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Macroeconomic implications of the COVID-19 pandemic: an analysis of early academic production.

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Macroeconomic implications of the COVID-19 pandemic: an analysis of early academic production.

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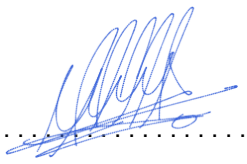
Firma del profesor: 

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RESUMEN

Esta investigación consiste en una revisión exhaustiva de literatura académica sobre Macroeconomía y COVID-19. Para esto, reviso treinta y cuatro publicaciones del catálogo de *Working Paper Series* del *National Bureau of Economic Research* (NBER) de los Estados Unidos, emitidas durante los cuatro meses siguientes al inicio de la pandemia (desde mediados de marzo a mediados de julio de 2020), dentro de la categoría de *Efectos Macroeconómicos Agregados*. El presente análisis está primordialmente enfocado en comprender la evolución metodológica que ha sido propiciada por las conciliación entre macroeconomía y epidemiología, y cómo ciertas herramientas del análisis macroeconómico contemporáneo han ayudado a comprender mejor el proceso epidemiológico y las consecuencias de éste sobre los resultados macroeconómicos agregados. Igualmente analizo algunas de las discusiones más importantes de política de contención óptima que han emergido de dicha evolución, en coherencia con las características metodológicas particulares que incluyó cada investigador en su modelo.

Palabras clave: Macroeconomía, Metodología económica, Modelización macroeconómica, Modelización epidemiológica, COVID-19

ABSTRACT

This paper consists of a comprehensive literature survey on Macroeconomics and COVID-19. For this, I revise thirty-four papers published by the Working Paper Series of the National Bureau of Economic Research of the United States during the four months that followed the pandemic's outbreak (from mid-March to mid-July, 2020), under the *Aggregate Macroeconomic Effects* category. The present analysis is primarily focused on understanding the methodological evolution that has been driven by the conciliation between macroeconomics and epidemiology, and how certain tools of contemporary macroeconomic analysis have helped at better understanding the epidemiological process and its effects over aggregate macroeconomic outcomes. I also analyze some of the most important optimal containment policy discussions that have been drawn from such evolution, in coherence with the particular methodological characteristics that each researcher included at their model.

Keywords: Macroeconomics, Economic methodology, Macroeconomic modelling, Epidemiological modelling, COVID-19

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1 Introduction

The unfold of the COVID-19 pandemic has brought the worst economic crisis since the times of The Great Depression, more than 90 years ago (Gopinath, 2020). Ever since this disease got the *pandemic* status, the entire scientific community turned its attention into what became an evident threat for humanity. In the case of economics' academia, these efforts have brought an extensive interest into trying to understand the several different faces of the crisis and the diverse fields where certain consequences are prone to be seen, both at a micro and at a macro level, from the households', the firms' or the governments' perspective, and either in the short or the long run.

Noteworthy, there has been an intensive use of elements from epidemiology in a way that, combined with modern tools of macroeconomic theory, has provided important results defying the previous standard in epidemiological modelling. In this context, what kind of methodological evolution has been provided by the combination of macroeconomic with epidemiological models, and what are some relevant results provided by such mixture?

To answer the question posed, in this paper I perform a critical literature review focused on the main theoretical findings that early academic production brought into discussion on Macroeconomics and COVID-19. This project aims at constituting, not exactly what may be identified as a classic review ("a presentation of the literature that eventually leads to an conclusive discussion section" (Van Wee and Banister, p. 282)), but rather I will try to dynamically integrate an holistic analysis of the models cited and their results.

The totality of the referenced material has been taken from the National Bureau of Economic Research Working Paper Series, published on a weekly basis, contained within the COVID-19 catalog, and ranging from the week of March 23^{rd}, to the week of July 13^{th}, for a total of sixteen weeks and 185 papers published. The classification applied by NBER includes

eight broad topics related to COVID-19. This review exclusively analyzes the production categorized under the ”Macroeconomic Effects” label within the indicated period, for a total of 34 academic papers. This selection has been made by conceiving the NBER catalog as a consistent and powerful sample of high quality, periodically published, economic research.

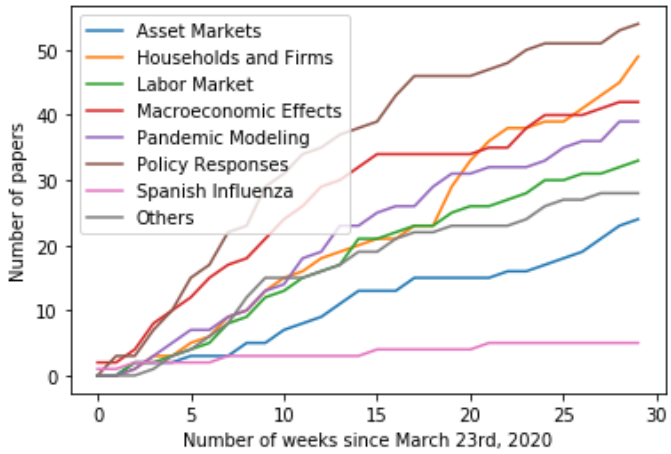

Figure 1: Cumulative evolution of the NBER publications within the COVID-19 category until October 12^{th}, 2020 (by topic)

The academic production of Covid-related papers on NBER started on the third week of March 2020 and has ever since followed an evolution as the one seen in Figure 1. The main Covid-related topics included at NBER by October 12^{th} were the *Policy Responses* to the pandemic, the effects over *Households and Firms* and the *Aggregate Macroeconomic Effects*. Once again, the focus of this paper is to analyze the production within the latter category. It is important to state, considering the fact that chapter 3 extensively analyzes the policy recommendations derived from the material involved, that the *Policy Responses* category has not been analyzed since the aim of this research is to synthesize the material that has specifically treated the evolution of macroeconomic estimations and modelling and, therefore, the policy recommendations that have been drawn from this particular approach.

The justification of this election relies on my believe that macroeconomic theory provides an integral perspective for the understanding of economic and social phenomena from an aggregate approach. This leads to concise forms of estimating the diverse ways on which the pandemic and the consequences of its propagation affect the aggregate social welfare, as rep-

resented by the macroeconomy. Complementary, I seek to identify some research gaps in this academic literature and propose potential venues for future research.

The paper is organized as follows: section 2 provides a synthesized generalization of the theoretical models applied in many of the papers studied in the form of a Workhorse Model. Section 3 contains an analysis of the main results drawn by the mentioned papers, while providing an insight into the optimal containment policy recommendations derived from such results from both a macroeconomic and epidemiological basis. Finally, section 4 provides some concluding remarks, including some research gaps and important results drawn during the period of study, specially concerning the optimal policy dilemma.

2 A Workhorse Model

In this section, I provide a general idea of the underlying theoretical structure implied by the referenced material. Most of the theoretical works in the "Macroeconomic Effects" category consist of variations to the classical SIR Epidemiological Model proposed by Kermack and McKendrick (1927) incoporated within a typical Dynamic Stochastic General Equilibrium setting. To have a general idea of the mechanisms in place, consider a simple version of the SIR model in which an infection propagates over a population that remains constant through time. I consider only three compartments in this model, so each individual can be in one of three possible states: susceptible, infected, or removed. Formally, we have that $S_t + I_t + R_t = N$, and:

$$S_{t+1} = \psi(S_t, I_t, \beta_t(\phi_t^j(a_{t,j}, \zeta_t, \ldots, m))) \tag{1}$$

$$I_{t+1} = \iota(I_t, S_t, \beta_t(\phi_t^j(a_{t,j}, \zeta_t, \ldots, m)), \gamma_t) \tag{2}$$

$$R_{t+1} = \rho(R_t, \gamma) \tag{3}$$

This system of dynamic equations is drawn considering an economy composed by J bachelor households which, in the spirit of Aiyagari (1994), may hold diverse forms of heterogeneity. Notice that $\beta_t(\cdot), \gamma \in [0,1]$ are the infection and recovery rates, respectively, for the classic SIR model. As implied by the system (1)-(3), $\phi_t^j(a_{t,j}, \zeta_t, \ldots, m)$ is a policy function defined over the state-space of the economy that can contain, among other variables, the stock of assets $a_{t,j}$, an idiosyncratic productivity shock and, importantly, the household's epidemiological state m (of course, there might be more states in more complex models).

An endogenous contention implies that the effective degree of exposure carried by the agent ultimately depends on individual choice. In theory, any rational and perfectly informed susceptible agent would chose the contention plan $\phi_t^j(\cdot)$ according to a series of factors associated to personal economic valuation of the tradeoff implied. That is, for a low exposure, the agent minimizes her risk of getting infected but loses on other valuable activities that enable labor and consumption. Different possible equilibria, both at the individual and the central planner's level may not actually be socially optimal. The optimal containment plan choice is rarely done explicitly, but rather represents an abstraction about the way on which each agent faces this hazard.

The decentralized macroeconomic model involves a dynamic optimization problem for the J bachelor households in the economy, perceiving utility from a single numeraire good defined as *consumption*, and from *leisure* (defined as $l_t = 1 - n_t$, such that the agent counts with one unit of time at each period t and n_t is defined as *labor*). The household solves one problem from (4), (6), or (7) conditional on belonging to one of the m epidemiological states. Therefore, conditional on being susceptible, the household can consume and work but faces the probability $\beta_t(\cdot)$ of becoming infected. Thus, a susceptible household solves:

$$\begin{aligned} V_t(a_t, \zeta_t, \ldots, s) \quad = \quad & \max_{c_t, l_t, a_{t+1}, \phi_{t+1}} u(c_t, l_t) + \delta \mathbb{E}_t \left[\beta_{t+1}(\phi_t) V_{t+1}(a_{t+1}, \zeta_t, \ldots, i) + \ldots \right. \\ & \left. (1 - \beta_{t+1}(\phi_t)) V_{t+1}(a_{t+1}, \zeta_t, \ldots, s) \right], \qquad (4) \\ \text{s.t.} \quad & c_t + a_{t+1} = \zeta_t (1 - l_t) w_t + (1 + r_t) a_t, \end{aligned}$$

where $\delta \in [0,1]$ is the discount factor and ζ_t represents a pandemic-related exogenous shock at the households' labor income that is independent to the agents' epidemiological state.

Notice that in this environment, ϕ_t^j is explicitly chosen by the agent. Afterwards, the optimal control problem of each agent j, conditional on her epidemiological state, would lead to a system of difference equations relating consumption, assets, and labor. Besides that, the susceptible would face the following equation:

$$\phi_{t+1} = f(\phi_t, n_t, a_t, c_t, \zeta_t) \tag{5}$$

Summed to the fact that the recurrence relations for labor and consumption among the susceptible will depend on ϕ_t^j, this portrays the fact that containment plans are not mutually independent of such variables in the economy. If it was the case that the containment policy was to be chosen by a central authority, then ϕ_t^j would not be a policy function anymore, but an exogenous parameter.

Now, suppose a susceptible agent becomes infected. Then, as I have assumed the infected are not able to work, utility is defined only over consumption and it is forced to live out of her savings. The only source of uncertainty for this household is how long would it take for it to recover and so it faces the probability γ of being removed from the infected group (i.e. by recovering). Formally, the infected agent solves:

$$\begin{aligned} V_t(a_t, \ldots, i) \quad &= \quad \max_{c_t, a_{t+1}} u(c_t) + \delta \left[\gamma V_{t+1}(a_{t+1}, \ldots, r) + \ldots \right. \\ &\qquad \left. (1-\gamma) V_{t+1}(a_{t+1}, \ldots, i) \right], \\ \text{s.t.} \qquad & \qquad c_t + a_{t+1} = (1+r_t) a_t, \end{aligned} \tag{6}$$

The removed population is assumed as belonging to the final possible stage (I assume there is no chance for re-infection) and so it does not face any probability of transition on the epidemiological state m (i.e. there is no epidemiological rate in the household's problem). Notice that

such agent returns to the working population. By this way, the problem faced by the removed is:

$$\begin{aligned} V_t(a_t, \zeta_t, \ldots, r) &= \max_{c_t, l_t, a_{t+1}} u(c_t, l_t) + \delta \mathbb{E}_t \left[V_{t+1}(a_{t+1}, \zeta_t, \ldots, r) \right], \\ \text{s.t.} \quad & c_t + a_{t+1} = \zeta_t (1 - l_t) w_t + (1 + r_t) a_t, \end{aligned} \tag{7}$$

notice that, in this case, the agent faces no uncertainty with respect to possible changes regarding her epidemiological status. A solution to each of these problems, as previously stated for the susceptible, would lead to a system of equations portraying the dynamic structure of the agents' choice. Generally, analytical solutions will not be feasible in this environment.

On the production side of the economy, I assume that there is a representative firm that sells its output and hires inputs in competitive markets to maximize its profits. Formally, the firm solves:

$$\max_{k_t, n_t} \Pi(n_t, k_t, w_t, r_t) \tag{8}$$

This problem leads to the demand for capital and labor at their correspondent market-determined prices: $k_t^*(w_t)$ and $n_t^*(r_t)$.

The general equilibrium in this family of models is included in Definition 1.1:

Definition 1.1: General Equilibrium during a Pandemic: *A general equilibrium occurs when, at every period t, conditions (4), (6), and (7) are met (households maximize their utility given their budget constraints), equation (8) holds (firms maximize their profits), and markets clear, that is, there exists a group of successions* $\{c_t, n_t, k_t\}_{t=0}^{\infty}$ *defined, respectively, as the optimal paths for the economy's aggregate consumption, labor, and capital, of successions* $\{w_t, r_t, \}_{t=0}^{\infty}$ *defined as the market prices, and* $\{\phi_t^j\}_{t=0}^{\infty}$ *defined as the optimal endogenous containment plan for the susceptible at each period t.*

Some further extensions to this general model (as have been applied to many of the referenced material) would be to consider firm heterogeneity and a strategic equilibrium being drawn by the agents' uncertainty. Yet another interesting generalization would be to try and establish discrete graphs that represent relations among the various different agents within the economy and the potential outcomes of such interdependent interactions (i.e. Akbarpour, et al, 2020).

3 A Literature Survey on Macroeconomics and COVID-19

This section provides an analysis of the scientific production published at the NBER Working Paper Series on the category of *Aggregate Macroeconomic Effects* from the group of papers related to COVID-19. This compilation includes material published four months after the pandemic's outbreak in the U.S. The start of this period matches what I have considered as the seminal publication within this group, Eichenbaum, Rebelo, and Trabandt's *The Macroeconomics of Epidemics* (2020.1).

Specifically, I analyze the main theoretical results provided by these various research papers in the light of the different methodologies that have been applied. Furthermore, I consider optimal containment policy recommendations derived from this research to be an extremely valuable element, as they are one of the most important links at which macroeconomics has been tied to epidemiology. This happens because such recommendations emerge from theoretical structures that understood the epidemiological process on new, different ways. A set of recommendations taken from estimations based on purely exogenous epidemiological models, as has been the case for policymaking in several countries, will not be the same as the ones provided by models that take into account factors from macroeconomic theory, as endogeneity, heterogeneous agents, information constraints, among many others.

A noteworthy fact is that there has been a rapid peer-learning process along the publication

process. Early estimations, as from the foundational publication, did not consider differential treatments on contention policies among individuals in the economy, diverse forms of information availability constraints, nor limited practical applicability of certain policies. These issues were progressively tackled by further publications. This fact draws on a proof to a crucial factor to this analysis, and it is that the development of economic theory relies on constantly finding mechanisms of improvement for the way complex aggregate socioeconomic phenomena are described. Furthermore, and as it is the case here with epidemiology, economists have been able to incorporate the object of study of other disciplines within a single framework. The basis for such conciliation within this paper's context appears via the various uses and extensions provided by the SIR model.

An early example of such treatment was brought via Atkeson's (2020) presentation of an exogenous SIR process, which aimed at serving as a brief introductory guide for economists to the standard epidemiological model and its potential extensions. A similar perspective was taken by Pindyck (2020), who analyzed the broad insights of a simple SIRD model in terms of general, potential policy design and welfare implications. Both early approaches, however, relied on the assumption that the economy and the pandemic where independent from each other.

The seminal treatment of the epidemiological process in simultaneity to a macroeconomic model (that is, within a single theoretical structure) was brought by Eichenbaum, Rebelo, and Trabandt's (2020) *The Macroeconomics of Epidemics* in early March, 2020. They provided the foundational precedent to the endogenous modelling of the pandemic's evolution within a macroeconomic environment. They did so by considering the households' optimal choice of consumption and labor in simultaneity to the contention measures in a way that both kind of variables (economic and epidemiological) were interdependent. This allowed them to provide two extensions to the basic problem: The *Basic SIR-Macro Model* and their very own benchmark model. They estimated variational effects considering the potential of optimal containment policies, ranging from a 7 to a 22% aggregate consumption contraction for the first

year, on a worst-case scenario, controlling by the probability of treatments and vaccines' development as well as medical preparedness (Eichenbaum, Rebelo, Trabandt, 2020a)

In the next few months that followed, they provided a bi-dimensional extension to their basic model in order to explain the comovement observed between consumption and investment during the pandemic's crisis (2020b). In the first case, they expanded the standard neoclassical model previously presented to account for monopolistic structures. For this case, they found that recessive comovement among consumption and investment is explainable by monopolistic competition because of the differential trade-off that both labor and consumption risky activities have over the recessive outcomes when accounting for the real wage contraction implied by monopolies as compared to perfect competition: "A lower wage means that the compensation to a worker for being exposed to the virus is lower" (p. 2). On the other hand, the New Keynesian model extension with sticky prices, while also explains the comovement, induces a marginally deeper recession explained by the model's tendency to "exacerbate negative demand shifts" while minimizing the effects of negative shifts over supply. The authors remark on the need to keep on accounting for other factors, such as financial frictions, in order to improve a further comprehension of the SIR-Macro model.

A recurrent concern among diverse authors is the efficiency differences that centralized containment policy poses with respect to a decentralized strategy, in terms of the externalities implied by imperfect information and differential levels of subjective life-valuation and risk aversion. Álvarez, Argente, and Lippi (2020) estimated a centralized containment solution in an endogenous SIR environment. The central planner seeks to simultaneously minimize fatalities and the aggregate economic costs associated with achieving that first goal. On their baseline simulation, they estimate an 8% contraction on the yearly GDP. Furthermore, they show that for estimations based on low lockdown efficiency rates (as with agents with different economic activities and accomplishment incentives) optimal centralized policy implied a shorter period of lockdown. The case for a fatality rate fixed at a 1% (theoretically never letting a healthcare system collapse) allegedly leads to an optimal policy that converges to zero lockdown. Interest-

ingly, in the no-testing scenario (with severe limitations on aggregate testing capacities, as some nations face), optimal policy would indicate a shorter lockdown than the standard benchmark model since there would be a constant share of the population isolated, of which an increasingly proportion would be suitable to get back to work.

Guerrieri, Lorenzoni, Straub, and Werning (2020) estimated the effect of demand shortages as caused by negative supply shocks via a simulation of economic interactions given among economic agents, while taking into account imperfect markets and multiple sectors. They show that the effect induced by the aggregate supply shock over workers could be so large that it may ultimately generate an aggregate demand contraction that comparatively overpasses the magnitude of the initial supply shock. By doing so, they neglect the efficacy of expansionary fiscal policy amid the pandemic (by terms of expenditure), and rather aim at a reduction in payroll taxes, and furthermore, claim the need for monetary mechanisms focused on lowering debt obligations for firms, while strengthening certain social insurance mechanisms and stating the importance of "closing down contact-intense sectors and insurance payments to affected workers" (Guerrieri, Lorenzoni, Straub, and Werning, p. 5).

Bethune and Korinek (2020), by applying a behavioral component, estimate the aggregate social cost of agents' effective internalization of their behavior over the pandemics' dynamics vs. the optimal containment counter-scenario implied by perfectly informed and rational agents. This leads them to study the different outcomes that a real economy with imperfect information and the limited role of a central planner may ultimately suffer with respect to a "quasi-perfect" state where policy designs may be rigorously treated among different population groups. A worst-case scenario was estimated with a recessive outcome of at least a 17% (vs. a centralized intervention with better information about the real dynamics at less than an 8%). They consider imperfect and incomplete information at the policymaking level to study the convergence into a decentralized solution, implying that the pandemic is inevitably impossible to fully overcome until herd immunity is achieved.

Chang and Velasco (2020) faced a similar problem given certain information constraints among differentiated actors from the perspective of Pareto-optimality. They argue that an economic transfers policy should not only be an incentive for individuals to contribute to the virus' contention, but it should also make it feasible for agents to expect that other agents will follow the optimal policy's lockdown. This argument, while providing evidence in support for expansionary policies at the peak of the epidemic, imply that an optimal policy would actually reduce the aggregate fiscal cost associated to the containment.

They argue, as well, that a decentralized containment strategy would lead to a suboptimal solution (due to the externalities each agent creates over others via their decisions and their choices' incidence over the pandemic's transmission). Actually, there may be a suboptimal level of risk-aversion behavior under which the extensive existence of locked workers may be excessive, causing that "having one more person go to work could in fact reduce the share of infected people in the workforce, and therefore cut back on the risk of infection" (p. 2). These authors brought into discussion what became a central debate topic among researchers: first, if whether or not there was an effective trade-off between health and economic outcomes, and second, if optimal testing policies should be massive or not. Chang and Velasco's response is a "no" to the first question but a "yes" to the latter. Furthermore, this approach remarks the fundamental role that information imperfectness play in the aggregate, even during processes of contagion.

Further applications of heterogeneous models provide important insights into diverse factors such as the labor market dynamics amid the pandemic. Gregory, Menzio, and Wiczer (2020) consider diverse worker types whose heterogeneity is determined ex-ante according to their productivity level and conditions of labor stability. They subsequently simulate the pandemic shock as faced by the workers, given the implied costs to the firm. Using U.S. data for providing a long-run estimation, they argue that recessive consequences via unemployment are expected to follow an "L-shape". This would imply up to a 35% of workers permanently terminating their contractual relationship and workers in the low productivity range taking up to 4

years to re-establish stable labor contracts (simulated with a 3-month lockdown and marginally decreasing in time thereafter).

Another methodological extension to the comprehension of the epidemiological process and its consequences in a macroeconomic context consists of the implementation of network models. Such applications have provided yet more results that are important to consider. Baqaee and Farhl base their research on a disaggregated macro model that allows for diverse factors and economic sectors, as well as input-output interdependent relationships in elasticities of substitution and downward nominal wage rigidities (2020b). They simulate a network effect that implies the hit of negative shocks gets dispersed across sectors in productive relations of dependence. Negative shocks (both at the side of demand and of supply) are simulated in order to estimate effects over output, inflation, and unemployment, and to propose subsequent policy recommendations. Negative supply shocks are found to be stagflationary and negative intertemporal demand shocks are deflationary.

By calibrating the model to the U.S. data, it is found that both demand and supply shocks are simultaneously needed to explain the real phenomenon, by jointly creating an impact of inter-dependence among sectors that results in a 13% reduction in output, a mild inflation of 0,3% and a 10% of ”Keynesian” unemployment. They also study differences within labor markets among those which are supply-constrained (”tight”) and those demand-constrained (”slack”). While both kinds are later modelled as endogenously affecting the further scope of the shock via credit constraints (and acting as negative multipliers), the match with data suggests a faster recovery among ”tight” firms. By this way, they assert the fact that regular economic policy amid the pandemic would be more inefficient than at regular times and rather insist on the need for a targeted stimulus for the most affected labor markets. Furthermore (2020a), they expand this modelling approach in order to account for the effect that heterogeneity plays over recessive outcomes when consumption and production phenomena are explained as structured, non-linear, networks of systemic co-dependence. When considering these conditions, the shocks range at between a 10% and a 100% of effect amplification, depending on the

calibration settings.

Similarly, Akbarpour, et al (2020) build a network model based on agents who differ by age, industry, and location, and whose interaction mechanisms boil down to contact matrices built for specific spatio-temporal characteristics from where a sub-graph of counterfactuals is drawn for each alternative containment policy. The data is taken from various, real-activity sources and considered within an expansion to the standard epidemiological model designed to control for exposed and deceased individuals, as well as some subsets to the infected and recovered groups (namely, a "Θ-SEIIIRRD Model"). Their research subsequently rests on finding dynamic successions of optimal containment policies given certain situations, as based on what real data can tell from an expanded and endogenous version of the epidemiological model. They find that geographical locations that were hit early and strongly by the pandemic are less likely to suffer a strong contagion growth after measures are relaxed (as estimated by June). Concerning optimal policy, they argue for measures such as alternated schedules at work and school as ways of, not only reducing cumulative deaths (40% in Chicago and 17% en New York) but also reducing expected unemployment against other alternatives.

By this way, Akbarpour, et al remark once again a crucial element common to many authors: the need for targeted containment policies. This is, certainly, something that became quantitatively approachable under the novel framework provided by macroeconomics, and particularly, the seminal paper within this research. In that sense, Baqaee, Farhi, Mina, and Stock (2020), expanded the standard SIR model to consider the exposed, the quarantined and the death (SEIQRD model) and classify each group as a vector containing five different age groups that among the population may be within a certain epidemiological category at a given time. They combine this with a sectorial economics model and build a GDP-to-Risk index by sector in order to measure the marginal impact of each additional worker (for a certain sector) to GDP (relative to the marginal contribution to $\mathtt{R}_0$).

The authors subsequently study optimal policies concerning back-to-work policies and

non-economic NPIs (for example, the allowance for regular consumption activities). They find three main results. First, that age-based, back-to-work policies have little impact over deaths reduction but rather significantly impact economic recovery, second, that a deregularized ”back to normal” policy potentially leads to a strong resurgence in cases, and third, that strong testing, tracing and quarantine policies are strong at leading economic recovery (proved useless if the second recommendation is not applied). They reinforce that ”smart” reopening plans (mostly age-based targeted policies) by the labor side, ”can lead to modest but worthwile improvements in economic and/or public health metrics” (p. 3).

Authors as Rampini (2020) work on other variations to the workhorse model. He studied economic and containment outcomes by expanding the diversity at the groups' characteristics, namely by age groups (as Baqaee et al, and Akbarpour, et al) and workforce characteristics. This leads to comparative policy recommendations consisting of a sequential lifting that at its baseline specification indicate an expected aggregate annual output contraction of about a 16% compared to the 10% for early lifting at both groups.

Sequential lifting is promoted in coherence with age differences. As the young get back to work (to avoid a more severe economic contraction), the healthcare system is alleviated, being allowed to develop more capacity and potential treatments by the time the elder are slowly allowed back to normal. Remarkably, mortality is reduced because by the moment when the older group is allowed back to work, the infectiousness is expected to have been significantly reduced. In Rampini's baseline specification, mortality is reduced by a 40%, while peak load hospitalizations by a 75%, and critical care demand by approximately an 80%. Noteworthy, “herd immunity is achieved with a lower fraction of the population ever getting infected” (p. 3).

As discussed with externalities, a crucial factor in this context is the diversity of preferences and relative trade-offs faced by different agents when contrasting economic activities with certain degrees of containment. This is what, at the policy level, Glover, Heathcote, Krueger, and Ríos-Rull (2020) call “distributional effects” as the welfare compensation mechanisms to

be considered, provided such differences. Noteworthy, they consider heterogeneity, besides by age, in terms of economic sectors (luxury and non-luxury) and by state of health. The central planner's problem is to optimally choose both the fraction of economic activity in the luxury sector that is to be shut down, and the level of income that is to be redistributed from those who are enabled to work to those who are not. Due to the cost associated to redistribution, there's a trade-off between distributive and mitigation costs. The optimal policy varies depending on the age group of the population at whom the planner gives its relative priority. Preferences for extensive mitigation policies among distributional groups are deepened proportionally to the certainty of a vaccine being available in the near future.

Life-valuation mechanisms are another recurrent concern among some researchers. As an example, Hall, Jones, and Klenow (2020) propose a life valuation model integrated into the household problem so that they can estimate a certain level of yearly consumption that a utilitarian agent would give up to avoid dying by COVID-19. The life valuation metric applied is weighted by life expectancy and the pandemic's death rate so that it portrays the "price of annual consumption". Taking into account the preferences' properties, it is found that such sacrifice would consist of a 41% in a year's consumption for a conservative estimation of the death rate, and of a 28% for a more untightened one.

Until now, most authors (as in the seminal paper) had implied an evident tradeoff between the pandemic's contention and the economy (excluding Chang and Velasco). However, the results of other authors seriously put into doubt this intuition and the nature of such relation. Aum, Lee, and Shin (2020) question this dichotomy from the perspective of the policymaker's various tools as simulated for both South Korea and the U.K. It is found that workers in the low-skilled jobs, despite suffering more from the pandemic shock, are simultaneously more benefited from "virus visas" awarded for recovered people to get back to work. This implies an optimal policy should be specifically directed at prioritizing low-skill workers. A fundamental implication from this research is that lockdown measures that are lifted too soon lead to a certain threshold of infection at which further countermeasures may lose potential efficacy at tackling

the pandemic. Furthermore, certain containment policies regarded as "too mild" applied to minimize the economic crisis, may actually turn out to produce worse recessive effects than in a scenario with initial tighter policies (as suggested by the simulations made for the U.K.)

A similar finding is provided by Acemoglu, Chernozhukov, Werning, and Whinston (2020) when considering differences among agents in terms of infection, hospitalization, and fatality rates (via age groups)). They establish important differences among standard uniform containment policies versus policies that differentially target individuals by risk groups, while providing a specific trade-off calculation for the U.S. by stating, for example, that a mortality rate target below 0.2% for the adult population will necessarily demand a full or partial lockdown for at least a year and a half, leading to a GDP yearly contraction of a 38% (a safety-focused objective). If the goal were economic (keeping contraction at less than a 10%) the consequences would imply a mortality rate over 1% (an economy-focused policy). With these results, they make the case once again for a targeted policy implementation.

Furthermore, they find that such policies follow a V-shaped trade-off relationship among output loss and deaths, meaning that at a scenario with poor spread control, not only that deaths rise, but there's an important output loss as well. An important conclusion is that "the trade-off between lives lost and economic damages improves substantially with targeted policies" (p. 45). These findings provide yet another critical perspective to the trade-off debate, and proves that implementing policies explicitly derived from a differential focus, significantly improves the level of complexity at which we understand the pandemic.

Besides household heterogeneity and the differences posed by simple epidemiological groups, some further extensions involve considering differentiated groups within each very epidemiological category. As an example, Chari, Kirpalani, and Phelan (2020) include two variants to the infected individuals' group and determine the virus' transmission via an exogenous activity-specific probability determined by the heterogeneous approach given to economic activities (production and consumption). Testing technology is applied based on an imperfect

signal about the state of the infected, and optimal contention policy is estimated by specifically targeting different population sets, leading to a comparison of the welfare gains within such approach. The welfare gains estimated from optimal containment policies will vary upon the acuteness of the signals the central planner receives, the actual capacity of testing, and the effective rate of isolation among individuals given the targeted policy.

As showed by Eichenbaum, Rebelo, and Trabandt's second approach (2020b), yet some other factors considered by some authors are the comparative consequences posed by the pandemic in the context of a New Keynesian environment (so that it may allow to account for other theoretical elements). In that sense, Auerbach, Gorodnichenko, and Murphy (2020) considered the dynamic heterogeneity structure of both households and firms (in terms of income and costs' structure, respectively) from a "neglible-marginal cost framework" that aims at comparatively addressing the effects of fiscal policy against standard Neo Keynesian approaches where the pandemic is modelled as a series of shocks. They find that aggregate output contraction and spending multipliers are considerably larger than in standard New Keynesian models. It is found, as well, that firms that are less profitable or that face more rigid capital operating costs are more vulnerable to the crisis and their transitory exit channels are much more costly than how it'd be initially estimated. This implies that fiscal policy aimed at firms may be the most inefficient if untargeted, but some of the best possible bets for recovery under a targeting framework.

They find, as well, that inequality harms the recovery effects, that is, the lowest the share of wealth that the lower percentiles of the income distribution possess, the greater the expected recessive effects each period (or the less effective the households' transfers). Furthermore, transfers to households are marginally more efficient when aimed at lower-income households. Also, the recessive (restriction) multiplier of firm exits is greater than one and proportional to capital costs' rigidity and profitability, and entry is positively proportional to transfers conditional to a targeted plan (the most cost-effective policy). This calls for an economic policy focused on targeted transfers among that certain type of firms an low-income households. Sub-

sequently, they estimate that an optimal lockdown policy in emerging economies would reduce the total death toll by half, but implying an output contraction on present value of a 19% and a crisis of debt lasting up to 43 months with defaults. The authors insist on the importance of sovereign debt relief programs aimed at providing stability to these economies, finding that one of such programs costing a 10% of benefit to the lender, would mean a welfare gain of 14% of output to the nation involved.

Certainly, this last one has been another persistent element in some papers, given the global context of the pandemic. That is the differential way on which emerging economies face the crisis comparatively to wealthy nations. Furthermore, there has been a focus on the role of international financial institutions for achieving economic stability. Céspedes, Chang, and Velasco (2020) develop a minimalist macroeconomic model from the perspective of credit constraints. The situation is modelled, first, as a productivity crisis dependent on a certain threshold determined by labor allowances, and second, as an imperfection at credit markets where lenders are uncertain about repayment. Both factors interact in what the authors call an ”unemployment and asset price deflation doom loop” which works as a negative multiplier, upon which they justify their call for unconventional economic policy. For instance, they propose mechanisms such as ”helicopter drops” of liquid assets, wage subsidies, loan guarantees, and equity injections to match the uncertainty among lenders and the firms' demand for credit. The authors remark the importance of government control in order for the adequate incentives to arise, as well as the need for multilateral institutions to provide adequate conditions among developing nations.

A similar effect is implied by Arellano, Bai, and Mihalache (2020) when studying the epidemiological process within the framework of the sovereign debt situation in emerging markets. The point is that an initial default risk increases the social cost of the containment measures by limiting fiscal capacity when facing the crisis. Despite not explicitly modelling it, the authors consider the agents' externalities (as Korinek and Bethune (2020), or Chang and Velasco (2020)), via a central planner that takes into account agents not internalizing that their behavior leads to sovereign debt crises. They find that while certain policies aimed at containing the

pandemic's effects (mostly transfers) may improve certain aggregate outcomes, they could simultaneously fuel a sovereign debt crisis, potentially leading to further constraints on the fiscal capacity needed to face the health hazard, subsequently demanding an easing of the contention measures, further deepening such crisis.

The concern about the differential effects faced by emerging economies arises again in Alfaro, Becerra, and Eslava's work (2020) when considering the labor market consequences of the pandemic in the context of an economy full of labor informality and small-sized firms as in Colombia (a proxy to most countries in the Latin American region) and comparatevely contrasting its implications to the U.S. scenario. They collect empirical data for employment and real firms and construct a model that estimates the mechanisms of recovery potentially available for such economic agents given their heterogeneous characteristics. They find that a wide proportion of jobs, because they belong to the informal sector or to small-sized firms, are more at risk of being absorbed given the pandemic shock, but they are paradoxically more likely to quickly get restored back because of the costs associated for those firms (an implication quite aligned to Auerbach, et al's findings). It is found that up to a 53% of jobs and a 43% of "aggregate value added" face a strong risk as the series of shocks associated to the pandemic hit (these fall, respectively, to 33% and 30% under the U.S.-like market structure). For a deepened crisis, the differential value among structures contracts, but as the situation improves, the Colombian case falls to just a 20% of jobs under risk and its kept at a 40% for the simulated developed economy.

Alon, Kim, Lagakos, and VanVuren (2020) further expand the workhorse model by considering an economy with the average characteristics of those nations at the top quartile of world income distribution and another one in the bottom quartile. They consider structural differences, remarkably modeling the broad fiscal constraints, labor informality, lower median age, and healthcare system's deficiencies among developing nations. By making these distinctions, they find differences in the way policies work, and subsequently, how the crisis should be optimally managed at each specific scenario. They find that generalized containment measures ("blanket lockdowns") are much less efficient in developing nations than in developed

nations. Respectively, 10 and 20 lives are saved per hundred-thousand people for each unit of output lost. Nonetheless, age-specific targeted lockdown measures save up to 95 lives per hundred-thousand people for each unit of GDP lost, double as much as in developed nations with targeted policies. This differences are mostly explained, among other factors, by the age structure of each group of nations, as well as by the labor markets conditions. Thus, these findings remark the importance, once again, and in this particular case, among developing nations, of carrying age-targeted policies (specially lockdown and transfers measures).

Another approach to the credit constrains implied by the crisis is modeled by Sims and Wu (2020) via the alternatives faced by the Fed at allocating capital trough quantitative easing policies aimed at firms in the financial markets vs doing so via productive firms in the real economy. They model financial firms as leverage-constrained (binding during both the 2007-2009 Great Recession and the COVID-19 recession) and conventional firms as facing liquidity constraints brought up by the consumption and labor crisis (only biding at the COVID case). The pandemic is modeled as a series of shocks over the firm's activities. They found that during this crisis, the reactivation measures fuelled via the support to non-financial institutions are considerably more efficient compared to a "Wall Street QE" and ultimately lead to an aggregate demand expansion. The logic behind is that a policy aimed at financial firms, despite loosening the constraint and allowing for more debt transactions, does not tackle the incentives issue of agents raised by the cash flow constraint faced by regular firms (which is on itself endogenously modelled as part of the pandemic's shock). On the other way round, the "Main Street QE" policy provides an untightening of the liquidity constraint, allowing for more investment, and helping the real economy as well.

Some other research papers consist of empirical strategies of identification only. Overall, these approaches rely on applying or expanding certain econometric models to fit Covid data and critically assess the current situation. Some persistent elements are the evaluation of counterfactual scenarios (Mulligan, 2020) or the look for causality (Ludvigson, Ma, and Ng, 2020) (Benmelech and Tzur-Ilan, 2020) (even on a very-long run context as with Jordà, Singh, and

Taylor (2020)). Noteworthy there is an application and remark on the need for real-time indicators (Lewis, Mertens, and Stock, 2020) (Diebold, 2020), uncertainty measures (Baker, Bloom, Davis, and Terry, 2020) or both (Altig, et al,2020). Given that this paper is focused on analyzing the intersection of COVID-19 and macroeconomics from rather a theoretical modelling approach, I will not analyze the results provided by the authors previously mentioned, as they base their research on purely empirical-econometric contributions.

Nonetheless, there is one paper whose consequences I considered particularly relevant to the discussion on containment policy. Goolsbee and Syverson (2020) collected county-level, cellphone ”foot traffic” data from 2.25 million businesses across the U.S. They controlled the data for sectors that were legally mandated to shut down and compared it to the ones which were not (i.e. ”essential businesses”). They analyzed the differential effects over consumption activities exactly during the weeks that restrictions were imposed, so that they may account for the role of legally imposed containment measures, comparatively to those effects explained by individual choice (on social distancing and voluntary behavioral change).

When asking to what extent the recessive effects due to consumption were explained by legal restrictions (containment policies), they found that they account for just a small share on the behavioral change associated to consumption habits. Total foot traffic data registered amid the early imposition of lockdown measures showed that while total traffic contracted at more than a 60%, only a 7% is explained by legal impositions. This result poses important implications at the policy level: if the dynamics of economic activity are actually explained by personal choice mostly, how effective may any containment policy really be at all?

4 Conclusions

This paper has provided an analysis of the evolution experienced by macroeconomic theory at modelling the epidemiological process implied by the Covid-19 pandemic on simultaneity to aggregate macroeconomic dynamics. It was found that some fundamental tools of contemporary macroeconomics, particularly heterogeneous agents and endogenous choice in a stochastic dynamic setting, proved to be crucial at better understanding, not only the macroeconomic effects of the pandemic, but the epidemiological process itself, while proposing refined policy recommendations. The contingency of such results on the degree of scaling complexity at their underlying theoretical structure asserted the importance of an ever growing peer-learning process that the analyzed material proved to have been gone through.

At the specific level of policy analysis, there are some crucial conclusions to be pointed out from the cited material. First, there will always be the need for nations to keep a differential approach among their very own population and with respect to other nations, with regards to the economic recovery measures and the pandemic containment policies, as both factors depend on structural variables relative to each country's characteristics. This is because their firms, households, governments, healthcare supply, and labor market structures are fundamentally different and internally heterogeneous. Second, there does not seem to exist an absolute trade-off between the health of the economy and the pandemic's containment. As implied by multiple authors (often drawn from rather complex models comparatively to others), there may be the case that extremely untightened containment measures may ultimately lead to even worse economic consequences (Aum, et al, 2020).

Third, it seems to occur that individuals often do not fully internalize their active role as endogenous pandemic-driver agents so that their "contention plan", even if aimed at so, is hardly ever really optimal in a decentralized equilibrium because of the externalities implied over other agents (however, a centralized equilibrium still posses important issues, mostly re-

lated to information constraints). And fourth, it may be the case, as implied by Goolsbee and Syverson (2020), that the containment outcomes may ultimately depend, to a very large extent, on voluntary behavioral choice, even in the presence of legally enforced measures. These two last points, in particular, pose severe doubts over optimal containment policies and their effectiveness.

A fundamental limitation that I faced in my analysis is that there has been an unprecedented amount of academic publications coming out on a periodical basis, and so the four months that I covered do not fully contemplate the further methodological innovations that the analysis of the Macroeconomics of Covid-19 may still keep on providing during the next months. This rapid growth on research is coherent with the divergent recessive estimations that at some point certain authors posed, as the development of real-time research evolves according to the actual process carried by the pandemic. Furthermore, some other valuable material regarding the modelling of the pandemic as based on tools from modern economics may have escaped my analysis as by design I chose to focus exclusively on the direct relationship of the pandemic with macroeconomics, as based on a single engine (NBER Working Paper Series). Finally, I consider that a deeper comprehension of this methodological transformation, should undeniably be accompanied by a rigorous epistemological analysis that may find it useful to study the foundations of such concerns from the philosophy of economics.

Despite the constrained delimitation of the papers involved, there are some important research gaps that may potentially constitute important extensions to the already existent research on macroeconomics and Covid-19. Some important ones would be to consider the longer-run effects of the pandemic over income distribution or over human development indicators. Another clear avenue for future research is the financial markets' outcomes amid the pandemic and the effects and consequences of public finance structures in this context. Additionally, I believe that it would be very useful to further estimate differential policy outcomes for emerging economies considering their specific heterogeneous structure (as in the work of Alfaro, et al, 2020). I also consider that a systemic cross-country analysis is crucial in this context.

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