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Research article

Does freelancing have a future? Mathematical analysis and modeling

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Abstract: During the past few years, freelancing has grown exponentially due to the pandemic and subsequent economical changes in the world. In fact, in the last ten years, a drastic increase in freelancing has been observed; people quit their jobs to be their own boss. There are various reasons for this: downsizing of employees, not having fun in their jobs, unemployment, part time work to earn more, etc. Observing this vast change, many individuals on Facebook/YouTube, NGOs, and government departments started teaching freelancing as a course; to date, thousands of youngsters have been trained to start their careers as freelancers. It has been observed that the ratio of informed freelancers is more successful than those who start their careers independently. We construct a compartmental model to explore the influence of information on the expansion of freelancing in this article, which was motivated by this surge in freelancing. Following that, the model is subjected to dynamical analysis utilizing dynamical systems and differential equation theory. To validate our analytical conclusions, we used numerical simulation.

Keywords: freelancing; social science; mathematical modeling; differential equation; numerical analysis; simulation

1. Introduction

Freelance (also called free-lance or free lance) or 'freelance worker' are phrases used to describe someone who is self-employed and not bound to a single employer for a long term. Thousands of individuals have lost their livelihoods; several organizations have closed in various regions of the world due to economic instability and technological advancement in the internet world since the 1990s. As a result, schools, media, and academics have promoted entrepreneurship as a viable and necessary means of surviving in the digital era, with the "freelancer" being one form of "entrepreneur". Because of the economic insecurity and technical development in digital media industries, media companies and academics have urged freelance media employees to view themselves as independent enterprises rather than a class of workers who should collectively preserve their rights and fair pay. There are various platforms on which freelancers provide their services, such as Fiverr, Upwork, Freelancer.com, Behance, Designhill, PeoplePerHour, etc. Apart from this, there are several groups on Facebook where freelancers and buyers connect and engage in business. Hiring managers seek out freelancers for various skills such as writing, creative design, web, mobile and software development, marketing, IT/networking, and database admin, engineering, online teaching, and many more. Nowadays, not only large enterprises but also small start-ups like to hire freelancers instead of hiring in-house teams or full-time employee due to various reasons, such as faster completion of projects, reduction of costs, lack of office space, or TADAs of any kind, and a variety of advanced employee skills to choose from. According to Upwork [1], hiring managers now prefer independent talent rather than those provided by staffing firms for the following reasons:

- 62% because of faster completion of projects
- 55% due to the reduced costs
- 49% for access to highly skilled talent
- 49% for the increased transparency in their process

According to statistics, the top three freelancing platforms earned billions of dollars in 2020 and 2021 [2]. Upwork's revenue has more than quadrupled since 2016, rising from 164 million in 2016 to 373 million by 2020. Around the world, there are an estimated 1.2 billion freelancers (almost a third of the overall employment). By 2028, it is expected that the overall number of freelancers in the United States will exceed 90 million. Due to the COVID-19 epidemic in 2020, an estimated 2+ million employees have entered the freelancing economy. Freelancers who began freelancing during the epidemic have reported a good financial effect, with 96% expecting to continue freelancing in the future. In fact, during the epidemic, 1/3 of Gen Z freelancers began their careers. Independent labor is not only a force to be reckoned with but is still on the rise. Because data suggest that the independent workforce is increasing faster than ever, the function of distributing information and understanding regarding freelancing is examined in this paper.

Pakistan's government has heavily invested in this sector in the last two decades. According to a report, IT & ITeS export remittances surged to $1.23 billion during FY 2019-20, including US$150

million earned by freelancers. Whereas, in the first seven months of the current FY 2020-21 (July 2020 – January 2021), freelancers' export remittances have rapidly increased to US$ 219 Million and are expected to cross US$ 350 Million by the end of FY 2020-21. It is estimated that, at present, around 100,000 "active" freelancers (who at least make $100 a month) are working from Pakistan and earning valuable foreign exchange for the country [3, 4].

Freelancing has gained more importance after the pandemic which is increasing daily, but not many researches have been done about freelancing. Even developed countries are still studying and developing policies for freelancers; training programs are being introduced to improve this line of career (for policies in Pakistan see [3] and [4]). Rawoof et al. [5] studied the impact of freelancing on women in Pakistan, whereas [6] statistically analyzed the impact of freelancing in Pakistan.

Researchers in other countries are also very much interested in studying the impact of freelancing on freelancers. Therefore, [7] studied the effect of fatigue on freelancers due to which their tasks remain incomplete and their profiles get effected in the market. Also, [8] studied the relationship of startups with freelancers. If startups outsource their software development tasks to the freelancers, how is it better for them than hiring a software developer in house?

When people in their immediate vicinity notice freelancers making far more than them, and saving time and money by not having to commute to work, the awareness and perception spreads like an epidemic throughout society. Also, due to the pandemic, many people who have lost their employment are looking for online work. We created this model using something called the epidemic modeling methodology.

One of the most effective approaches for investigating emerging and reemerging infectious diseases is mathematical modeling. It is employed to provide insights on their epidemiological features and transmission behavior, as well as their influence on global public and the evolution of socioeconomic status. Moreover, many epidemiological models have been developed and analyzed to explore the transmission dynamics and to estimate the influence of prevention and control strategies on the spread of disease, see, for example, [9–18] and the references therein [19–22].

This paper is divided into the following parts. Section I contains a brief literature review of this work. Section II is the mathematical formulation of the freelancing mathematical model in terms of epidemic modeling. Section III contains this paper's major contributions as it discusses the reproduction number for this model and its equilibrium analysis. Section IV discusses the stability of this model analytically. In Section V, the numerical stability is discussed, and different aspects of its numerical solution is described. In the end, Section VI gives the conclusion of this whole paper.

2. Mathematical formulation

SIR (Susceptible Infected Recovered) models have been discussed in many forms and with many assumptions but in this paper, model will be formed on the mathematical basis given in [23]. Let us consider our population in two categories: freelancers $F(t)$ and non-freelancers $N(t)$. Also, let $I(t)$ be the function of information generated by the class $F(t)$. Therefore, we can say that the growth rate of $I(t)$ is directly proportional to the class $F(t)$, so the rate at which information is spread effectively will be denoted by α. Now, this does not always mean that the information presented is inspiring and compelling in favor of freelancing; it might be based on a freelancer's unpleasant experiences, which can operate as the information depletion rate denoted by β. All new entrants into the earning system are

expected to start earning from non-online sources, and hence all new entrants into the earning system enter the $N(t)$ class at a constant rate γ. It is also believed that a person in the non-online earners class $N(t)$ will shift to the $F(t)$ class once he learns about the advantages of online earning. The rate at which information about the advantages of online income is disseminated among persons of class $N(t)$, causing them to shift into the freelancer class, is ϵ. Some $F(t)$ class members left the online earning class at a rapid rate and joined the $N(t)$ class for various reasons, including a lack of knowledge about technology, a lack of expertise in skills, and so on. According to the model, individuals in each class with rates $N(t)$ and $F(t)$ quit the earning system owing to inactivity and death. Also, freelancers who have not adequately learned about freelancing platforms, are not excellent enough in their talents, or whose gigs are not impressive, may be ready to look back to non-online earning opportunities at a rate of μ.

$$\begin{aligned} \frac{dN}{dt} &= \gamma - \epsilon NI - \delta N + \mu F \\ \frac{dF}{dt} &= \epsilon NI - \delta F - \mu F \\ \frac{dI}{dt} &= \alpha F - \beta I \end{aligned} \tag{2.1}$$

To perform the dynamical study on Eq (2.1) we obtain the following region

$$R = \left\{(N, F, I) : 0 \leq N, F \leq \frac{\gamma}{\delta}, 0 \leq I \leq \frac{\alpha\gamma}{\beta\delta}\right\} \tag{2.2}$$

3. Reproduction number and equilibrium analysis

Such dynamical system when solved by taking derivative term equal to zero as

$$\begin{aligned} \gamma - \epsilon NI - \delta N + \mu F &= 0 \\ \epsilon NI - \delta F - \mu F &= 0 \\ \alpha F - \beta I &= 0 \end{aligned} \tag{3.1}$$

gives two equilibrium solutions. Trivial equilibrium solution as $Eq_1 = (\frac{\gamma}{\delta}, 0, 0)$ and a non trivial equilibrium solution as $Eq_2 = (N^*, F^*, I^*)$. To find the nontrivial equilibrium solution we solve Eq (3.1) as taking the value of $I = \frac{\alpha F}{\beta}$ and put in second equation to obtain $N = \frac{\beta(\delta+\mu)}{\epsilon\alpha}$. Using this value of N and I in first equation of Eq (3.1) we have $F = \frac{\epsilon\alpha\gamma - \beta\delta(\delta+\mu)}{\epsilon\alpha\delta}$. For F to exist $\epsilon\alpha\gamma - \beta\delta(\delta + \mu) > 0$, then $\epsilon\alpha\gamma > \beta\delta(\delta + \mu)$ So from this we can see that $\frac{\epsilon\alpha\gamma}{\beta\delta(\delta+\mu)} > 1$

$$R_0 = \frac{\epsilon\alpha\gamma}{\beta\delta(\delta + \mu)} \tag{3.2}$$

Hence Eq_2 exists only if $R_0 > 1$ [23].

3.1. Parameter analysis based on R_0

Let us discuss in this section the role of each parameter in the growth of Freelancer class based on R_0. Let the first parameter be ϵ, the critical value of ϵ for $R_0 = 1$ from Eq (3.2) be taken as

$$\epsilon^* = \frac{\beta\delta(\delta + \mu)}{\alpha\gamma} \tag{3.3}$$

Let us denote the derivative of R_0 it becomes $\frac{\partial R_0}{\partial \alpha} = \frac{1}{\epsilon^*} > 0$, then according to its definition we observe that it is positive so R_0 is an increasing function. Therefore, it can be deduced that $R_0 > 1$ only if $\epsilon > \epsilon^*$.

Now for $R_0 = 1$, we have the corresponding critical value of α from Eq (3.2) be

$$\alpha^* = \frac{\beta\delta(\delta + \mu)}{\epsilon\gamma} \tag{3.4}$$

Now if we take $\frac{\partial R_0}{\partial \alpha}$ we get $\frac{1}{\alpha^*} > 0$. This implies that for $\alpha > \alpha^*$, $R_0 > 1$. For β, taking $R_0 = 1$ in Eq (3.2) we get

$$\beta^* = \frac{\epsilon\alpha\gamma}{\delta(\delta + \mu)} \tag{3.5}$$

Taking partial derivative of R_0 with respect to β, we get

$$\frac{\partial R_0}{\partial \beta} = -\frac{\epsilon\alpha\gamma}{\beta^2\delta(\delta + \mu)} < 0 \tag{3.6}$$

which implies that R_0 is a decreasing function for β. Therefore, we deduce that for $\beta < \beta^*$ implies that $R_0 > 1$ always.

Now to analyze the critical value of μ when $R_0 = 1$ we have

$$\mu^* = \frac{\epsilon\alpha\gamma - \beta\delta^2}{\beta\delta} \tag{3.7}$$

We also can see from the partial derivative that μ is a decreasing function

$$\frac{\partial R_0}{\partial \mu} = -\frac{\epsilon\alpha\gamma}{\beta\delta(\delta + \mu)^2} < 0 \tag{3.8}$$

From this result we can say that $R_0 > 1$ if and only if $\mu < \mu^*$.

4. Stability analysis

To better understand any dynamical system it is very important to perform its stability analysis. In this section, we provide our findings in the form of theorems.

Theorem 4.1. *The stability and instability of the free equilibrium point Eq_1 of the freelancer class appear when $R_0 \leq 1$ and $R_0 > 1$ respectively. On the other hand, Eq_2, which represents a non-trivial equilibrium point appears when $R_0 > 1$, and its stability is asymptotic and local when following hold:*

$$\begin{aligned} &3\epsilon\mu I^* < (\epsilon I^* + \delta)(\delta + \mu) \\ &3\beta(\delta + \mu) < 3\epsilon\alpha N^* \\ &(\mu + \delta) < 2\mu \end{aligned} \tag{4.1}$$

Proof. The Jacobian matrix for the Eq (2.1) is written as

$$P = \begin{bmatrix} -\epsilon I - \delta & \mu & -\epsilon N \\ \epsilon I & -(\delta + \mu) & \epsilon N \\ 0 & \alpha & -\beta \end{bmatrix} \tag{4.2}$$

At trivial equilibrium point Eq_1 this matrix becomes

$$P_{Eq_1} = \begin{bmatrix} -\delta & \mu & -\epsilon\frac{\gamma}{\delta} \\ 0 & -(\delta + \mu) & \epsilon\frac{\gamma}{\delta} \\ 0 & \alpha & -\beta \end{bmatrix} \tag{4.3}$$

From this matrix we obtain the following characteristic equation

$$(\delta + \lambda)((\delta + \mu + \lambda)(\beta + \lambda) - \frac{\alpha\epsilon\gamma}{\delta}) = 0 \tag{4.4}$$

This characteristic equation shows that the eigenvalue for $\lambda = -\delta$ is negative, also the other two eigen values are negative when $\frac{\alpha\epsilon\gamma}{\beta\delta(\delta+\mu)}$, which implies that $R_0 < 1$. Therefore, it is proven that Eq_1 is unstable for $R_0 < 0$. Now we study Eq_2 for $R_0 > 1$. Consider the following Lyapunov function

$$V_1 = \frac{q_1}{2}N_1^2 + \frac{q_2}{2}F_1^2 + \frac{q_3}{2}I_1^2 \tag{4.5}$$

where V_1, N_1, F_1, I_1 are small perturbations in N, F, I, which are taken from $N = N^* + N_1$, $F = F^* + F_1$ and $I = I^* + I_1$. Also q_i where $i = 1, 2, 3$ are positive constants. Now differentiating Eq (2.1) with respect to time t, we have

$$\frac{dV_1}{dt} = -q_1(\epsilon I^* + \delta)N_1^2 - q_2(\delta + \mu)F_1^2 - q_3\beta I_1^2 + q_1\mu F_1 N_1 - q_1(\epsilon N^*)I_1F_1 + q_3\alpha I_1F_1 \tag{4.6}$$

The derivative term $\frac{dV_1}{dt} < 0$ for the following conditions

$$\begin{aligned} &\frac{1}{3}q_2(\epsilon I^* + \delta)(\delta + \mu) > q_1\mu^2 \\ &\frac{4}{9}q_3\beta(\epsilon I^* + \delta) > q_1(\epsilon N^*)^2 \\ &\frac{1}{3}q_1(\epsilon I^* + \delta)(\delta + \mu) > q_2(\epsilon I^*)^2 \\ &\frac{1}{3}q_3\beta(\delta + \mu) > q_2(\epsilon N^*)^2 \\ &\frac{1}{3}q_2(\delta + \mu)\beta > q_3\alpha^2 \end{aligned} \tag{4.7}$$

These conditions can be satisfied and this theorem is proven by taking $q_2 = 1$ and suitable values of q_1, q_3.

Now, to check the global stability of the non trivial equilibrium Eq_2 we prove the following theorem.

Theorem 4.2. *The non trivial equilibrium Eq_2 is globally stable if and only if the following conditions are satisified*

$$
\begin{aligned}
&3\epsilon\mu I_P < (\epsilon I_P + \delta)(\delta + \mu) \\
&\beta(\delta + \mu) < 3\epsilon\alpha N^* \\
&(\mu + \delta) < 2\mu
\end{aligned} \tag{4.8}
$$

Proof. To prove this theorem, we take into consideration the Lyapunov function presented below

$$
V_2 = \frac{p_1}{2}(N - N^*)^2 + \frac{p_2}{2}(F - F^*)^2 + \frac{p_3}{2}(I - I^*)^2 \tag{4.9}
$$

where $p_i > 0 \forall i = 1, 2, 3$, now taking derivative of Eq (4.9) with respect to t by inserting Eq (2.1) we get

$$
\begin{aligned}
\frac{dV_2}{dt} &= -P_1(\epsilon I + \delta)(N - N^*)^2 - P_2(\delta + \mu)(F - F^*)^2 \\
&- P_3\beta(I - I^*)^2 - P_1\epsilon N^*(I - I^*)(N - N^*) \\
&- P_1\mu(F - F^*)(N - N^*) + P_2\epsilon I(N - N^*)(F - F^*) \\
&- P_2\epsilon N^*(I - T^*)(F - F^*) + P_3\alpha(I - I^*)(F - F^*)
\end{aligned} \tag{4.10}
$$

For the following conditions Eq (4.10) will be negative

$$
\begin{aligned}
&\frac{4}{9}p_3\beta(\epsilon I^* + \delta) > p_1(\epsilon N^*)^2 \\
&\frac{p_2}{3}(\epsilon I^* + \delta)(\mu + \delta) > p_1\mu^2 \\
&\frac{1}{3}p_3\beta(\delta + \mu) > p_2(\epsilon N^*)^2 \\
&\frac{1}{3}p_1(\epsilon I + \delta)(\delta + \mu) > p_2(\epsilon I)^2 \\
&\frac{1}{3}p_2(\delta + \mu)\beta > p_3\alpha^2
\end{aligned} \tag{4.11}
$$

These conditions can be satisfied and this theorem is proven by taking $p_2 = 1$ and suitable values of p_1, p_3.

Hence, from these theorems, it is clear that the spread of information regarding freelancing primarily depends on the parameters α and β. It can be said that the large values of α and β can depict the growth behavior of freelancing.

5. Numerical simulation

Now, in this section, we will verify our theoretical results numerically about the impact of the growth of information on freelancing. These results can depict other interesting factors as well. In this section, all these calculations are done by a software Mathematica 11.0 and the numerical method used for simulation is RK4. For simulation, we are using the following values of parameters:

$$
\gamma = 10, \epsilon = 0.0002, \delta = 0.02, \mu = 0.03, \alpha = 0.05, \beta = 0.06 \tag{5.1}
$$

For this set of values of parameters, the value of $R_0 = 1.6667 > 1$. The value of R_0 shows the equilibrium E_2 exists. Theorems 1 and 2 can also be verified for this set of values. Now, the equilibrium points that we obtained from the stability condition are

$$N^* = 300 \quad F^* = 200 \quad I^* = 166.667 \tag{5.2}$$

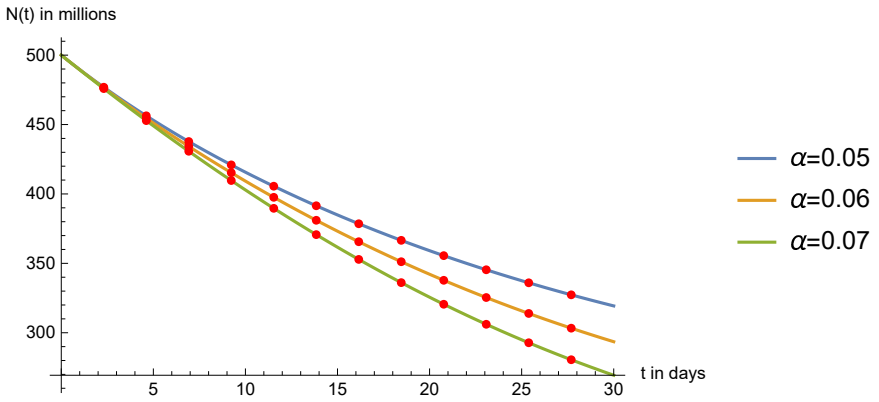

Figure 1. Graph that shows the behavior of N(t) for different values of α by keeping $\beta = 0.05$.

As the theoretical results showed that the system behavior is based on two parameters α and β, so here we observe these changes graphically. Figure 1 shows the behavior of workers who are non-freelancers, for different values of α the graph of N(t) varies as α increases the number of $N(t)$ reduces. Whereas Figures 2–4 show the graphical representation of $F(t)$ and $I(t)$, in which it can be observed that as α increases the value of $F(t)$ and $I(t)$ also increases when $\beta = 0.05$, which means that as the parameter of freelancing information increases or the information about freelancing spreads it positively impacts $F(t)$ and increase in freelancers can be observed. Plus, it negatively impacts the $N(t)$, and the number of $N(t)$ reduces, which is exactly coherent with our theoretical results in Theorems 4.1 and 4.2. The green line shows highest value of $\alpha = 0.07$, in Figures 1–3 for the value of $\beta = 0.05$ that is $\beta < \alpha$.

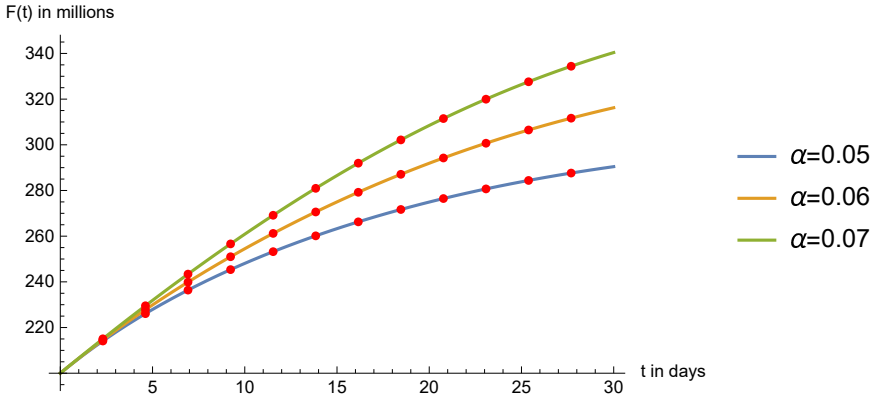

Figure 2. Graph that shows the behavior of F(t) for different values of α by keeping $\beta = 0.05$.

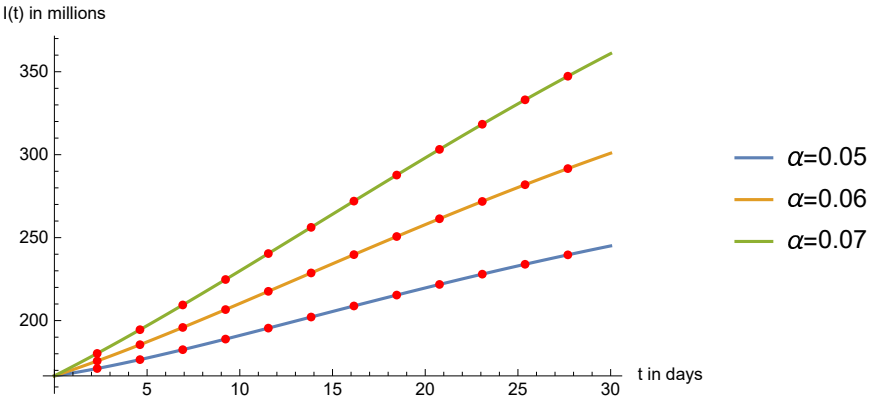

Figure 3. Graph that shows the behavior of I(t) for different values of α by keeping $\beta = 0.05$.

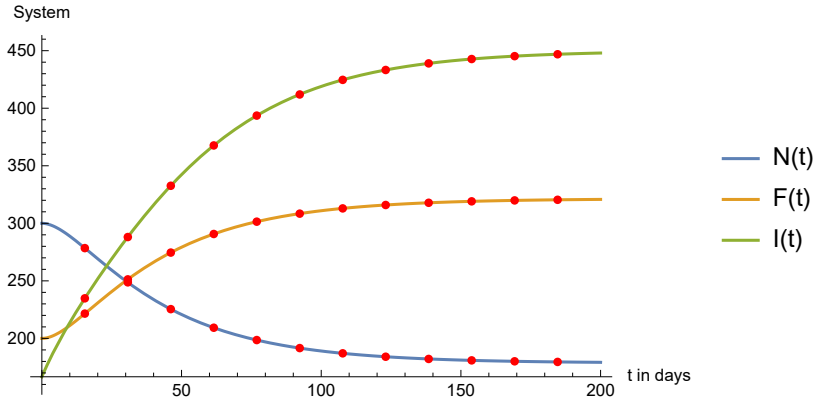

Figure 4. Graphical representation of system Eq (2.1) where $a > b$.

Since we are studying the role of information spread in freelancing as a career option, it is crucial to visualize the impact of parameters such as α and β. The increase in β shows that if various platforms spread negative information then it definitely effects the rise in $F(t)$. So Figures 5–8 show that if β increases, rumors increase i.e. $I(t)$ increases, but $F(t)$ decreases and $N(t)$ increases, hence, validating theoretical results in Theorems 4.1 and 4.2. The green line shows highest value of $\beta = 0.07$, in Figures 5–7 for the value of $\alpha = 0.05$ that is $\alpha < \beta$.

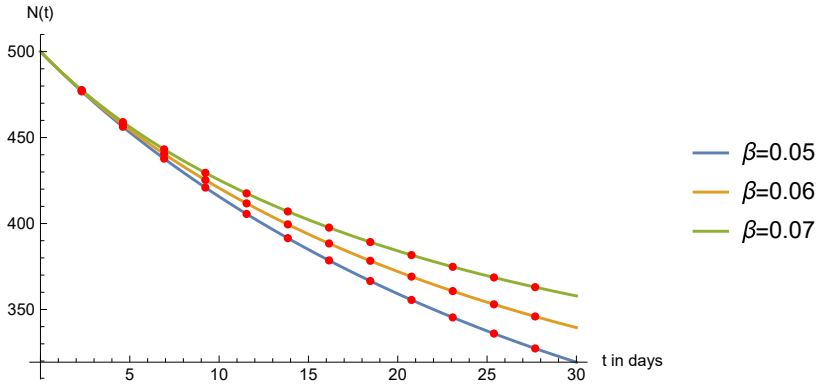

Figure 5. Graph that shows the behavior of N(t) for different values of β by keeping $\alpha = 0.05$.

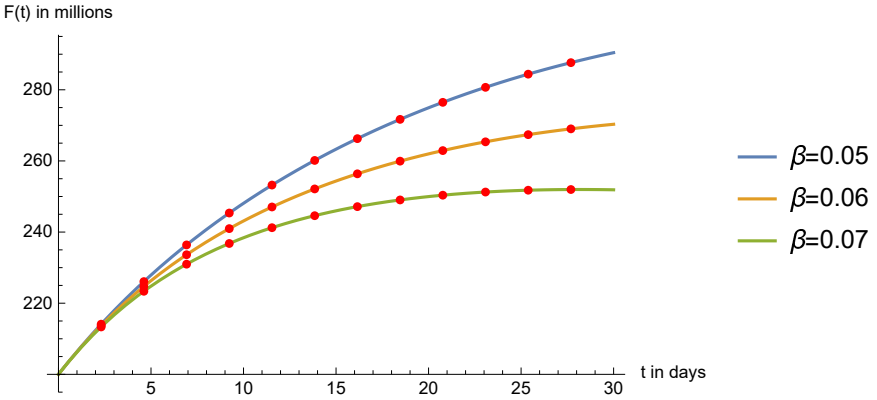

Figure 6. Graph that shows the behavior of F(t) for different values of β by keeping $\alpha = 0.05$.

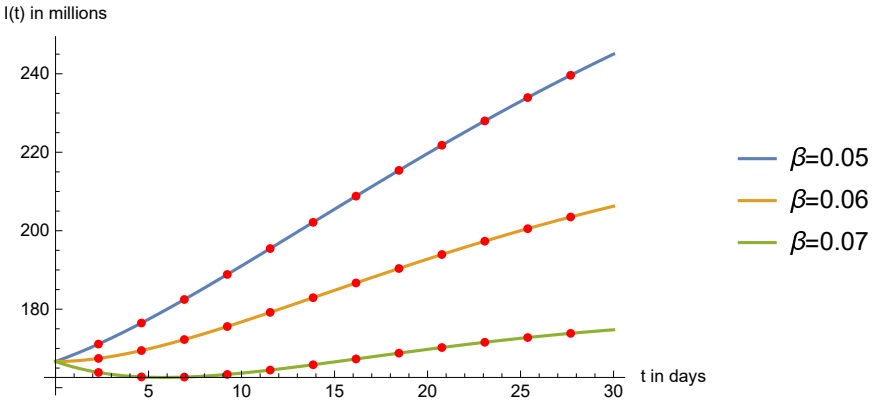

Figure 7. Graph that shows the behavior of I(t) for different values of β by keeping $\alpha = 0.05$.

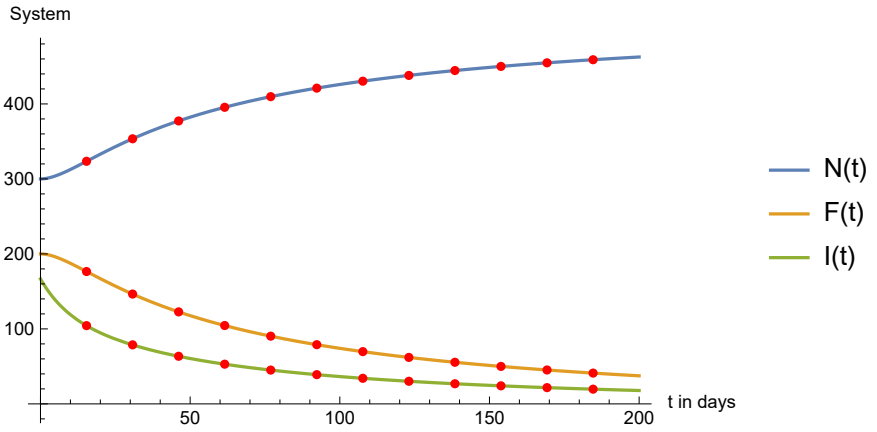

Figure 8. Graphical representation of system Eq (2.1) where $\alpha > \beta$.

Now, to validate a mathematical model, we need to show the effectiveness of this theory in real life. For this purpose, we collected information from [24] and [25] US citizens (see also the [26–28] and reference therein). Although, data can be verified for any origin or country, we consider US because

their data was readily available and ready to use. Therefore, by using this data, we compared the results with the data our model predicted in Figures 9 and 10. As it can be seen, they correlate very well, and our prediction for $F(t)$ shows in Figure 9 that it will keep increasing the future due to the change in Covid-19 circumstances.

Table 1. Number of freelancers and full time employees in US.

Year	No of freelancers (in million) [25]	No of Employees (in million) [24]
2014	53	118.72
2015	53.7	121.49
2016	55	123.76
2017	57.3	125.97
2018	56.7	128.57
2019	57	130.6

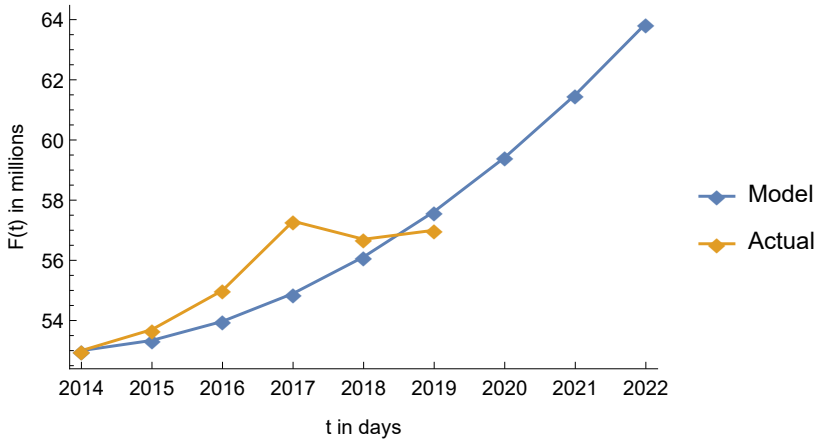

Figure 9. Comparison of our model and actual data collected in Table 1 for the number of freelancers in US. Also, predicting the future trend for freelancers in US.

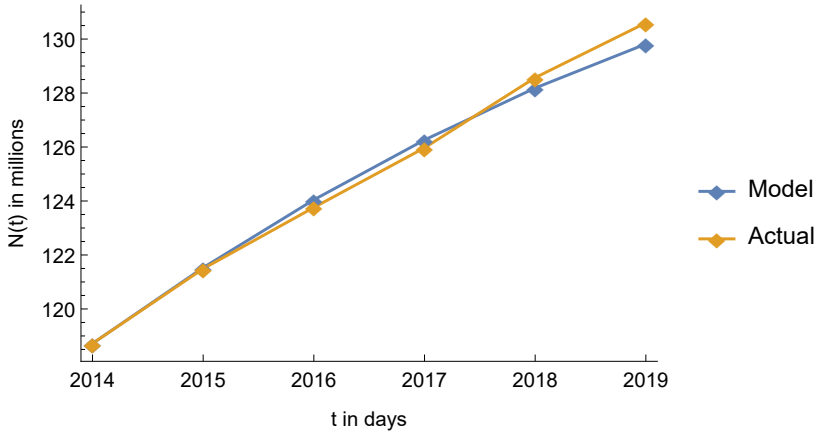

Figure 10. Comparison of our model and actual data collected in Table 1 for the number of workers in US which are non-freelancers.

6. Conclusions

Freelancing is getting very popular and attention these days. As previously stated, in Section I, the fast growth of freelancing, particularly after COVID-19 when everything went online, can be compared to the spread of infection. As a result, the compartmental epidemic modeling technique is appropriate for studying the phenomena of freelancing. As a result, we present a mathematical model to study the role of information on freelancer growth in this paper.

We believe that after being enlightened about the benefits of freelancing, the population of non-online employees became interested in it. Many people are motivated to work through various online freelancing platforms because of the information created by freelancers in their social networks. We also obtained the reproduction number R_0 expression. This is quite comparable to the commonly used basic reproduction number in epidemiology. The reproduction number collected here allows us to discover the factors that contribute to the spread of online work. The equilibrium analysis in Section 3 resulted in two equilibrium points: freelancing free E_{q1} and non-trivial equilibrium point E_{q2}. When $R_0 < 1$, the free equilibrium point E_{q1} of the freelancer is locally asymptotically stable. The Lyapunov function is used to find local and global stability criteria for the non-trivial equilibrium point E_{q2}.

Sections 4 and 5, also investigated the numerical influence of various factors on freelancing. Figures 1–3 demonstrate the growth in freelancers for increasing rates of α, demonstrating the beneficial influence of knowledge production. In brief, information has a significant impact on the growth of freelancing see Figures 4 and 8. Also, from Table 1 and Figures 9 and 10, this model proves its validity on US data. This states that its not a mere theory; if we actually work on this epidemic, it can benefit our youth to showcase their talent in the best possible way.

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Conflict of interest

The authors declare there is no conflict of interest.

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