ILO has developed multiple advices as to how maximize the returns to teleworking technologies, see: https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_739879/lang--en/index.htm

[5] Crises such as 9/11 had already pushed a shift toward more telecommuting, but the scale of the shift is an order of magnitude larger with covid, see: https://www.brookings.edu/blog/up-front/2020/04/06/telecommuting-will-likely-continue-long-after-the-pandemic/

launched in about 40% of countries worldwide, and which has affected nearly 80% of the world population is a case in point, which has been imposing citizens to stay home and limit contagious contacts. Contact reduction has declined by 60% in Belgium in about 2 months after the lockdown [6]; by 80% in the same time span in France (Angot, 2020) and up to 90% in less than 5 weeks in the case of Wuhan, China, where the pandemic kicked in (Lin et al, 2020).[7]

Shifts in interactions obviously occur beyond exogenous shocks, when individuals adapt their behaviors as a reaction to pandemics. For instance, Coibion et al. (2020) documents a major voluntary reduction in labor supply in the US, as a result of the outbreak in covid-19, that is totally consistent with the idea that older people have decided to retire, following their perception of health risk and hope to find a new job during the pandemic. There is also a large literature suggesting that, depending on information collection on the riskiness of a virus and own preferences, people may engage in major protective behaviors as a way to minimize risky interactions, see Eksin, et al. (2019), or Tyson, et al. (2020).

We take this route in this paper, where we model change in interactions, and in protective tool offering as the result of rational, economic, agents. As said, our zoom is on the link between agent's interaction in the labor market, and covid-19. We first focus on the supply side of labor, in consistency with results by Coibion et al. (2020) which suggest that changes in labor participation have been drastic in the US, driven in large part by covid crisis; in particular, they document a fall of 8 points of the employment-to-population ratio, which is as large as what happened during the Great Recession, or an equivalent to 20 million people losing their jobs.

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[66] See https://www.linkedin.com/pulse/selectivity-versus-reach-flattening-curve-covid-19-joint-bughin/

[7] The challenge is however to make sure that the lockdown exit does not have $\Delta\alpha<0$

In our model, the decision to supply labor is the result of an optimal decision between expected benefit of going to work and risk of being infected. This also is emphasized in more general equilibrium models such as Eichenbaum et al. (2020), who emphasize that pandemic may also lead to recession as the result of people not willing to go back to work.

Our second focus is also on labor demand where we look at how firms may find relevant to offer teleworking. While offered as an option by many companies during lockdown, the question remains whether the option remains valid during exit. Casual evidence like Yahoo CEO in 2013 deciding to limit teleworking, and economic data may sometimes suggest that productivity may be hampered by lack of interactions during teleworking. In case of lower productivity, we show that the risk of pandemic creates an externality that if sufficiently strong make the case profitable.

Our model is a model of multistage of decision making - where we endogenize the mix of contact between work and non-work, as a function among others of the externality to be infected or not, as well as other labor market decisions such as wage development and employment, that themselves may be adjusted during covid time. Taking into account those externalities is similar in spirit to Garibaldi, et al (2020), - where the authors look at how a classical matching function can be extended to account for those health risks. Here, we consider rather that the matching is perfect, but the amount of interactions is the decision variable that affects both the productivity of labor, as well as the level of profit and wage of the economic agents.

New features we incorporate in our model is the existence of a wage curve. Most labor markets operate with some forms of negotiation, to date, and there is also some conjectures that covid may lead to a rebound of unionization, even in markets like the US, as unions typically offer safeguard measures during crisis and have incorporated provision regarding the needs of healthy workplaces.[8] Finally, our model explicitly looks at arbitrage between work, community leisure and home - as interactions in those three domains have different wealth and/or health values. Typical models such as Eichenbaum (2020) only looks at consumption versus leisure - not interactions like we do here. This is rather important as we show that interaction preferences have a large impact on the type of behavior of agents during the pandemic.

While highly stylized, the model shows how agent may optimally determine α and how they may adapt the interaction mix along the path of the covid-19 infection. Those dynamics are further shown to be influenced by the interplay of economic preferences and risk profile of the pandemics. As a feedback loop, it also means that the pandemic diffusion may behave also differently as a result of agents' change in behavior. One key result is that the socio-economic reaction is especially severe for the older cohort, given the disproportionate effects of health risk linked to ageing, and the preferences of older people to lower their active participation in the workforce. This theoretical outcome is in fact totally consistent with the empirical findings of Coibion et al. (2020), of a significant drop in employment of older age groups being witnessed during covid time in the US.

A last section concludes.

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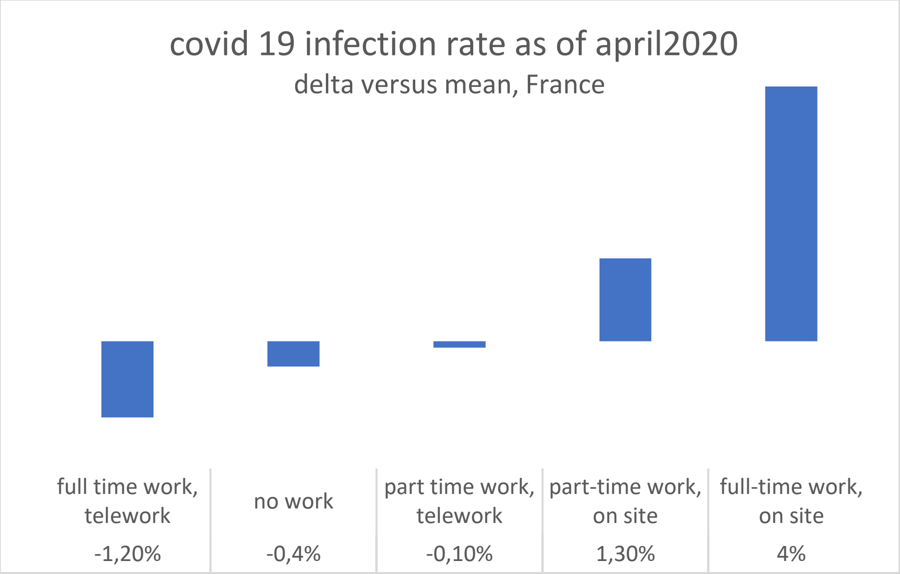
[8] https://whowhatwhy.org/2020/04/30/could-a-pandemic-spur-the-resurgence-of-labor-unions/

Figure 1. Health versus wealth: covid infection in and out work, France (illustrative only)



Note: marginal effect of work style derived from a probit of covid 19 infection, no control effects.

2. A simple model of interacting health pandemics and labor market performance

2.1. An economy without covid-19

We consider a constant, willing and able to work population N, as in Chang and Velasco (2020). The population may decide either to work, to enjoy socialization outside work, or still to stay at home. We consider that on average, there are ν contacts per period. As we are interested in the mix of contacts between work and non-work, we normalize $\nu = 1$.

The utility of the representative agent is $U = U(\alpha, a)$ where a is the portion of time contacts outside home, $(\alpha - a)$ is the share of time allocated for social enjoyment, and the balance, α, at work. The difference $(\nu\text{-}\alpha) = (1\text{-}\alpha)$ is the portion of connections made in isolation at home.

Agents will have different health according to the SIR model (see later). Further, one might add additional differentiation in an agent's will to socialize outside home γ or still in her preference, ε between work and social community exchanges. For example, young generations tend to have lower γ and higher ε than the older generation, and are found to be critical factors shaping pandemics, see Fumanelli et al. (2012). At current, we consider one economically representative agent, with same ε and γ (we show some sensitivities later). Her utility U is given by:

$$(1)\ U = a.w + \varepsilon.\ (\alpha - a)^2 + \gamma.(\nu - \alpha)$$

ε, γ are preference parameters respectively towards, leisure versus work, and versus staying home or socializing. w/p is unit real wage, and p = 1 is the numeraire. Assume also that τ is a scaling factor, up to $(\alpha\text{-}a)$, or the value of the social interactions outside work. In general, $1 > \tau$ and $\tau = (\alpha\text{-}a)$ under the Metcalfe law (Zhang and Xu, 2015), which we assume here to hold.[9]

We also have a set of M identical profit maximizing firms, which we scale to a representative firm. Each firm is the same, and is a price taker, and the production function is using only labor, L, such that:

$$(2)\ Q = \zeta.a^2$$

The scaling effect reflects the value *of interactions* at work, but the effect might be less than one, as social connections are bounded by firm size.

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[9] The value of a network may scale much less than induced by a simple power of a, e.g., $t = \ln(\alpha\text{-}a)$, see Oldlyko and Tilly (2005).

2.1.1. Labor demand

Given (2), it is straightforward that marginal profit will increase with a.n. Thus, firms will go for maximum potential of a = α_d*, to the extent that:

$$(3)\ \alpha_d{}^* > \alpha_{min}{}^* = w/2.\zeta$$

In normal times, firms negotiate with agents to induce them to come to work; otherwise, no one works, and no normal profit is made. They lure the agent to work by offering at least a value above her fall-back/threat point, which is the value of spending all of her time, s, in social communities.

2.1.2. Wages

Consistent with the existence of a wage curve (Blanchflower, 1995) we posit a model of wage formation, whereby firms and agents negotiate wage, w (see Bulkley and Myles, 1997; or Bughin, 1999). The supply of labor is a decision, and is predetermined in early stage, before the negotiation.

For a sub-game perfect solution, w* is the solution to the generalized Nash equilibrium:

$$(4)\ \text{argmax}_w\ NA = (U-U_0)^{\delta}.\ \Pi - \Pi_0{}^{1-\delta}$$

where δ is the relative bargaining power of the representative agent vis-à-vis the representative firm.

Equation (4) is net of fall-back points, respectively, U_0 (resp., Π_0) is the fall-back agent’s utility (resp., profit). $\Pi_0 = 0$, given there is no other production factor than labor. U_0 is given by the fall-back of social community time, e.g., when setting $\alpha=0$:

$$(5)\ U_0 = \varepsilon.\alpha^2 + \gamma.(1-\alpha)$$

By setting the derivative of (4) with respect to wage, imposing that a = α*, and equalizing to zero, we compute:

$$(6)\ w^{*}= \alpha^{*}.(\delta.\zeta+(1-\delta).\varepsilon)= \alpha^{*}.\sigma$$

subject to a positive profit, that is:

$$(7)\ 2.\zeta >(\delta.\zeta+(1-\delta).\varepsilon)>0$$

That is, an interior solution to (6) only prevails as far as $((2-d)/(1-d)).\ \zeta > \varepsilon$.[10]

2.1.3. Labor supply

Now, if we move to optimal labor supply, $\alpha_S{}^{*}$, and integrate the equilibrium labor market constraint that $\alpha = \alpha_S{}^{*}$ into utility (1), we find that:

$$(8)\ dU/d\alpha_S{}^{*}=0 \text{ -> } 2.w^{*}=\gamma/\ \nu \text{ -> } \alpha_S{}^{*}=\gamma.\nu\ /2.\sigma$$

while the labor market equilibrium between supply and demand, $\alpha^{*}=\alpha_S{}^{*}=\alpha_d{}^{*}$, leads to the following economy:

$$(9)\ w^{*}=\gamma.\ \nu\ /2$$

$$(10)\ \alpha^{*}=\gamma\ \nu\ /2.\ (\delta.\zeta+(1-\delta).\varepsilon) \text{ if } \sigma<2.\ \zeta$$

$$\text{otherwise } \alpha^{*}=\gamma.\ \nu\ /4.\zeta)$$

$$(11)\ \text{For } \sigma<2.\ z,\ \Pi^{*}= \gamma.\ \nu\ \ (\zeta.\gamma.\ \nu-\sigma\ )/4.\sigma^{2}$$

$$\text{if } \sigma <\zeta.\gamma.\nu \quad (\text{otherwise, } \Pi^{*}=0)$$

$$(12)\ \text{For } \sigma>2.\ \zeta,\ \Pi^{*}= \gamma.\ \nu\ .\ (\gamma.\ \nu-2)/16.\ \zeta$$

$$\text{if } \ \gamma.\ \nu >2,\ \ (\text{otherwise, } \Pi^{*}=0)$$

Additionally, the total welfare of the economy, W, is such that:

$$(13)\ \ W= \zeta.\ (\alpha^{*})^{2}+ \gamma.\ (\nu- \alpha^{*})$$

Hence, if the planner had the full power to maximize the economy, rather than done by agents separately, we would have that:

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[10] Otherwise (3) determines the final salary as: (6') $w^{*}=2.\ \zeta.\ \alpha_{min}{}^{*}$

$$(14)\ \alpha_w^* = \gamma\ \nu / 2.\ \zeta > \alpha^{*}$$[11]

In fact, the labor supply would be *higher* under the planner rule, as it would internalize the right to manage of the firm to decrease wages against its level of committed employment.

2.1.4. Stylized economy

We now run some basic sensitivities to see how this economy looks like. In general, firms remain in control of wage setting, and δ varies in the range (0.15-0.40) depending on industries (see e.g., Dobbelaere, 2004). We also assume that $\zeta < 1$, and we assume range like 0.7 to 0.1, with lower bound highly plausible (see Oldlyko and Tilly, 2005).

Second, the absolute elasticity of substitution between « outside » and « inside » activity (that is, between s and 1-s) can be estimated to be: $E_o = \gamma.2.(2.\sigma - \gamma)/\gamma$. Similarly, the elasticity of substitution between labor and non labor activities is given by $E_l = \varepsilon.(2.\sigma - \gamma)^2/4.\sigma.\gamma^2 = E_o.(2.\sigma - \gamma)/8.\sigma.\gamma$. As typical empirical estimates of labor/ non labor are found in the range of 0.3-0.4 (see Blundell and MaCurdy, 1999), plausible values range for γ and ε are then to be found around: $\gamma = (0.7\text{-}0.9)$ and $\varepsilon = (0.4\text{-}0.7)$.[12]

Sensitivities, using the range of parameters are reported in Table 1, and one sees that the economy contact mix is such that $\alpha > 50\%$ in most of plausible scenarios. This means that a majority of economic contacts may be subject to *contagion*.

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[11] Provided that $\delta < 1$ and $\zeta > \varepsilon$. The latter is in practice more likely given the constraint above for an interior solution.

[12] Based on those ranges, the weights in the utility function are more favorable to work than non labor.

We also see that, at the lower end of parameters, we have a more active economy and a lower value share of leisure. But this is not necessarily the one that maximizes GDP or welfare potential. This happens in the mid scenario, where the reduction in activity is more than compensated by higher value of non-work activities, and higher scale in productivity. *Our mid scenario will be our reference scenario for most illustrations going forward*.

Table 1. Outside home activity and welfare in a non-covid economy

SCENARIO/ : Parameters	Low	Mid	High
δ	0.15	0.25	0.4
ε	0.4	0.55	0.7
ξ	0.7	0.85	0.95
γ	0.7	0.85	0.9
Output			
A	0.78	0.68	0.56
GDP	0.61	0.67	0.57
W	0.67	0.76	0.68
Share : wage income	58%	65%	71%
Profit	36%	26%	16%
Leisure	16%	19%	23%

Note: GDP and welfare are measured relative to optimal welfare-optimised α.

2.2. Covid-19 and FOG

Assume now that covid-19 has been hitting the market. From the above, we might suspect that the workers would want to pass through some of the extra risk of work to the firm in the form of higher wages, but in the same time, the firm holds some power to prevent a too drastic reduction in profit, as it may hit the labor demand constraint. As a result, we might anticipate that the economic activity diminishes. The dynamics of how infection diffusion affect economic behavior may also mean that infection pace might also slow down. Firms may also decide to offer teleworking as a protective measure.

We start by considering that a covid economy with *no* teleworking; we study the opportunity of teleworking later in the article.

2.2.1. Labor demand under covid 19

Assume then that covid-19 behaves like in a SIR epidemiologic model, and we are at time *t* of infection diffusion. We drop the suffix t for simplicity now, and we have a portion I of infected, as well as a portion R of recovered from the past; we note, using the notation above, $R= \psi.I$, with $\psi<1$.

A portion $(1-\alpha)$ of contacts happens at home, which is isolated by definition. Then, the maximum expected portion of productive workers is thus: $\alpha.(1-I).(1-(\beta_0-\psi)).I$ and by notation, $\phi=(\beta_0-\psi).I$, and the firm choses the total share of employment such that

$$(15)\ a=\alpha_\delta,$$

and the firm does not produce below:

$$(16)\ \alpha_{dmin}'=w' /2.\ ((1-I).(1-\phi) + \psi.I).\zeta,$$

with w is determined here-after.

2.2.2. Wages under covid-19

For wage determination, we know that a portion I of workers has been contaminated. They are suffering a health cost, c[13]. As sick leave, they may receive as well a replacement wage, which is a function of their salary, $\mu.w$, with,

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[13] The health cost does not include psychological costs, which may appear relatively high for much part of population and may inflate the total cost of the disease - see for instance Dryhurst et al. (2020).

$\mu < 1$; with a net utility of $\mu.w-c$. For the portion I of the past, this is sunk, so the real portion of time/work subject to bargaining is for the portion $\alpha.\phi.(1-I)$. For the portion of the susceptibles who remain in good health, plus the recovered, $((1-I).(1-\phi))$, the negotiation involves salary, net of credibly enjoying the time outside of work. This means that the total net utility becomes:

$$(17)\ U'-U'_0 = \alpha.w.((1-I.(1-\psi)).((1-\phi.(1-\mu)) - \varepsilon.\alpha^2.((1-I.(1-\psi)).(1-\phi)) - \alpha.\phi.(1-I).c,$$

While the net profit is:

$$(18)\ \Pi-\Pi_0= ((1-I.(1-\psi).(1-\phi)).(\zeta.\alpha^2-\alpha.w)$$

The worker negotiated wage is the optimal solution to the Nash bargaining solution (assuming no corner solution):

$$(19)\ w'= \alpha'((\delta.\zeta)+(1/\rho).(1-\delta).\varepsilon.(1-\phi))+(1/\rho).(1-\delta).\phi.c$$

$$(19')\ w'= \alpha'.\sigma' + m.c$$

With $\rho = (1-\phi.(1-\mu)$ and $\sigma'<\sigma^*$ as far as $\mu>0$, and $m=(1/\rho).(1-\delta).\phi <1$ when $\phi< 1/(2+(\delta-\mu))$.

Equations (19-19') converge to the solution without pandemic in equation (6), when I=0 (and therefore, $\phi=0$ and $\rho=1$). For both I and $\phi > 0$, (12) adds an extra term versus equation (6). This term corresponds to the pass-through of the expected cost of the pandemic, $\phi.c$, among the pool of susceptibles.

The effect of I on wages can only be fully figured out when we know $\alpha=\alpha(I)$ in the last stage of the game. However, it is worth to look at how wage dynamics evolve with pandemic, for the same level of employment as in the non-covid economy.

Then, the dynamics of wages with respect to infection diffusion are inflationary when:

$$(20)\ w>(1-\delta)/(1-\mu)).(\varepsilon-c).$$

In accordance to intuition, (20) holds, the higher the health cost, and the lower the replacement wage, μ. Both a higher c and a lower μ make the pandemic a higher burden (and fear, FOG) to the agent, leading her to include this opportunity cost as a hurdle to come to work.

To illustrate the extent of the inflationary pressure above, let us take our mid scenario from Table 1. We further consider that c = 0.6 times income, that is, roughly what emerges from the expected loss of the value of statistical life for the working population in the US, regarding the covid-19 fatality rate, see Bethune and Korinek (2020). As referred above, we also have $R_0 = \beta 0/\psi = 2.5$ with $\beta_0 = 0.30$ and $\psi = 0.12$. We finally consider $\mu = 0.6$, which is roughly the current ratio of unemployment benefit to wages in OECD countries.[14]

Table 2 illustrates an inflation that builds up along the covid-19 diffusion. The time at which the disease stops its exponential curse is at I = 60%, and dies out at I = 87%, which are the last two lines of Table 2. The wage inflation is up to 4%, for the same level of employment as for the economy *without covid-19*.

Note as well the sensitivity to replacement wage and health cost. Assume that someone has only 30% replacement wage[15], the wage premium inflation requirement at same level of employment would be 5 times bigger than what is illustrated in the n of Table 2 and would thus mean an inflation at 90% disease diffusion, of up to 7.2%.

Likewise, the expected cost of covid-19 increases as a power law with age, and doubles for every decade of life—thus, there the wage inflation would go in this case, at 90% diffusion to 7.7%.

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[14] https://www.oecd.org/about/publishing/36965805.pdf

[15] As say, in Oceania, being at the bottom of OECD countries regarding unemployment benefit ratio.

Table 2
The dynamics of wages as activity level of the non covid economy mid-scenario from Table 1

Infection	Base case Mid scenario	10% less replacement wage	10% higher health cost
10%	0.4%	0.4%	0.4%
30%	1.1%	1.4%	1.3%
50%	1.9%	2.3%	
60%	**2.4%**	**2.8%**	**2.7%**
90%	**3.7%**	**4.4%**	**4.1%**

Source : authors' computation.

Proposition 1: Negotiated wages may increase under covid-19, as a way to compensate the fear of going back to work (FOG) with the benefit of higher labor participation

Note that this proposition holds given the value of work interaction. Wage increase is bounded by the constraint of the labor demand.

2.2.3. Work participation under covid 19- the representative agent case

Let us now turn to the optimal supply of labor. As discussed in the introduction, we are not modelling the matching process of supply to demand, like done by Garibaldi et al. (2020) - rather the matching is instantaneous, but the supply (and demand) may be adjusted as the pandemic unfolds.

While health cost may be passed through to higher wages, labor participation may also change, depending on the actual revenue, if getting contaminated (see Adams et al., 2020).[16] The participation to work is given by the intersection between the marginal disutility of not staying home (γ) and the marginal benefit of going to work, which is given by:

$$(21)\ U = \alpha.(1-I.(1-\psi)).\phi.(\mu.w-c) \\ +(1-I.(1-\psi)).(1-\phi).(\alpha.w+\gamma.(1-\alpha))$$

When compared to (7), equation (21) now includes an additional term that represents the utility linked to quarantine. If this is only a negative cost, then it is clear that labor supply will shrink. However, if there is large protection in the form of high μ, some of the labor supply reduction induced by quarantine may be more than compensated in the form of reservation wages.

To define the exact amount of supply, we take $dU/d\alpha = 0$. Rearranging, we have:

$$(22)\ w' = \gamma.(1-\phi))+\phi/\rho.c.\ ((1-\delta).(1-\phi)-\rho))\ /\ (2.(1-\phi)-\phi.\mu)$$

Noting from above that $w'=\alpha'.\sigma'+m.c$, α' is found to be:

$$(23)\ \alpha' = (1-\phi).\ (\gamma+c.((\rho-1/\rho).m-\phi)\ /\ \sigma'.(2.(1-\phi)-\phi.\mu)$$

Which, when $I = 0$, leads to $\phi = 0$ as well as to $\rho = 1$ and to $\sigma* = \sigma'$. In this later case, equation (23) collapses to $\alpha_s{}' = \alpha_s* = \gamma/2.\sigma$, that is, is the same as equation (7). Further, if $\mu=0$, then equation (14) collapses to:

$$(24)\ \alpha' = (\gamma-c.\ \phi.\delta\ /\ 2.\sigma) < \alpha_s* = \gamma/2.\sigma,\ \text{for } I>0$$

Further $d(\alpha_s{}'/\alpha_s*)/\delta I < 0$, $d(\alpha_s{}'/\alpha_s*)/\delta c < 0$, $d(\alpha_s{}'/\alpha_s*)/\delta(\beta 0-\psi) < 0$,

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[16] Covid-19 morbidity leads usually to four to six weeks out of work, among 11 months FTE, or 10%. Further, assuming a fatality of 0.5 percent for workers getting the covid at median average of 40 years old, we add 20 % or 30% of current revenue.

highlighting the fact that agent would rationally *decrease* the supply of labor in function of the severity of the pandemic. As discussed above, $\mu > 0$ goes into the other direction, so that μ is an important driver of the dynamics of supply.

In order to give more flavor to the above results, let again consider our base average scenario, see Table 3, that highlights for each given level of infection, the *marginal* decision of non-infected people to come or not to work. The marginal labor participation accelerates in absolute value but with a bifurcation, that is towards toward *lower* participation when *there is no reservation wage*, and toward increased participation in the case of a *(sufficiently high) reservation wage*.

Table 3

How α evolves with pandemic,

base scenario, vs. no covid 19

infection rate	μ=0	μ=0.6
0 to 10%	-1.15%	1,14%
10 to 20%	-1.21%	0.99%
20 to 30%	-1.28%	1.35%
30 to 40%	-1.36%	1.31%
40 to 50%	-1.46%	1.43%
50 to 60%	-1.55%	1.54%
60 to 70%	-1.65%	1.68%
70 to 80%	-1.79%	1.85%
80 to 90%	-2.41%	2.01%

The later finding, as discussed, is not surprising as the reservation wage, $\mu.w$, is a fraction of negotiated salary ; if the later increases with the pandemic (as a result of passing through the expected health costs through the wage curve), and the reservation wage is large enough versus the expected cost of disease, participation may even be stimulated.

Based on table 3, it is also easy to show that the neutral participation μ is just « below » the average of the two columns, as both columns are roughly symmetric in terms of labor market participation. In fact, the exact value is μ=29,5% of negotiated wages. From equations above, also, the neutral participation reservation wage increases if *d* increases and especially, when the healthcare cost, c, increases.

We can also look at GDP (or welfare) as a measure of activity, see Table 4[17].

Table 4

How marginal GDP evolves with pandemic, base scenario

infection rate	μ=0	μ=0.6
0 to 10%	-0.60%	-1.40%
10 to 20%	-1.30%	-0.90%
20 to 30%	-1.90%	-0.10%
30 to 40%	-2.50%	0.70%
40 to 50%	-3.30%	0.50%
50 to 60%	-4.00%	0.80%
60 to 70%	-4.90%	2.00%
70 to 80%	-5.70%	2.60%
80 to 90%	-6.60%	3.60%

In fact, when there are no reservation wages, GDP *declines* as labor participation drives the economy in our base case scenario. In contrast, for a sufficiently attractive reservation wage, GDP may increase. At the start, the benefit of receiving the reservation wages is larger than those lured to work as infection i slow, and thus GDP shrinks. However, at about 30% of contamination, the reservation wage plays its role and allows for *a better participation* in the economy.[18]

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[17] We focus on GDP as welfare provides the same picture along the dynamics of the disease diffusion

[18] The cost of financing this reservation wages is not included in our model. But let us assume that there is one month of reservation wage that needs financing for 90% of people with no hospitalisation,

Proposition 2: Work participation tends to be reduced by FOG (high expected cost of covid), especially if there is low reservation wage.

This proposition may look surprising if put with the first, side by side. Wage will increase as a result of the risk of pandemic indeed, but this pass through is on the wage threat point, not on the final wage, which itself depends on workers' power during negotiation and other preferences and technology parameters. In final, proposition 2 is the result, and the higher the absence of alternative revenue.

Note that models such as Eichenbaum et al. (2020) also demonstrate a labor supply effect that leads to lower human capital put at work—and a lower GDP growth. The effect is linked to arbitrage between consumption and leisure. In our case, the arbitrage is linked to contact mix as well including social leisure versus home—and is shown to depends on the mechanics of wage formation, including ability to pass through health costs into wages and fall-back wages.

2.2.3. Work participation under covid-19 archetypes

As clear in equation (24), the participation change with the pandemic relies on the interworking between economic parameters (wage power. preferences for work activities and home activity and productivity of interaction) and health parameters.

The value of parameters is likely to be very different for different clusters of the population. For example, the expected health cost may be up to *100 times larger for someone in her sixties than say someone of 15 years old*, according to Bethune and Korinek (2020). We also know that front and back end work is the largest driver of work contact, twice more in front than in back office. Finally, there is a

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and for 90% of population given R0 of 2.5, for the covid-19. The cost, according to our assumption will then be 0.9*0.9*0.6*1/12 months of work, or 0.4% point of GDP. The difference in GDP between the two scenarios with and without reservation wage is already larger than this cost, when infection rate reaches about 25% of population.

large set of social contact studies, that look at frequency of contacts by socio-demographics, which describe a consistent pattern where the intensity of contact is negatively correlated with age, and positively with education as well as income (see e.g., Hoang et al. 2019).

The key a dimensions linked to covid-19 that seem relevant for describing are a) different workers' archetypes are age, (young versus old, as this drives very different expected cost of disease as well as preferences for work versus non-work interactions) ; b) front versus back office work (as this defines the needed level of social exposure at work), c) low versus high skill (as this drives bargaining power, and amount of contacts) as well as d) gig or not (as this defines level of protection wages, but also platform versus firm productivity).

We illustrate four archetypes.

The first two relate to the young generation, 30 years old, but the first archetype is low skill, gig economy, and more back-office (e.g., she does perform some Mechanical Turk tasks, or help label data for Google).

The second is more high skill, front-end, and work with a traditional company (say, a young investment banker, etc). The last two archetypes encompass baby boomers ; one is doing front end, low skill, non-gig, e.g., like someone doing logistic work or retail, and the other is more high profile, already doing some gig type and front end, e.g. a software engineer with own company, etc.

As we are concerned with the work contact, we rely on Leung et al. (2017), which gives data at work as well non-work level as well their nature (physical instead of other type of contacts like digital). Difference in physical contacts versus average working population is 23% higher for 30 years old, and 25% lower for 60 years old and low-high skill/education is -10% to 15% versus the mean. Difference in front and back office is twice more for front than back. Using those parametrizations, we have that $\beta_0 = 0.3$ for our first segment, $\beta_0 = 0.8$ for the second, $\beta_0 = 0.4$ for the third and $\beta_0 = 0.5$ for the last segment. Based on health susceptibility and cost, the first two segments have a c =0,05 for then times more for the last two.

The difference in parameters by archetype is displayed in Table 5 versus our average case where we also assume $\mu = 30\%$ so that it becomes the reference neutral case.

The bottom of the Table 5 illustrates the labor participation for three points in time of the covid-19 diffusion, e.g., when the pandemic is in full force (30%) when it comes at its peak (60%) and is on the verge of disappearance.

Table 5

How work participation with covid depends on archetypes

		Archetype:			
	base case	1	2	3	4
m	0.3	0.15	0.6	0.6	0.15
c	0.15	0.05	0.05	0.5	0.5
b_0	0.3	0.23	0.65	0.5	0.625
d	0.25	0.12	0.4	0.12	0.4
e	0.55	0.7	0.4	0.4	0.7
x	0.85	0.5	0.85	0.5	1
g	0.85	0.45	0.60	0.60	0.9
Participation rate					
I=30%	100%	100%	108%	91%	86%
I=60%	100%	100%	120%	76%	67%
I=90%	100%	100%	145%	54%	36%

Notes: archetypes described in the main text.

We notice a clear distinction between the first two and last two segments. The difference is driven mostly by the *risk exposure* to the disease, as well as by the relative preference towards non-work. The last archetype is one who is especially reducing the work exposure, as the archetype does not rely on a secured reservation wage, while his skills/bargaining power allows the archetype to build a wage premium than more work.

For this archetype, low participation is increasingly becoming an optimal participation strategy, along the diffusion of the pandemic.

The first segment has limited exposure as it faces both back office remote work and low expected risk of disease but the second archetype is happy to work more as the archetype benefits from protection wages and exposure to covid has however low risk of fatality given young age.

This leads to following proposition:

Proposition 3. The effect of pandemic on labor market is not uniform and is dependent on the mix of age, skills, and preferences of types of social interactions. In particular, the participation rate at covid time may decrease significantly with age.

This proposition fits with the empirical evidence on lower participation of older age groups in the workplace, since covid 19 unfolds. There is established evidence in the UK that two-thirds of the most exposed groups to covid have at least one flag associated with elevated covid risk that prevent them to go back to work– « and about a sixth have one of the age-related flag » (Costa et al , 2020). Coibion et al (2020) shows also for the US an unusual rise in the share of retirements accounting for the exceptional decline in labor force participation during the covid crisis.

2.3. Covid-19 FOG and SIR

As discussed, the impact of health risk on the labor market, may also build a loop from labor participation to disease diffusion, as diffusion is driven by level of contagious contacts, that is α. Based on table 5, we build Table 6 that shows how the change in labor participation affect the diffusion through the workplace. Given the fatality rate increasing with age, the recovery rate is accordingly lower and reflected in the dynamics too.

We know that the work economy is on average parametrized to peak at I = 60%. (that is R(I = 60%) =1) but this varies among segments - with archetype 1 already peaking before 60% and archetype 4 peaking only at 84%[19], according to our parametrisation, as the segment has large contamination given work type and age tenure.

With endogenized allocation of time, segments 3 and 4 start to reduce exposure significantly especially when infection rate becomes relatively high. We thus conclude that economic dynamics can affect the dynamics of diffusion, especially for segments with high expected health risk.

Proposition 4: Pandemic diffusion will be limited by economic agents labor market participation decisions.

This proposition echoes the importance of extending the classical SIR model with the endogenization of behaviors. Rational agents, even if decentralized in their decision, may slowdown disease spread as a result of more protective behavior.

Table 6
evolution of infection ΔI. covid 19 economy

α fixed	I=30%	I=60%	I=90%
archetype 1	1.0%	-2.1%	-9.2%
archetype 2	9.9%	8.1%	-5.4%
archetype 3	7.5%	6.0%	-4.5%
archetype 4	10.1%	9.0%	-3.4%
a evolving according to optimal labor participation			
archetype 1	1.0%	-2.0%	-9.2%
archetype 2	11.0%	11.2%	-2.8%
archetype 3	4.7%	1.6%	-8.8%
archetype 4	7.5%	2.6%	-9.2%

Implied Evolution of R(I). covid 19 economy

α fixed	I=30%	I=60%	I=90%
archetype 1	1.26	0.72	0.18
archetype 2	3.64	2.25	0.62
archetype 3	3.50	1.60	0.38
archetype 4	4.38	2.15	0.42
a evolving according to optimal labor participation			
archetype 1	1.26	0.73	0.18
archetype 2	3.93	2.50	0.75
archetype 3	2.80	1.52	0.28
archetype 4	3.76	1.68	0.23

2.4. How covid-19 may influence labor demand

While labor supply may thus shrink as part of protective strategy by some susceptible without sufficiently high reservation wage and when there is high health risk, firms may also want to avoid that a too large portion of infected is reduced - even if firms must have to incur some opportunity costs in the form of limited interactions between workers.

Let us note that, if k is the portion of worker allowed to telework, the productivity may change to $\zeta' = \zeta - g.k$. There is large likelihood that $g > 0$, that is, there is a productivity gap linked to teleworking. While this may evolve with better technology use, this gap has been prevalent especially when it comes to those necessary tasks for which interactions are key but have become socially risky like in the covid-19 crisis (see Battiston et al., 2017).

Let's take the assumption $\zeta = 1$, as well $\mu = 0$, as a sufficiently high $\mu > 0$ makes the supply of labor not decreasing, thus does not need teleworking as solution to rebuild supply. We thus have a profit to be maximized over k:

$$(25)\quad \text{Max}_k\ (1-((1-k).\ \phi)).((1-\gamma.k).a^2 - a.w)$$

The second derivative to a is positive, so that the firm will still choose the max $a = \alpha''$. Solving (25) for $k = k''$, we find that

$$(26)\ k'' = (\phi.((\alpha.(1+\gamma) - w) - \gamma.\alpha) / 2.\ \phi.\gamma.\alpha$$

and $k'' > 0$ provided that $((\alpha - w)/\alpha) > g$

which is obvious for $g < 0$, that is, when there is enhanced productivity to teleworking. For the positive case, the condition means that the relative marginal revenue $((\alpha - w)/\alpha)$ of doing teleworking must be higher than the cost of lower productivity, in order to offer it.

Given this case of $g > 0$, we then can show that $dk''/dg < 0$, that is, the risk of lower productivity to the entire working population increases versus the gain of protective measure, so that the company will use less teleworking.

We also see that the change in k due to change in ϕ is given by:

$$(26)\quad dk''/d\ \phi = 1 + dk''/d\alpha.\ d\alpha/d\phi + dk''/dw.\ dw/d\phi$$

or:

$$(27)\quad (dk''/d\phi) = \gamma.(1 - d\alpha/d\phi) - \phi.(dw/d\phi)$$

Rearranging:

$$(28) \quad (1 - d\alpha/d\phi) > \phi/\gamma \, .(dw/d\phi)$$

We know from the economy with covid-19 that $dw/d\phi > 0$ as well as that $d\alpha/d\phi < 0$. We thus find that with increased diffusion of covid-19, firms will have a *higher incentive to offer teleworking* to the extent that more people engaged with teleworking provide *more benefit than the relative productivity loss and the increase in wages* as a result of passing through the cost of disease through the fall-back wages.

We can thus derive two final propositions.

Proposition 5: Teleworking may be a firm profitable strategy to the extent that possible productivity shortfall of teleworking is sufficiently compensated by more people put into work.

Proposition 6: Teleworking scope decreases with wage inflation but increases with pandemic and with the average productivity of labor.

Proof: follows directly from above.

Proposition also means that teleworking is rather relevant if productivity linked to teleworking will be matching, even better, improves on traditional office productivity. This possibly meets the profiling of the fourth archetype - a segment which is already more tuned to digitization (as leveraging the gig economy) and who may want to work only when risk of covid-19 is sufficiently hedged.

3. Conclusions

This article belongs to the emerging economic literature that formalize the interaction between economic behavior and pandemic diffusion. The focus is on economic behaviors affect the behavior in the labor market, and vice versa.

Our model extends the burgeoning literature in different ways. First, it is based on a more realistic setting of a wage curve, and second on the fact that labor productivity may be directly tied to social contacts. Third, it also looks at the relevance of teleworking as a strategy to continue even after lockdown exit. Fourth, it illustrates the parameters leading to the emerging reluctance to work for (mostly aged) segments of population afraid of getting contaminated by the covid-19. FOG is a real phenomenon and significant decrease in worker participation has been noticed, with a steep decline, as high during the last two months, as the total decline during the entire time of the Great Depression in 1929.

While highly schematic, the model illustrates that pandemics affect economics and vice-versa. It also demonstrates that many factors mediate the link between health and labor participation and labor demand. This includes relative preferences of social interactions, bargaining power to set wages and pass-through expected cost of disease, etc. Given those parameters, a representative agent may be a too simplistic working assumption. In particular, segments with high social exposure, high skilled and relative age mature may be more prone to change in labor dynamics than low skill back office young workers. Finally, one key for protection under severe pandemic is health protection via teleworking, reinforcing the need to scale those solutions going forward.

Multiple extensions to the model exist; First, we focus only on labor - it might be relevant to expand this to more general technology, including automation. With automation, firms may find a solution for decreased participation, yet a large part of the issue is not efficiency, but loss of productivity scale linked to social contacts. Second, firms are considered price-takers, but, in a more general price setting context, firms may also find attractive to restrict output, or to expand it, depending on type of market conduct and structure. Finally, firms may also provide simple protective tools like masks, etc, as a way to keep the value of social interactions under covid-19 lockdown exit. All this is left for other research.

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