Covid-19, economy and the 'drop of honey effect' metaphor – a note on the Portuguese case. Situation and measures

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Abstract: Covid-19 appeared in Wuhan (China), by December 2019 and rapidly spread to the rest of the world. Many countries adopted measures against its spread to protect people and national healthcare services. However, at the moment, more than 2.5 million people got infected and more than 175 thousand died in the 213 countries, areas and territories reached by the disease (official records at April 23, 2020). Countries began to adopt also measures to protect the economy and to prepare the economic recovery, once the effects are tremendous worldwide. In Portugal, measures allowed a flattered curve for Covid-19 spread. In this paper, we use an analogy to the 'drop of honey effect' to show how this curve develops. The 'drop of honey effect' is studied in terms of chaos theory and dynamic systems and is used as a framework to the way systems change in social phenomena.

Keywords: Covid-19; SARS-CoV-2; virus; coronavirus; Portugal; economy; measures; 'drop of honey effect'; chaos theory; systems.

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1   Introduction

The disease that later would be named Covid-19 appeared in Wuhan, Hubei Province, China, by December 2019. The coronavirus (SARS-CoV-2) that causes the Covid-19 disease is highly contagious and rapidly spread to the rest of the world. Since the World Health Organization (WHO) declared Covid-19 as pandemic in March 11, 2020, many countries began to adopt measures against its spread to protect people and national healthcare services.

After the effects in the global public health, countries are nowadays realising about the real consequences of Covid-19 in the society, economy and finance. Imperative measures are needed, and after the confinement of people and the adoption of fast measures in many countries for restricting the spread of the disease, countries began to prepare the economy's recovery.

This paper intends to present some measures and give some clues about the situation in Portugal, which is considered a successful case. Our aim here is mainly to present the Portuguese situation, show how Portuguese Government prepared a plan to fight the consequences of the crisis in the short-term and use the 'drop of honey effect' metaphor to make an analogy with the development of the disease.

In this paper, the 'drop of honey effect' metaphor is applied to Covid-19 disease, after the disease's appearance in China and its arrival to Europe. The 'drop of honey effect' framework performs a powerful capacity to show the chaos theory's usefulness for the explanation and understanding of this disease spread.

A discussion is also made around the way adopted by Portugal to fight the disease's effects. In this discussion, measures implemented timely by Portuguese Government were taken in account, what made possible to have for this country a flatter shaped curve representing the spread of the disease up to this moment. Measures undertaken and people's behaviour made the National Health System be able to respond suitably to the population's needs along this crisis.

The difference obtained in the final result, considering these fast measures compared with the alternative of no major timed measures have been taken, may be significant. The analogy to the 'drop of honey effect' allows to make a correspondence to the shape of the curve and to the understanding of the consequences of government's measures and the behaviour of Portuguese population as a whole.

In Section 2, a literature review is made to make a contextualisation of the 'drop of honey effect' in the setting of chaos theory. In Section 3, a view on the Covid-19 disease is given. In Section 4, we present the 'drop of honey effect' and its application considering the Portuguese case. Follows the Portuguese situation after the arrival of the coronavirus to the Portuguese territory and we present the measures adopted by the Portuguese Government (Section 5). Section 6 was left for the discussion and for final considerations.

2   Literature review

In chaos theory and complexity theory, many phenomena reflect dynamic forms of analysis and a very complex and widespread reality, which is specific of complex systems (Prigogine, 1993; Prigogine and Nicolis, 1989). The reality is a process in which

structure and chaos rotate between form and deformation in an eternal cycle of death and renewal (Filipe et al., 2010).

Chaos theory focuses, in mathematics terms, on the study of chaos in systems. The apparently-random states of disorder and irregularities of the dynamical systems are often governed by deterministic laws that are highly sensitive to initial conditions.

The butterfly effect is a metaphor closely associated to Lorenz, in the chaos theory context, reflecting the sensitive dependence of a phenomenon to the initial conditions. A small change in one state of a deterministic nonlinear system can result in large differences in a later state.

As referred in Ferreira et al. (2013), chaos is easily identifiable in mathematical computer problems and in laboratory research. Lorenz (1963) published the theoretical results from his previous work when he studied a model in computer for weather prediction. He noted significant differences in computer calculations after small changes in initial conditions. With these results, the chaos theory was founded. Lorenz (1963) showed that even detailed atmospheric modelling cannot, in general, make precise long-term weather predictions. Grabinski (2008) referred to this situation saying that it was proven in the early 1960s that weather forecast is not possible for an arbitrarily long period of time for principle reasons (no supercomputer will ever be able to calculate whether it will rain in exactly 30 days or not). Grabinski (2008) added that when changing the input variables (e.g., present temperature) very slightly (about 0.1%), the predicted weather changed completely.

A metaphor for such a situation may be considered as a butterfly flapping wings in China that can cause a hurricane in Texas, USA. As mentioned by Grabinski (2008), this "butterfly wing effect is due to the mathematically well-known effect of chaos. It was arguably Jacques Hadamard who first wrote about the mathematically effect in the end of the 18th century. The first application to science was probably performed by Lorenz as mentioned above. Meanwhile chaos has standard applications in science. In the 1980s it became the content of standard text books (Schuster, 1984)."

Being the 'butterfly effect' metaphor very suitable for applications to physical phenomena, in our opinion, the 'drop of honey effect' is very particularly interesting for social phenomena. When phenomena in social systems are considered, there is a high degree of unpredictability associated to the human behaviour because, in its essence, the human species has a large range for unexpected actions (Filipe and Ferreira, 2013).

The 'drop of honey effect' comes from the tale written by the Armenian poet Hovhannes Tumanyan (1869–1923). In the story, a big quarrel happens from basically nothing (from a little drop of honey). Events spread with huge consequences. The tale allows clearly to explain a phenomenon that begins with an apparent 'insignificant' event and reaches enormous consequences, a war.

In several works, Filipe and Ferreira proposed the 'drop of honey effect' metaphor to represent these phenomena. See for example the following works with applications in several areas: Ferreira and Filipe (2012, 2017), Filipe and Ferreira (2013, 2014), Ferreira et al. (2014) and Filipe (2020). We suggest a look on the Tumanyan's tale, which is reproduced for example in Filipe (2020), where the tale's similarities with many phenomena in humanities can be seen, as the recent Covid-19 spread, that is approached on that paper. These similarities to Covid-19 spread are obvious.

Filipe and Ferreira (2013) proposed the 'drop of honey effect' metaphor for some examples involving chaos theory in international relations area, such as the Iranian

Revolution of 1978–1979 (Farazmand, 2003), the predictions made on the post-Castro environment in Cuba (Radu, 2000), Adolf Hitler in Germany (Peled, 2000), September, 2001 in the USA, Alexander in the Persian Empire, the arrival of Attila to Europe, or the arrival of gunpowder in Europe. For particularities and other illustrations, see the above mentioned works.

Plaza i Font and Régis (2006) stated that the introduction of the notion of chaos that is derived from the chaos theory, as developed in mathematical and physics sciences, into the study of socio-political phenomena allowed a better understanding of the dynamic evolution of the nonlinear systems. Some years later, Plaza i Font (2014) referred that among the many metaphors that could be brought up in that context, perhaps the so-called butterfly effect (Lorenz, 1972, 1993, 2000) is the one that has best captured the attention of not only academic but also a much wider public. However, when approaching the political science in the chaos theory context, this author recognised our 'drop of honey effect' applications as an interesting metaphor proposal for the explanation of these phenomena.

Grabinski and Klinkova (2020) by their turn, when studying the Covid-19 pandemic, stated that, mathematically, such chaos effects of the disease were more like "the 'drop of honey effect' as defined in Filipe & Ferreira, 2013 […] in contrast to chaos effects like in the weather forecast."

3   Covid-19

The now called SARS-CoV-2 (the new coronavirus), that causes the Covid-19 disease, appeared in Wuhan, Hubei Province, China, by December 2019, and then spread all over the world. A pandemic was declared by the WHO in March 11, 2020. This disease is very contagious and can infect anybody. In general, it reaches older people more severely and more deadly. Although all the measures that were adopted all over the world and the support given by healthcare systems, this coronavirus already made more than 175 thousand deaths around the world.

Timely decisions are key for the control of this coronavirus dissemination. An opportune decision in the very initial moments could have made all the difference in the virus spread. The 'drop of honey effect' is a very suitable framework to explain the way how the virus spread all over the world after the virus began to infect people in Wuhan. Consequences in the public health, and in the social, economic and financial dimensions were tremendous worldwide.

This big impact of Covid-19 was rapidly visible in the public health and in economies. The social and economic crisis we are experiencing, due to the spread of Covid-19, is the worst in recent history, allowing to expect difficult times ahead. The importance of this phenomenon's study has already allowed a huge number of scientific articles in the very different research areas.

As the consequences of the Covid-19 disease spread are tremendous, it is crucial that a vast set of measures be taken to reduce its impact on the society. It is not possible to know yet how long this coronavirus pandemic 'attack' will remain. It is not also possible to know exactly when effective and safe forms of treatment for the disease will appear and when the onset of vaccines will be available for being applied massively.

What we have at this moment in health area is a situation that reflects the need for the implementation of drastic measures by countries to combat the possible exhaustion of

National Health Systems' services. It is also expected that a better phase in the evolution of the disease can arrive soon, either as a result of measures adopted or by introducing solutions such as medication or vaccination.

In view of this, we can make a desirable reflection, propose measures and solutions and try to learn from recent experiences. We must learn from scientific studies already carried out and we must learn from measures that have been implemented and from which results can be analysed.

The confinement is often asked to the generality of the population. The strategy 'stay at home' has been one of the effective strategies to fight against the Covid-19 disease. Many governments are committed with the defence of populations by attempting to decrease the impact of the first wave of this coronavirus disease, contributing for supporting National Health Systems and safeguarding their capacity to respond to the demanded services on the context of the disease spread. Some countries began trying the population's immunity as the first strategy by letting the population get exposed to the virus. Some of these countries went back after realising the coronavirus deadly power.

On the context of the spread of this coronavirus, we also know that if a half of a population behaves like staying at home and adopts adequate measures and the other one does not, the final result is expected not to be good, i.e., the effort of the very careful ones is (almost) wasted (see Grabinski and Klinkova, 2020). As in Grabinski and Klinkova (2019), although 'sometimes an average makes perfect sense', others it makes no sense. This is one of those cases.

4   The 'drop of honey effect' and the Portuguese case

As stated above, in several previous works, we used the 'drop of honey effect' to show how a small change in the initial conditions can produce huge changes in the final result. In the present context, as seen also above, Filipe (2020) uses the 'drop of honey effect' metaphor in the chaos theory context to study the effects of Covid-19 spread.

A Dawson (2020) press article shows that Chinese authorities delayed the implementation of the initial measures. Dawson (2020) states that "models […] show [that] if the country had taken steps to contain the virus one week earlier, it could've prevented 67% of all cases […]. If the Chinese Government had acted three weeks prior, at the beginning of January, […] it would've slashed the number of cases to 5% of the total." This statement shows the importance of acting timely.

As exposed in Filipe (2020), citing BBC News (March 23, 2020), up to March 23, 2020, "it took 67 days from the first reported of Covid-19 to reach 100,000 cases, 11 days for the second 100,000, and just 4 days for the third 100,000."

In the Coronavirus disease (COVID-19) outbreak situation update of April 23, 2020, 01:00 WEST there were 2,549,632 infected confirmed people, 175,825 deaths, in 213 countries, areas or territories with cases (World Health Organization, https://www. who.int/emergencies/diseases/novel-coronavirus-2019).

The Dawson's description and the evolution of the disease around the world shows the suitability of the 'drop of honey effect' to explain the spread of the virus, after its appearance in December, 2019 in Wuhan, China.

When the coronavirus spread after the initial stage, maybe also there was a huge governments' concern with a priority 'no panic' strategy. Only after the panic got generalised governments adopted hard measures.

Although the factual effectiveness of the implemented measures is not the aim of the present study, in the case of Portugal the relatively timed intervention of the Portuguese Government may have been decisive in the reduction of the infection spread. This organised intervention did not happen in several other countries after the virus appearance in Wuhan, China. One of the reasons may be the fact that the disease, being very new, was devalued. As soon as the effects began to get visible at their entire extension, behaviours have changed for both governments and populations.

António Sales, the Portuguese Secretary of State for Health, in an interview with the British newspaper *The Guardian*, said that the Portuguese Government "took the right measures at the right time." The Portuguese Government explains the 'secret' of success as a quick and flexible response to the 'worst case scenario'. This response, in his view, was based on "the best scientific advice and the experience of other countries."

Portugal had its first cases declared some time after other European countries and this fact allowed an apprenticeship that was put into practice by the central government.

Another important factor was the political consensus in the Portuguese political system around this phenomenon, which required quick measures for which political support was desirable.

Measures adopted by the Portuguese Government allowed to reduce the number of infection cases and deaths and to support the National Health System to respond to the demand for its services.

Figure 1   Examples of curves for Covid-19 spread (see online version for colours)
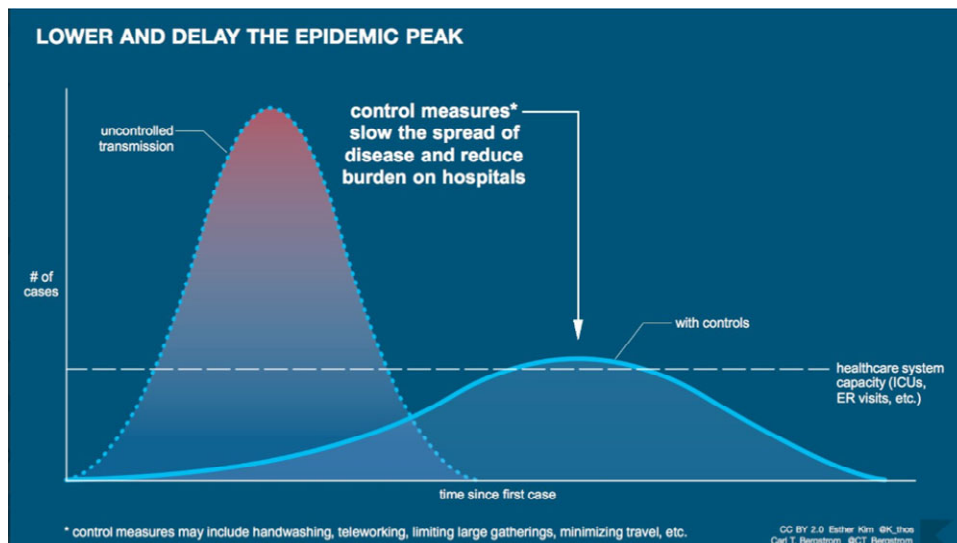
Source: Lacina (2020)

Up to this moment, a flatter curve was possible to be shaped. Strong levels of control helped the reduction of the coronavirus spread. There are infections, but they happen over a longer period of time (see the curve with controls in Figure 1). Healthcare workers and

facilities are not overwhelmed and infected people are possible to receive a better treatment at the same time that there are also fewer deaths.

To explain the spread of the disease, Grabinski and Klinkova (2020) presented the population growth being represented by

$$\dot{n}(t) = \frac{1}{\tau} \cdot n(t) \tag{1}$$

and its limitation given by

$$\dot{n}(t) = \frac{1}{\tau} \cdot n(t) \cdot (1 - n(t)) \tag{2}$$

Considering the conditions showed in Grabinski and Klinkova (2020), the solution for this equation can be given by

$$n(t) = \frac{n_0 \cdot e^{t/\tau}}{1 - (1 - n_0) \cdot e^{t/\tau}} \tag{3}$$

and after calculating the derivative with respect to time for this equation (3),

$$\dot{n}(t) = \frac{n_0}{\tau} \cdot \frac{e^{t/\tau}(1 - n_0)}{\left(1 + (e^{t/\tau} - 1) n_0\right)^2} \tag{4}$$

is obtained, being possible to study the specific curves for the way the infection spread in countries according to their populations' particular behaviours. These authors simulate and exemplify with $\tau = 0.5$, 1.5 and 2.5 (taking $2 \cdot 10^{-5}$ infections as the starting value n_0) – see Figure 2 (Grabinski and Klinkova, 2020). The higher the value, more flattered the curve.

Figure 2   Plot of equation (4) for $\tau = 0.5$, 1.5 and 2.5 (see online version for colours)
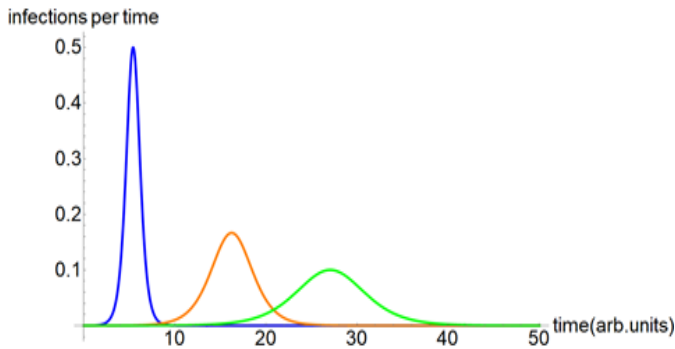
Source: Grabinski and Klinkova (2020)

In the case of Portugal, a big value for τ is expected to occur, slowing the growth of the disease spread (when $n(t)$ approaches its maximum 1, growth becomes slower and slower). This represents a system that allows the Portuguese National Health System to respond better to the evolution of the disease. Considering the metaphor of the 'drop of honey effect' and using Grabinski and Klinkova (2020) model, with a (discontinuous)

change in τ or in the ratio of n_1 to n_2, chaos effects are very likely, what might be a good quantification for the 'drop of honey effect'.

After the panic emergence and the stay of people at home, it was possible to get a higher value for τ, meaning that the curve was flattered, becoming the spread of the disease less accelerated. This situation allows to have a better response from the National Health System.

At the present moment, the Portuguese health system is still away from reaching the exhaustion in this crisis time, still existing a big capacity for new patients' demand of services in the near future.

5   The Portuguese situation and measures

5.1   General considerations

Considering specifically the arrival of the coronavirus to Europe, it is relevant to note that when the Covid-19 reached the European countries, national authorities may have not considered the severity of the virus and took soft measures in a first instance.

The reality is that there are many national differences in approaching the problem within European Union and different ways of looking at solutions. Huge short-term European GDPs deteriorations are a reality and unemployment is increasing significantly.

Europe is impacted by a high incidence of the disease, with some countries being harmed more than others, for different reasons. Europe as a whole suffers from the same economic 'illness' and is now travelling in the same 'boat', although it impacts on a different magnitude on each country.

The Portuguese case has been seen as a successful case. Regardless of whether or not all indicators are as meritorious as they may be considered to be, one of the great merits of the Portuguese case is that measures adopted allowed that the National Health System was not pressured in a way it could not be able to respond to requests. The health system was kept operational, and up to this moment, all patients could have the best treatment possible to give, with the available medical treatment.

Central Portuguese political management had remarkable merits in considering measures such as social confinement in a timely manner, which the Portuguese population very satisfactorily knew how to comply with, as well as the closure of establishments according to rules that made possible to reduce the general infection rate. Also important were the successively three declared 'state of emergency' announced by the President of the Portuguese Republic, given the need of controlling the spread of the disease.

Tests were also being extended as much as they were made available in number, in order to allow more and more suspicious cases to be tracked.

Some of the short-term measures are presented, considering what was proposed and has been done in the Portuguese case, after the Director-General of the World Health Organization declared Covid-19 a pandemic on March 11, 2020 (see WHO Director-General's Opening Remarks at the Media Briefing on COVID-19, 2020).

On March 13, some measures were declared, such as the closing of nightclubs and similar establishments, the reduction of capacity in restaurants and public spaces, the limitation in the frequency of shopping centres and the limitation, at national level, of visits to nursing homes.

In a declaration to the country, made from his official residence in S. Bento, the Portuguese Prime Minister stressed that this "is a battle and a struggle for all, for our survival and protection"; adding that the pandemic is "a situation in all respects exceptional" and that is "new for all of us in contemporary times and that poses immense challenges."

Shortly thereafter, on March 15, the Prime Minister informed that schools would be closed and supplementary measures would be taken as a result of this need.

On March 18, the Portuguese President of the Republic declared for the first time the 'state of emergency', having defined the guidelines for the introduction of measures. These measures would be tightened in his next 'state of emergency' declaration according to what was demanding for the Easter vacation period. He would later alleviate the measures for the third declared period.

The Portuguese Government has, meanwhile, launched an additional package of measures to combat the coronavirus pandemic and mitigate the economic impacts of Covid-19.

Trying to protect jobs, the executive eased the conditions for the access to the new lay-off regime, which had, however, been enacted, and made official a six-month moratorium on credit for families and companies. It also enacted measures from the point of view of digital payments, municipalities and European funds for companies.

From the measures proposed by the Portuguese Government for fighting the effects of the social and economic crisis, the following ones stand out, as Nunes (2020) summarises.

5.2　Some particular measures

The economy suffered significantly in a very short period of time due to the spread of the virus. The concerns are very high worldwide, being urgent measures needed to reduce the impact on the economy and on the employment.

The Portuguese Government has adopted a set of measures to be enacted urgently, some of which are presented next:

- After the layoff declared previously, the government has proposed a new package of measures relating the layoff. The access to the layoff, in this second proposal, has become less demanding, lasting less time than the defined firstly, as being an 'exceptional and temporary measure for the protection of jobs'. A 40% drop in activity in the previous month would suffice for a company to meet the requirements or an equivalent drop in the same period the previous year. In addition to the activity factor, it is allowed to access the regime of companies or products that had the closure of measures enacted with the state of emergency, such as companies that 'experienced a total or partial stoppage of their activity that results' from problems with supply chains or with orders suspension/cancellation. The support remains in force 'for periods of one month, renewable for the next three months, if justified'. In addition, and as was already known, companies that access the new regime cannot interrupt employment contracts 'through collective termination or extinction of a job' in the period in which they are in force or dismiss, nor in the 60 days following their application.

- Six-month moratorium on credit to families and companies. The government also approved a decree-law that 'determines exceptional support and protection measures for families, companies and other entities of the social economy', specifically a six-month credit moratorium to 'apply the reinforcement' of treasury and liquidity in that period of more difficult economic situation. "Since the financial system has a special duty to participate in this joint effort due to its essential role in financing the economy, a six-month moratorium is approved, until September 30, 2020, which prohibits the ban on revoking credit lines contracted, extension or suspension of credits until the end of this period, guarantee of financing for families and companies and prevent possible defaults", informed the Council of Ministers, in a statement. This measure covers housing loans for families and credit for companies. This is the legal regime promised by the Minister of Finance and that some banks were waiting for.

- The government approved a proposed law to place the Institute of Housing and Urban Rehabilitation (*Instituto da Habitação e da Reabilitação Urbana – IHRU*), a grantor of loans to pay rent to tenants who have suffered test breaks because of the economic effects of the pandemic.

- The regime of absences justified by assistance to the family was reinforced. The executive approved a decree-law that regulates the exceptional and temporary regime 'of justified absences motivated by assistance to the family'. The reinforcement involves "the support of situations in which the need for assistance to a relative in the straight ascending line that is in charge of the worker and who frequents social facilities whose activity is suspended." A worker is able to take time off work, for example, to provide assistance to an elderly relative who was in charge due to the temporary closure of a nursing home. He will receive a remuneration of 66% of the base salary (does not include other components of the remuneration), up to a minimum limit of 635 euros and a maximum limit of 1,905 euros, calculated according to the number of days absent from work. This support was already foreseen for workers who were supposed to stay at home to take care of children under the age of 12, as a result of the closure of schools. In this case, it does not include the period of school vacations, being thus assigned only between March 16 and 27. In the case of children attending social facilities which support early childhood or disabilities, the support is granted until April 9, not being allowed to overlap periods between parents.

- Schools open to provide support during the Easter period.

- Fees are suspended on electronic payments. The visa measure provides an alternative to coins and banknotes, through which this new coronavirus can be transmitted.

- Government wants municipal expenses in the *FAM – Fundo de Apoio Municipal* (Municipal Support Fund) to not count towards indebtedness. As a support to municipalities, the government sent a proposal to Parliament so that the 12 municipalities with support from the Municipal Support Fund (FAM) can fight Covid-19 without financial restrictions. The 12 municipalities under the FAM are Alandroal, Alfândega da Fé, Aveiro, Cartaxo, Fornos de Algodres, Fundão, Nazaré, Nordeste, Paços de Ferreira, Portimão. Vila Franca do Campo, Vila Nova de Poiares and Vila Real de Santo António.

- Cultural events cancelled because of the virus will be supported by the state. A decree-law was approved by the Council of Ministers to ensure 'special protection for the cultural agents involved' in the performance of shows that were cancelled because of the new coronavirus. The measure covers 'shows not performed' between February 28, 2020 and 'up to 90 business days after the end of the state of emergency'. "In the face of the Covid-19 pandemic, and with a view to preventing the transmission of the virus, the government took measures that included, inter alia, the closure of facilities and establishments where cultural and artistic activities are carried out. Therefore, it is important to ensure special protection for cultural agents involved in the performance of these shows, as well as to guarantee the rights of consumers", defends a government responsible.

- Government accelerates the payment of the incentives provided in the Portugal 2020 Program. The Council of Ministers approved a "decree-law that alters the general rules for the application of European structural and investment funds, in order to allow for the anticipation of payment requests, as regards to balances."

- Other measures already introduced by the executive at the level of European funds: reimbursement of expenses incurred with participation in international events that have been cancelled; 12-month moratorium on amortisation of reimbursable subsidies under the *QREN – Quadro de Referência Estratégica Nacional* and Portugal 2020, with expiration term until September 30; introducing a change to consider that a failure to achieve objectives that had been 'contracted within the scope of the incentive system' is no longer considered non-compliance; considering a proposal to launch an 'extraordinary training and qualification plan', which includes the payment of supportive amount to companies for half the employee's remuneration, up to the limit of the guaranteed minimum monthly remuneration, supported by the *IEFP – Instituto de Emprego e Formação Profissional* (Employment and Professional Qualification Public Agency); the postponement for one year of the return of subsidies of Portugal 2020 Program for all companies.

6　Discussion and final considerations

As stated in Grabinski (2004), "due to chaos, small causes may evolve in time and have tremendous effects." After the appearance of Covid-19 in Wuhan, Chinese Authorities may have made a wrong management of the situation, having as a consequence the large-scale virus spread to the world (an analogy with the 'drop of honey effect' in the context of chaos theory is made).

The initial conditions are very important for the control of the disease spread. In this case of Covid-19, the delay in adopting the measures to confine the virus may have made the virus spread, first from Wuhan for the rest of the province, then for the rest of China and finally for outside China.

The present paper also shows the importance of having timed measures, which are very important in the way the virus spread in communities; and analyses the measures undertaken in Portugal in this problem context. As the disease first reached other countries in Europe, Portuguese authorities adopted some measures which major merit

may have been the safeguard of the National Health System to respond the services demand.

The 'drop of honey effect', as a very adequate framework, is operated in this paper to explain the spread of the disease and the importance of measures adopted in the right time. The serious situation activated by the Covid-19 disease had severe implications in the public health and social, economic and financial dimensions of societies. This methodology in the context of the chaos theory contributes to get an improved awareness of the new reality for which the world has to have now an increased responsiveness to deal with this new kind of situations.

In future work, it will be interesting to study the role of coordination and cooperation of different entities to implement efficient measures. As it is possible to see in the current coronavirus crisis, many entities were involved in cooperation processes, what made possible the implementation of strategies that brought relevant benefits for communities themselves and for the society as a whole. It is important to study these situations considering these strategies as much as the way they may bring relevant benefits for communities.

References

Dawson, J. (2020) *Caller Blasts Idaho Gov. Brad Little's Response to Coronavirus During Town Hall*, 17 March [online] https://www.boisestatepublicradio.org/post/caller-blasts-idaho-gov-brad-littles-response-coronavirus-during-town-hall#stream/0 (accessed 24 March 2020).

Farazmand, A. (2003) 'Chaos and transformation theories: a theoretical analysis with implications for organization theory and public management', *Public Organization*, December, Vol. 3, No. 4, pp.339–372.

Ferreira, M.A.M. and Filipe, J.A. (2012) 'The 'drop of honey effect'. A note on chaos in economics', *International Journal of Latest Trends in Finance and Economic Sciences*, Vol. 2, No. 4, pp.350–353, ExcelingTech Publisher.

Ferreira, M.A.M. and Filipe, J.A. (2017) 'The "drop of honey effect" metaphor in chaos theory', *Acta Scientiae et Intellectus*, Vol. 3, No. 6, pp.27–42, Universum Research E-Center.

Ferreira, M.A.M., Filipe, J.A., Coelho, M. and Pedro, I. (2013) 'Managing fisheries in light of complexity and chaos theories', in Banerjee, S. (Ed.): *Chaos and Complexity Theory for Management: Nonlinear Dynamics*, Chapter 13, pp.270–282, IGI Global, Hershey, USA, DOI: 10.4018/978-1-4666-2509-9.ch013, 10.4018/978-1-4666-2509-9.

Ferreira, M.A.M., Filipe, J.A., Coelho, M. and Pedro, I. (2014) 'Chaos in world politics: a reflection. The 'drop of honey effect'', in Banerjee, S., Erçetin, S.S. and Tekin, A. (Eds.): *Chaos Theory in Politics*, Vol. 1, pp.89–104, Springer, Netherlands.

Filipe, J.A. (2020) 'Epidemics and pandemics: Covid-19 and the "drop of honey effect"', *International Journal of Economics and Business Administration*, Vol. 8, No. 2, pp.240–249, DOI: 10.35808/ijeba/456.

Filipe, J.A. and Ferreira, M.A.M. (2013) 'Social and political events and chaos theory – the "drop of honey effect"', *Emerging Issues in the Natural and Applied Sciences*, Vol. 3, No. 1, pp.126–137

Filipe, J.A. and Ferreira, M.A.M. (2014) 'Chaos in social and political phenomena – the "drop of honey effect"', *Aplimat – Journal of Applied Mathematics and Engineering*, Vol. 6, pp.83–90.

Filipe, J.A., Ferreira, M.A.M., Coelho, M. and Pedro, M.I. (2010) 'Chaos, anti-chaos and resources: dealing with complexity', in *9th International Conference on Applied Mathematics – APLIMAT 2010 (Proceedings)*, Slovak University of Technology, Bratislava, Slovakia.

Grabinski, M. (2004) 'Is there chaos in management or just chaotic management?', *Complex Systems, Intelligence and Modern Technology Applications*, Paris.

Grabinski, M. (2008) 'Chaos – limitation or even end of supply chain management', *High Speed Flow of Material, Information and Capital*, Istanbul.

Grabinski, M. and Klinkova, G. (2019) 'Wrong use of averages implies wrong results from many heuristic models', *Applied Mathematics*, Vol. 10, No. 7, pp.605–618, DOI: 10.4236/am.2019. 107043.

Grabinski, M. and Klinkova, G. (2020) 'Why individual behavior is key to the spread of viruses such as Covid-19', *Theoretical Economics Letters*, Vol. 10, pp.299–304, Scientific Research Publishing Inc.

Lacina, L. (2020) *Minimizing Coronavirus' Impact is a Race Against Time – This Chart Explains Why*, 8 March, World Economic Forum [online] https://www.weforum.org/ agenda/2020/03/this-one-chart-shows-why-minimizing-coronavirus-impact-is-a-race-against-time/ (accessed 30 March 2020).

Lorenz, E.N. (1963) 'Deterministic nonperiodic flow', *Journal of the Atmospheric Sciences*, March, Vol. 20, No. 2, pp.130–141.

Lorenz, E.N. (1972) 'Does the flap of a butterfly wings in Brazil set off a tornado in Texas?', Paper presented at the *139th Meeting of the American Association for the Advancement of Science (AAAS)*.

Lorenz, E.N. (1993) *The Essence of Chaos*, University of Washington Press, Washington DC.

Lorenz, E.N. (2000) 'The butterfly effect', in Abraham, R. and Ueda, Y. (Eds.): *The Chaos Avant-garde Memories of the Early Days of Chaos Theory*, pp.91–94, World Scientific, Singapore.

Nunes, F. (2020) *Uma a uma, as novas medidas do Governo contra a crise do Covid-19*, 26 March [online] https://www.msn.com/pt-pt/noticias/ultimas/uma-a-uma-as-novas-medidas-do-governo-contra-a-crise-do-covid-19/ar-BB11LaTa (accessed 1 April 2020).

Peled, A. (2000) 'The new sciences, self-organization and democracy', *Democratization*, Vol. 7, No. 2, pp.19–35.

Plaza i Font, J.P. (2014) 'In defence of chaology in political science', *PRISMA.COM*, No. 26, pp.106–116.

Plaza i Font, J.P. and Régis, D. (2006) 'Chaos theory and its application in political science', Paper presented at the *IPSA World Congress*, Fukuoka, Japan, 9–13 July.

Prigogine, I. (1993) *Les Lois du Chaos*, Flammarion, Paris.

Prigogine, I. and Nicolis, G. (1989) *Exploring Complexity: An Introduction*, W.H. Freeman and Company, New York.

Radu, M. (2000) 'Festina Lente: United States and Cuba after Castro. What the experience in Eastern Europe suggests. Probable realities and recommendations', *Studies in Comparative International Development*, Winter, Vol. 34, No. 4, pp.7–22.

Schuster, H.G. (1984) *Deterministic Chaos: An Introduction*, Physik-Verlag, Weinheim.

WHO Director-General's Opening Remarks at the Media Briefing on COVID-19 (2020) 11 March [online] https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020 (accessed 24 March 2020).

World Health Organization, *Coronavirus Disease (COVID-19) Pandemic* [online] https://www. who.int/emergencies/diseases/novel-coronavirus-2019 (accessed 24 April 2020).