Defying Gravity: The Economic Effects of Social Distancing

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Abstract

The COVID-19 pandemic has forced changes in production and especially in human interaction, with "social distancing" a standard prescription for slowing transmission of the disease. This paper examines the economic effects of social distancing at the aggregate level, weighing both the benefits and costs to prolonged distancing. Specifically we fashion a model of economic recovery when the productive capacity of factors of production is restricted by social distancing, building a system of equations where output growth and social distance changes are interdependent. The model attempts to show the complex interactions between output levels and social distancing, developing cycle paths for both variables. Ultimately, however, defying gravity via prolonged social distancing shows that a lower growth path is inevitable as a result.

Keywords: COVID-19, social distancing, GDP, Economic Dynamics

JEL Classification: C61, E32, I18, O33, O38

1 Introduction

It is a well-known maxim in physics tracing back to Newton (1987) that the force between two objects is proportional to the masses of these bodies but inversely
proportional to the square of their geographical distance, suggesting that the proximity of an object is of paramount importance to its attraction to others. Indeed, the gravity model of trade (Isard, 1954) is based precisely on this insight, predicting trade flows between countries to be higher (after controlling for trade costs) for countries which are more proximate. Extensions to the gravity model have also been employed for movements of peoples across borders and regions (Stouffer, 1940; Niedercorn & Bechdolt Jr, 1969; Vanderkamp, 1977), using the size of various regions as attractants (an agglomeration effect) and the distance between specific regions as a deterrent to migration. While there have been some paradoxical findings from both of these literatures (see (Brun, Carrère, Guillaumont, & De Melo, 2005) or Malmberg in (Hammar, Brochmann, Tamas, & Faišt, 2021, p. 21-48)), the underlying premise of the benefits of proximity has been generally accepted.

However, what occurs when distance is actually imposed, not a naturally occurring phenomenon of fixed geography but where economic actors are deliberately separated or forced further apart? Does the lesson of the gravity model hold, with artificial distance leading to less economic interaction and, subsequently, less output? The new reality of the COVID-19 pandemic has introduced precisely this possibility into economic life, as individual actors – in order to lessen the likelihood of catching the disease – are remaining “socially distanced” from each other; with an eye on keeping individuals at least 2 meters apart from each other, this distancing has been accomplished via a number of public policies and directives, including stay-at-home orders (both limited and more draconian), bans on large gatherings, and business closures (Abouk & Heydari, 2021).

In an economic sense, the effects of social distancing should be seen as a positive in the long-term, as the spread of a potentially fatal disease is halted (Sheridan, Andersen, Hansen, & Johannesen, 2020). By halting the destruction of the labor stock and reducing the burdens on healthcare systems, a country can return to a long-term growth path (Bodenstein, Corsetti, & Guerrieri, 2021). Seen in this light, social distancing acts as a collective good, imposing (hopefully) short-term restrictions and upfront costs in order to avoid larger costs in the long run. This would be amplified in certain specific conditions, where pre-existing attributes can make social distancing especially effective: for example, in countries where population has low density, where there are strong borders, or where there is either trust (Durante, Guiso, & Gulino, 2021) or social discipline which can make individuals adhere to social distancing more stringently. In these situations, social distancing can indeed be a one-time shock, and modelled accordingly (Mandel & Veetil, 2020).

Unfortunately, the short-term consequences of social distancing may be substantial (Ashraf, 2020) and could even outweigh the longer-run costs of a protracted pandemic in situations where social distancing may not be a discrete event, leading to “waves” of contagion and, ultimately, output declines. In such an environment, there can be significant effects on poverty and inequality (Palomino, Rodríguez, & Sebastián, 2020) or the labor market (Gupta et al., 2020). The distribution of effects is also not uniform and may fall heavily on
specific sectors, in particular, industries which rely on turnover (such as hospitality and travel, see Gunay and Kurtulmus (2021) and Koren and Peto (2020)), which may find restrictions to be highly cumbersome (De Vos, 2020) or even impact the most vulnerable members of society (Mongey et al. 2020). Additionally, the uncertainty surrounding the ability of business to transact as normal (combined with other potentially economically destructive interventions by government) may deter long-term productive investment and increase risk aversion (Piccillo & Van Den Hurk, 2020). Under these conditions, the collective good of social distancing becomes just another risk management decision, sacrificed when other collective actions such as economic activity become necessary.

The purpose of this paper is to explore the economic ramifications of individual social distancing within a broader macroeconomy, capturing the complexity of the trade-offs between social distancing and economic activity. This is the first paper, to our knowledge, to incorporate the dynamics introduced during the COVID-19 pandemic in an attempt to understand the effect that social distancing might have on an economy. Building a model of production which accounts for the complex interaction between output level and social distancing, our results show that social distancing, if maintained, can result in lower output growth.

2 The Literature on Distancing

Perhaps not surprisingly, given the extraordinary public health measures associated with “social distancing,” there is a sparse literature on the effects of physical distance amongst individuals on economic activity, as opposed to the vast literature on distance between countries. Indeed, most of the work done on social distancing over the past year has come from the public health and epidemiological literature, exploring the efficacy of distancing on stopping the spread of COVID-19. Papers such as Delen et al. (2020), McGrail et al. (2020), and Park et al. (2020) provide data or modeling on the effectiveness of social distancing, and there appears to be near unanimity within the epidemiological and (especially) the public health literature on the desirability of social distancing in a pandemic.

Of the few economic analyses which have been produced, they too have focused on the economic effects of the disease and how distancing could, by hastening an end to the pandemic, have salutary economic benefits. Key in this vein is Greenstone and Nigham (2020), who estimated that the lives saved from distancing, monetized using the US government’s value of a statistical life, could have a value of approximately US$60,000 per household (as a working paper, the authors admit that there is no estimation of the corresponding costs of social distancing). A similar working paper from the NBER focuses instead on the cost side, coming to the conclusion that no social distancing would lead to COVID-related costs of US$12,700 per person, while an optimal social distancing policy would reduce these costs to US$8,100 per person; however, the “optimal policy” explored here would “curtail activity for decades or until a cure
is found” (Faroodi, Jarosch, & Shimer, 2020, p. 36). Even though these costs are, like Greenstone and Nigham (2020), linked to the costs associated with fatalities, the longer-run implications of curtailed activity over a decade – and their likely astounding economic costs – are not explored. Thunström et al. (2020), on the other hand, attempt to combine both costs and benefits into a net tally and (using a slightly lower value of a statistical life, US$10 million, than Greenstone and Nigham (2020)) find that the benefits of lives saved exceed the projected economic disruption of social distancing by US$5.16 trillion.

Despite these papers focusing on the aggregate effects of social distancing, it is only a very small subset of these well-known papers which have examined the channels via which the economic cost of social distancing accrues, and which then attempt to array them against estimated benefits. Koren and Peto (2020), focusing on industries which rely on face-to-face contact, find that sectors which use customer visits or have a high proportion of customer-facing workers have fared the worst due to social distancing measures; in terms of cost, the retail sector, forced to virtually shut during the first wave of the pandemic in the United States, would have required a 234% wage subsidy in order to avoid unemployment losses. Similarly, Mongey et al. (2020), using individual level data to show the most at-risk sectors, conclude that the costs of social distancing falls disproportionately on lower educated workers, those unable to work from home and those requiring high physical proximity, resulting in losses greater than those seen during the global financial crisis. Work from Barnett-Howell and Mubarak (2020) echo this finding on an international level, showing that social distancing is both less effective and more destructive in poorer countries, increasing hunger, deprivation, and morbidity from other causes. Barrot et al. (2020) also expand this analysis beyond the most directly affected sectors to show how downstream industries in France are also affected, arriving at an estimate of the cost of social distancing at approximately 5.6% of GDP. And, while attempting to show a positive view of social distancing as preventing larger and more protracted costs to an economy due to lost working hours and lives, Bodenstein et al. (2020) note that consumption holds up well despite social distancing, but at a cost of a lower capital stock over time. This certainly has longer-term ramifications for society, an intertemporal shift away from investment which can place an economy on a lower growth path.

Another strand of the social distancing literature has focused on the drivers of compliance with social distancing as a contingency on their effectiveness. While not directly related to the idea of costs from social distancing policies, this work does reveal possible follow-on effects which can impact an economy. For example, research from Durante et al. (2021) shows that social distancing was utilized most on a voluntary basis in areas where there were high levels of “civic capital” (trust in others). In such a situation, cultural closeness could have mitigated the effects of social distance, although their work does not extend to the economic effects of this voluntary distancing. In a highly interesting study, Stockmaier et al. (2021) also explore the voluntary social distancing behavior of animals and insects, finding that social distancing is limited where there is social or work pressure, and the need to provide and/or fend off other predators.
makes social distancing a luxury.

A final note is necessary here to bring us full circle: as noted at the beginning, the public health literature has concentrated on the efficacy of social distancing in reducing the spread of disease, but there are additional studies from this literature which hint at the broader costs from social distancing. For example, Venkatesh and Edirappuli (2020) discuss the sometimes-sizeable effects which can come to mental health from social distancing, especially for those already at risk. Block et al. (2020) recognize this issue and argue for a “strategic social network-based reduction of contact”, but as of yet the nuances of such alternatives to strict social distancing are in their infancy (meaning that the deleterious effects of actual isolation persist). There is unfortunately little understanding and no attempts (to our knowledge) to quantify these possible effects on the workforce and, thus, on economic activity.

3 Formal presentation

We have seen in section 2 that the underlying effects of social distancing, and especially the channels by which these effects come to be, have been analyzed in the literature using their own form of distancing, i.e. being rather isolated and focusing on specific aspects of distancing rather than examining the issue holistically. Indeed, this approach has yielded some insights, as it has examined the long term benefits of preserving the labor force (Bodenstein et al., 2021; Greenstone & Nigam, 2020) given the possible cost of distancing (Farboodi et al., 2020; Greenstone & Nigam, 2020), with the immediate economic cost also calculated (Koren & Pető, 2020). However, as the relations between the various attributes of social distancing are complex and may have differential economic impacts, this section attempts to present a more comprehensive view to better understand this complexity in an economic setting.

In order to model these relationships, we first present a production function; the agent’s decision exercise on how much labor he will supply subject to constraints which are adapted to the particular environment (social distancing and the risk of being out of the market due to the spread of the pandemic). Along the line of section 1 these assumptions are very Newtonian, in the sense that their structure is very broadly used and is related to the forces acting upon the agent externally.

The production function used in the model is:

$$Y_t = FN\bar{K}$$

(3.1)

by integrating constant capital $\bar{K}$ and the technological constant $F$ into a single coefficient $A$ for simplicity we get

$$Y_t = AN$$

(3.2)

where $Y_t$ represents output\(^1\) of period $t$, $A$ is scale coefficient; whereas $N$ represents unconstrained production factors. Given that a minimum production

\(^{1}\text{We use output and income as synonyms in this paper.}\)
should be maintained we may subdivide 3.2

\[ Y_t = Y_{min} + AN \]  \hspace{1cm} (3.3)

3.1 Budget restriction

With fixed \( \bar{K} \) and \( A \), we may approximate

\[ \frac{\dot{Y}}{\bar{Y}} \approx \frac{\dot{N}}{N} \]  \hspace{1cm} (3.4)

Further, in view of 3.4, we assume that the utilization proportion of the production factor \( N \) develops in the following way;

\[ N_{t+1} = N_t + [gN_t + \mu(-d)N_t] \]  \hspace{1cm} (3.5)

where \( g \) represents the growth rate of utilization of \( N \) (and therefore production output) and \( \mu \) is a parameter defined in subsection 3.2; while \( d \) represents social distancing.

With the following restriction to production with capital fixed in the analysis period

\[ Y_{t+1} = Y_t + [gY_t + \mu(-d)Y_t] \]  \hspace{1cm} (3.6)

leading in continuous time to

\[ \frac{\dot{Y}}{\bar{Y}} = (g + \mu(-d)) \]  \hspace{1cm} (3.7)

Equation 3.7 shows the effect of social distancing as imposing a restriction over dynamic paths of output \( Y \). The factor \( g \) is a growth rate which may assume modest positive values in normal times (usually scaled as no greater than 0.1 per year), whereas in exceptional times or a crisis may assume negative values.

3.2 Policy and structural parameters

The factor \( \mu \) of equation 3.7 is set as a parameter. The greater social distancing \( d \) the more impact over output \( Y \) will occur, as indicated by \( \mu \). The higher \( \bar{Y} \) or \( d \), the higher the restraint of the growth of \( Y \). The intuition is that the higher income \( Y \) is, the more possibilities exist to restrain or cut production as shown in section 1.

While the general direction is set by the relations of equation 3.7, the precise quantitative impact depend on the set of complex economic policies\(^2\) put forward. This is the justification to leave \( \mu \) as a parameter with some degree of freedom. It is constrained by policies setters and by the reaction of the system and determined by the technological relation of the production function. For

\(^2\)Among other drives as seen in section 2.
example, if a policy of closing borders is set, the impact on output is given by the existent technology and sector breakdown; i.e. if the tourism branch constitute a huge proportion of the economy $\mu$ will be greater.

As a concrete example of the problems involved in setting the value of $\mu$, consider the (extreme) case of an economy whose production consist almost entirely of the output of the software sector. In this case, it is even conceivable to assume that the second term of the RHS of equation 3.7 may be positive.

Another important point of the model is that it is able to deal with the acceleration in the technological change in some labor markets routines. When the working force mobility is replaced by home working and teleworking, the output recovering may be faster and higher.

### 3.3 Response to distancing

For the possibility to derive the response of the agents as an individual behavior\(^3\), we take

$$U = U(C_t, 1 - N_S)$$

where $U$ represent utility and $C$ consumption. In this context, we interpret $1 - N_S$ not as leisure, but as tolerance to social distancing $d$, which is subject to

$$P_t C_t = W_t N_t$$

with $W$ standing for Wage and $P$ for prices.

Upon introducing the definition of consumption form equation 3.9 to equation 3.8 we obtain

$$U = U \left( \frac{W_t N_t}{P_t}, 1 - N_S \right)$$

and by differentiating completely we obtain the first order condition for utility maximization for the agent

$$\frac{dU}{dN} = \frac{W}{P} - U_{1-N_S} = 0$$

where the first term of the RHS measures the marginal benefit of the use of the unit of labor whereas the second term refers to the cost, which we assume

$$U_{1-N_S} = \tau d$$

By taking $N_S = N_D$ which is equivalent to state that factor’s $N$ demand is enough at the wage rate $\frac{W}{P}$ to employ $N_S$.

So, social distancing $d$ will decline as

\(^3\)It is important to note that this approach is not the only possibility, as cultural factors may be taken into account also as base for the proportion in which the effectiveness of $d$ decays.
\[ d = -\tau d \] (3.13)

The intuition behind equation 3.13 is that, with time, wage earners will be willing to work for a lower wage rate. This not necessarily implies a lower real wage rate for each individual, it is conceivable that the wage rate becomes lower due to various types of risk involved; such as fines, difficulties in transportation and social critique among others. From equation 3.13 we may see that with time, owners of factor \( N \) will tend to accept lower retributions because of most urgent necessities. The last effect operates simultaneously (is the counterpart of) with a lesser tolerance of social distancing \( d \). Therefore we expect that \( \tau \) will take positive values, less than one taking account of a progressive decay of the effectiveness of \( d \).

### 3.4 Susceptibility

Now let us formalize the causes of growing social distancing \( d \). This measure is imposed to protect factor \( N \) by limiting social interaction. By doing so it reduces also output \( Y \) by assumption 3.4. For simplicity we assume that the growth of \( d \) can be expressed with a parameter \( \rho \).

To explain parameter \( \rho \) we may have in mind the effect of the infection by referring to the simple Susceptible-Infectious-Recovered (SIR) model:

\[ \dot{\Omega} = a\Omega \Gamma \] (3.14)

\[ \dot{\Gamma} = a\Omega \Gamma - b\Gamma \] (3.15)

\[ \dot{\Lambda} = b\Gamma \] (3.16)

where \( \Omega \) is the fraction of susceptible individuals, \( \Gamma \) is the fraction of infectious individuals, and \( \Lambda \) is the fraction of recovered individuals\(^4\); \( a \) is the transmission rate per infectious individual, and \( b \) is the recovery rate.

Linearizing about the disease-free equilibrium (DFE)

\[ \dot{\Gamma} = (a - b)\Gamma \] (3.17)

Thus, if \( a - b > 0 \), then \( \Gamma \) grows exponentially around the DFE.

By 3.17 we may approximate \( \rho \) by the following equation:

\[ \rho \approx \Phi(a - b) \] (3.18)

So, \( \rho \) will be defined as function \( \Phi \) of the rate of infection \( a \) less recovered cases \( b \). In this way we have no restrictions over \( \rho \) allowing changes in a wide range to see the impact on activity and output.

The variable \( d \) will change as a function of the impact that \( \rho \) (net of recovered) has on a given level of output.

\(^4\)Where we suppose that all these proportions \( \Omega, \Gamma, \Lambda \) are related to the unrestricted production factor \( N \) and by equation 3.4 to output \( Y \).
Hence, social distancing $d$ will grow in a proportion $\rho$ respect to factor $N$ (which is susceptible to lose his productions capabilities) and therefore by assumption 3.4 to output $Y$.

In short, social distancing $d$ will be growing in proportion $\rho$ respect to income $Y$.

This would lead to adjust equation 3.13 with an additional term

$$\frac{\dot{d}}{d} = -\tau + \rho Y \tag{3.19}$$

### 3.5 The system of equations

If we put together equations 3.7 and 3.19 we obtain the system

\[
\begin{align*}
\frac{\dot{Y}}{Y} &= g - \mu d \\
\frac{\dot{d}}{d} &= -\tau + \rho Y,
\end{align*}
\]

This system defines the dynamic interactions between output and social distancing based on an unconstrained growth rate $g$, a parameter $\mu$, the reaction (decay of $d$) $\tau$ and $\rho$ which refers to the susceptibility of $d$ to income $Y$ or factor $N$ given the relation 3.4. In particular, the assumptions are: a budget restriction given by equation 3.6, a behavior assumption of agents via equation 3.13 and the susceptibility of the factor to not being able to produce via equation 3.18. The remaining factor $\mu$ is set as a policy and structural parameter which may vary with policies, economic structure or system responses to different scenarios; it refers to the effect that $d$ has over the variation of $Y$.

When all parameters have positive values, the point $(\tau, g, \mu)$ is also the center around which the orbits eventually evolves, in this sense it is the second point of equilibrium apart from $(0, 0)$.

We take variables $Y, d, \frac{\dot{Y}}{Y}, N$ with dimension of indexes, whereas parameters $g, \mu, \tau, \rho$ are dimensionless.

Note that if $d = 0$ we obtain a simple case of income growing at his technical possibilities.

Under this framework, social distancing dynamics are lagging that of output\(^5\), an increase in output means an increment of contacts of $N$.

The dynamics of the model implies that some quantity adaptation in output is done; distancing necessarily triggers lower output\(^6\).

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\(^5\)From equation 3.20 we that $\frac{\dot{d}}{d} \left(\frac{\dot{d}}{d}\right) = \rho$.

\(^6\)From equation 3.20 we that $\frac{\dot{Y}}{Y} \left(\frac{\dot{Y}}{Y}\right) = -\mu$.  

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Note that while the structure of the assumptions is very broadly used, we are not able to present deterministic results (or a range given some stochastic assumption). We present drivers of the parameters $g, \mu, \tau, \rho$ but we are not aware of models that have sufficient theoretical and predicting power to provide these type of quantification. The alternative is to simulate some paths.

4 Simulations and results

To avoid the problems that simple binary presentations of benefit and costs may suggest\(^7\) (i.e. health vs output) in terms of actions that they may trigger; we work with a more complete set of parameters which we presented in section 3.

As the interrelation between the different elements are extremely complex, in our attempt to get a sense of these combined dynamics we use some basic simulations (see subsection 3.5).

We run dynamic paths\(^8\); two figures are presented, one for the space of output and distancing and another for the temporal evolution of both variables. We present the parameters in annual scale and use $Y$ for Income, $d$ for distancing, $T$ for trajectories and $t$ for time in the figures.

4.1 Extreme cases

First we present two extreme cases. In both, the short range of time does not allow to show the impact of contagion or distancing interactions with output making it difficult to match real economic conditions. This extremely short time convergence may explain why we are not able to see examples of this paths in practice.

We may see a "$d$ dominant, recession" case in figure 1\(^9\). For the recessive case the high value of reaction of the economy to distancing ($\mu = 1.1$) does not allow the system to react to retain a cycle with income fluctuations.

![Figure 1: Case Recession](image)

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\(^7\)See the rationale at the beginning of section 3.

\(^8\)Using Maxima for calculations.

\(^9\)Passes at $Y=0.25$ and $d=0.5$, case $g = 0.04, \mu = 1.1, \tau = 0.5, \rho = 1$.  

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We may label the trajectories of figure 2 as case recovery\(^\text{10}\). This would be a case when the economy is pushed by sector like software or logistics which experience growth given the need for his services.

\[ \text{Figure 2: Case Recovery} \]

### 4.2 A path of changing parameters

We show a sequence of cases where the first one represent the initial state of the system once distancing is imposed. In each case, the complete set of parameters is redefined, so the path is robust from a Lucas critique (Lucas Jr, 1976) perspective.

In the case of figure 3 we have high contagion with low distancing measures (agent have not learned how to protect themselves and distancing measures are at a low level)\(^\text{11}\).

\[ \text{Figure 3: Phase 1} \]

Once measures of distancing are imposed and as seen in section 2 social discipline holds (lower \(\tau\)); output fluctuates at lower levels and contagion is somewhat

\(^{10}\) Passes at \(Y=0.5\) and \(d=0.25\), case \(g = 0.04, \mu = -0.49, \tau = 0.46, \rho = 0.37\).

\(^{11}\) Case \(g = 0.04, \mu = 0.48, \tau = 0.79, \rho = 2\) that may pass at \(Y=0.3\) and \(d=0.25\).
smaller too$^{12}$.

The fatigue of distancing impact on contagion because "civic capital", trust in others (section 2) collides with opposite incentives such as social and work pressure generating cycles of huge magnitude for distancing as seen in figure 5$^{13}$.

Figure 4: Phase 2

Figure 5: Phase 3

Figure 6: summarizes the paths of figures 3, 4, 5;

$^{12}$Case $g=0.04$, $\mu=0.29$, $\tau=0.46$, $\rho=1.75$ that may pass at $Y=0.2$ and $d=0.2$.

$^{13}$Case $g=0.04$, $\mu=0.2$, $\tau=0.4$, $\rho=2$ that may pass at 0.25 and 0.5.
Following the sequence of the figures (3; 4; 5) as phases of the dynamic process we can see that initially the impact of the contagion finds a first phase where the level of activity continues to exceed the distancing (phase 1). However, the increase in infections forces the system to enter a new phase (phase 2), where the level of activity begins to fluctuate in a lower range. As restrictions are imposed (phase 3), activity continues at low levels, while greater distancing restrictions are imposed.

The example of figure 6 shows the dependency on the susceptibility parameter $\rho$. Even when we see $\mu$ falling (say, due to that the economy is adapting to a mode of production with remote working) and $\tau$ is also decreasing, given the adaptation of factor $N$; the cyclical behavior of $\rho$ force the system to a cycle with lower output $Y$ with high fluctuations in social distancing $d$.

The dynamics presented in figure 6 is similar to the path presented by countries like Germany with a first peak of a little more than 5000 in March-April (2020) following a long valley (cases in the hundreds) reaching more than 25000 in November 2020 with a valley of near 7000 cases in February 2021 and a new high of more than 20000 in April 2021. For Argentina the first peak was near 15000 cases in October 2020 followed by a valley with values as low as 5000 and intermediate peaks of near 12000 reaching near 25000 in April 2021 for contagion for the 7 days average (John Hopkins University CSSE Covid 19, 2020, (accessed April 25, 2021)). Following waves of contagion, social distancing is widely implemented.

Similar paths (tendencies) for GDP to the one presented in figure 6 are reported in empirical evidence. Worldwide, GDP presents a huge fall in the first half of 2020, while the recovery that followed was not enough to reestablish
previous levels. In the G20 area GDP rebounded 8.1% in the third quarter of 2020, while remaining 2.4% lower than pre-crisis levels of the last quarter of 2019 (OECD, 2020, (accessed April 21, 2021)).

5 Conclusions

In the model of gravitation created by Isaac Newton, the force of gravity requires a significant counterforce in order to escape its bounds, as, for example, to launch a rocket from Earth to outer space. If that counterforce were reduced beyond the threshold needed for escape velocity, the rocket would once again come under the influence of gravity and fall back to Earth. If the counterforce is somehow recovered, the rocket would raise again, generating trajectories with cyclical patterns.

The COVID-19 pandemic and the manner in which it is spread has presented economic agents with extremely unpleasant choices regarding their behavior – in many cases, pushed along by government mandates - leading to direct effects in the real economy. In particular, the prophylactic of social distancing may have been a useful mechanism by which to slow the spread of the disease, and, if it actually is effective in limiting contagion, would yield long-term benefits in preserving the work force and hastening an end to the pandemic. On the other hand, the restrictions of social distancing had more immediate and likely medium-term effects, namely the opportunity cost of lower economic activity and output and possible follow-on effects in lower investment for the future. To come back to Newton and our space-bound rocket, the pandemic has shown us that social distancing forces, used to reduce contagion, were counterbalanced by the resistance imposed by the organization of production and the institutions created and sustained by human interaction. It is a “social gravitational force” which resists distancing and is necessary for production, and the force/counterforce interplay creates different trajectories depending upon which force is favored.

This paper models these trade-offs in the context of an economy, integrating various parameter configurations into a succession of phases associated with social distancing. Our key result is that the trade-off of lower output in the long run for defeating the disease via social distancing cannot be avoided: lower contagion means lower output ceteris paribus. One may defy gravity for a short time, but there are consequences. Indeed, this economic reality, that various courses of actions are mutually exclusive trade-offs, is the motivating factor behind the key point of our model, namely that it does not have an explicit singular solution. Instead, the model is offered as an attempt to illuminate some of the variables and parameters which may be significant in the context of the optimization problem. However, this also highlights one of the limitations of the model, as well as of public policy in response to a pandemic in general. As the model depends on a specific set of parameters, $g$ Gdp growth, $\mu$ economic structure and policies, $\tau$ response of the labor force to distancing and $\rho$ the susceptibility of the system to the need of more social distancing $d$, our simulations
show the complex nature of the casual relations between the variables. Even in a sterile, disease-free, simulation setting, we may not be able to provide the exact relations and responses, as, they are highly path dependent: much like the meltwater under a glacier in Greenland (Poinar et al., 2015), which may deposit quietly in a lake or gain force, melt more ice, and form a river to the ocean, we do not know which force will predominate and determine the reaction of the system.

Despite this limitation, we hope to have provided a simulation tool as a first attempt to model these relationships explicitly and understand the extent of the trade-offs in setting policy. Indeed, the limitations of the model also provide a warning for policymakers, as the complexity of pandemic response means that there are no simple solutions, but rather, difficult trade-offs. Moreover, our findings suggest that the interaction of forces at play during the pandemic were non-linear, introducing additional complexity. As a policymaker, veering from policy to policy and influenced by the ecosystem of institutions surrounding policymaking, trade-offs and non-linearities may not be readily apparent but must be considered and, importantly, communicated. Pandemic response is not a binary “health or the economy” choice, but instead a continuum where there are opportunity costs in the short-, medium-, and long-term. To pretend otherwise is folly and, most likely, counterproductive for building the trust necessary to overcome such an exogenous shock.

A Appendix: A non-consistent case

Economic consistency may help us to discard some cases. We may dismiss the case with negative income grow and a positive influence of distancing over the growth rate (think of an economy based on logistic distribution or strong software capabilities)\textsuperscript{14}. We present several theoretical possible trajectories in figure 7.

\textsuperscript{14}For example, case saddle at Y=0.5 and d=0.25, with $g = -0.04, \mu = -0.15, \tau = 0.5, \rho = 1$. 

Figure 7: Non consistent cases

References

Abouk, R., & Heydari, B. (2021). The immediate effect of covid-19 policies on social-distancing behavior in the united states. Public Health Reports, 136(2), 245–252.

Ashraf, B. N. (2020). Economic impact of government interventions during the covid-19 pandemic: International evidence from financial markets. Journal of behavioral and experimental finance, 27, 100371.

Barnett-Howell, Z., & Mobarak, A. M. (2020). The benefits and costs of social distancing in rich and poor countries. arXiv preprint arXiv:2004.04867.

Barrot, J., Grassi, B., & Sauvagnat, J. (2020). Sectoral effects of social distancing covid economics (Vol. 3) (No. 5). Issue.

Block, P., Hoffman, M., Raabe, I. J., Dowd, J. B., Rahal, C., Kashyap, R., & Mills, M. C. (2020). Social network-based distancing strategies to flatten the covid-19 curve in a post-lockdown world. Nature Human Behaviour, 4(6), 588–596.

Bodenstein, M., Corsetti, G., & Guerrieri, L. (2021). Economic and epidemiological effects of mandated and spontaneous social distancing.

Brun, J.-F., Carrère, C., Guillamont, P., & De Melo, J. (2005). Has distance died? evidence from a panel gravity model. The World Bank Economic Review, 19(1), 99–120.

Corsetti, G., Bodenstein, M., & Guerrieri, L. (2020). Social distancing and supply disruptions in a pandemic. Covid Economics, 19(1), 1-52.
Delen, D., Eryarsoy, E., & Davazdahemami, B. (2020). No place like home: cross-national data analysis of the efficacy of social distancing during the covid-19 pandemic. *JMIR public health and surveillance, 6*(2), e19862.

De Vos, J. (2020). The effect of covid-19 and subsequent social distancing on travel behavior. *Transportation Research Interdisciplinary Perspectives, 5*, 100121.

Durante, R., Guiso, L., & Gulino, G. (2021). Asocial capital: Civic culture and social distancing during covid-19. *Journal of Public Economics, 194*, 104342.

Farboodi, M., Jarosch, G., & Shimer, R. (2020). *Internal and external effects of social distancing in a pandemic* (Tech. Rep. No. w27059). National Bureau of Economic Research.

Greenstone, M., & Nigam, V. (2020). Does social distancing matter? *University of Chicago, Becker Friedman Institute for Economics Working Paper*(2020-26).

Gunay, S., & Kurtulmuş, B. E. (2021). Covid-19 social distancing and the us service sector: What do we learn? *Research in International Business and Finance, 56*, 101361.

Gupta, S., Montenovo, L., Nguyen, T. D., Lozano-Rojas, F., Schmutter, I. M., Simon, K. I., . . . Wing, C. (2020). Effects of social distancing policy on labor market outcomes. *NBER Working paper*(w27280).

Hammar, T., Brochmann, G., Tamas, K., & Faist, T. (2021). *International migration, immobility and development: Multidisciplinary perspectives*. Routledge.

Isard, W. (1954). Location theory and trade theory: short-run analysis. *The Quarterly Journal of Economics, 305–320*.

John Hopkins University CSSE Covid 19. (2020, (accessed April 25, 2021)). *Daily new confirmed cases covid 19, 7 days average*. Retrieved from "https://ourworldindata.org/coronavirus"

Koren, M., & Pető, R. (2020). Business disruptions from social distancing. *PloS one, 15*(9), e0239113.

Lucas Jr, R. E. (1976). Econometric policy evaluation: A critique. In Carnegie-rochester conference series on public policy (Vol. 1, pp. 19–46).

Mandel, A., & Veetil, V. (2020). The economic cost of covid lockdowns: An out-of-equilibrium analysis. *Economics of Disasters and Climate Change, 4*(3), 431–451.

McGrail, D. J., Dai, J., McAndrews, K. M., & Kalluri, R. (2020). Enacting national social distancing policies corresponds with dramatic reduction in covid19 infection rates. *PloS one, 15*(7), e0236619.

Mongey, S., Pilosof, L., & Weinberg, A. (2020). *Which workers bear the burden of social distancing policies?* (Tech. Rep. No. w27085). National Bureau of Economic Research.

Newton, I. (1987). *Philosophiæ naturalis principia mathematica* (mathematical principles of natural philosophy). *London (1687)*, 1687.

Niedercorn, J. H., & Bechdolt Jr, B. V. (1969). An economic derivation of the “gravity law” of spatial interaction. *Journal of Regional Science, 9*(2), 17
OECD. (2020, accessed April 21, 2021)). *Gross domestic product-annually.* Retrieved from "https://www.oecd.org/newsroom/g20-gdp-growth-third-quarter-2020-oecd.htm"

Palomino, J. C., Rodríguez, J. G., & Sebastian, R. (2020). Wage inequality and poverty effects of lockdown and social distancing in europe. *European economic review, 129,* 103564.

Park, S. W., Sun, K., Viboud, C., Grenfell, B. T., & Dushoff, J. (2020). Potential role of social distancing in mitigating spread of coronavirus disease, south korea. *Emerging infectious diseases, 26*(11), 2697.

Piccillo, G., & Van Den Hurk, J. (2020). The surprising effect of social distancing on our perception: Coping with uncertainty1. *Covid Economics, 132.*

Poinar, K., Jougnin, I., Das, S. B., Behn, M. D., Lenaerts, J. T., & Van Den Broeke, M. R. (2015). Limits to future expansion of surface-melt-enhanced ice flow into the interior of western greenland. *Geophysical Research Letters, 42*(6), 1800–1807.

Sheridan, A., Andersen, A. L., Hansen, E. T., & Johannesen, N. (2020). Social distancing laws cause only small losses of economic activity during the covid-19 pandemic in scandinavia. *Proceedings of the National Academy of Sciences, 117*(34), 20468–20473.

Stockmaier, S., Stroeymeyt, N., Shattuck, E. C., Hawley, D. M., Meyers, L. A., & Bolnick, D. I. (2021). Infectious diseases and social distancing in nature. *Science, 371*(6533).

Stouffer, S. A. (1940). Intervening opportunities: a theory relating mobility and distance. *American sociological review, 5*(6), 845–867.

Thunström, L., Newbold, S. C., Finnoff, D., Ashworth, M., & Shogren, J. F. (2020). The benefits and costs of using social distancing to flatten the curve for covid-19. *Journal of Benefit-Cost Analysis, 11*(2), 179–195.

Vanderkamp, J. (1977). The gravity model and migration behaviour: An economic interpretation. *Journal of Economic Studies.*

Venkatesh, A., & Edirappuli, S. (2020). Social distancing in covid-19: what are the mental health implications? *Bmj, 369.*