

Analysis of chaos dynamics of emotions in employment relation model

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Abstract. This paper studies the mathematical modelling and analysis of chaos for employment relation system in which the interactions between tendencies of employer, employee and intermediate employee are being studied. In the modelling the social frame work of an urban class office system is being considered where employee and employers have their own set of disappointments and grief in their mutual relation. Stable phase, critical phase and chaotic phase have been observed in the simulation of the dynamics of the office system for different parameter values. Through bifurcation plot for variation in the level of disappointment the critical value of disappointment is observed to be in accordance with the critical value evaluated through stability analysis. It is concluded that the tendencies of both employer and employee remain stable till they have their disappointment level below the critical value. The moment the critical value is crossed the employment relation transits from stable to critical phase where the tendencies of both the partners start oscillating which later becomes chaotic as disappointment level further increases.

Keywords: intermediate model, stability analysis, employment relations, individualistic interactions, chaos, bifurcation.

1. Introduction

An office is a functional unit of a trading society where different individuals work together in an institutional frame work and hierarchal system. In this hierarchal system the employer is at the topmost position being the governing authority of the corporate enterprise while employees under his/her supervision

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work for the institution. The employment relation is the connection between the employer and employee through which the exchange of labour take place in the economy. All employees and employers have fundamental interests which they pursue through the employment relationship. Such a relationship in corporate world are mediated and governed strictly by rule and regulations documented in the form of a contract.

Evolution of dynamics between the employee and employer in an office is governed by set of various types of interactions that take place between the employer and employee often mediated by intermediating colleagues. Every interaction is different with its own interaction parameter accounting for direct and indirect dependence of the couple on each other's evolution of emotions. Baker [1] examined and extended Noer's theoretical model of the new employment relationship. Relationships among ID (interpersonal deviance), OD (organizational deviance), and their common correlates were meta-analyzed by Berry et al. [3]. It was observed ID and OD were highly correlated and had differential relationships with five key variables and organizational citizenship behaviours, lending support to the separability of ID and OD. Bodankin and Tziner [4] further showed that neuroticism and agreeableness were related to both types of constructive deviance, whereas conscientiousness was associated with both types of destructive deviance. The relationship between pay satisfaction and outcomes was investigated by Currall et al. [6] using multi-level and multi-method data, at the organizational level of analysis.

The main advantage of developing such models is to study the effect of various factors which affect an employment relation between the employee and employer who live in an urban working class social set up. They are educated, mature and thus hold sufficient self-esteem to be confident in presenting their opinion with firmness. Nikolski et al. [11] discussed the distinction between industrial and employment relations. They concluded that employment relations unlike industrial relations are more focussed on individual relationship between employee and employer than the collective ones. The study of interaction of different individuals coupled in the employment system and mathematically modelling them is an important aspect to study the evolution of emotions and growth of different individuals in the corporate sector driven by professionalism and work ethics in principle. The level of authority is limited as observed in the corporate arena but available in adequate amount to be uniformly envisaged between the employee and employer. With passage of time situation arise where both assert their authorities and opinion in accordance to their self-discretion and start affecting each other's emotions depending on reciprocations.

Every argument followed by unsettled grievances intolerance grows which leads to faster exhaustion of faith and respect for each-other's status of equality generating disappointment. Thus decrease in mutual status of equality leads to increase in encounters between both the employer and employee which is used by the intermediates who utilize it to make their position stronger taking advantage. Both the employees and employer may interact through linear or non-linear

interactions in employment relation depending on which the dynamics can be simple or complex respectively. The interaction parameters of the employee-employer relation govern the direction in which the dynamics between them evolves.

These parameters can be controlled in preventing separation of the couple or suppression of any one partner's individual authority at cost of others' dominance and thus conserving the mutual tolerance in the relation by promotion of status of equality in the couple. In direction of understanding the employment relation [17] studied the underlying factors that gives rise to job idiosyncrasies in jobs which required workers to hold non trivial job and task specific skills during the course of employment. It was shown by him that implied demands on the rationality demands limit human actors severely and costs associated with adapting to changing market circumstances and job are considerable jobs of idiosyncratic kind. The significance of implication of conceptualization of company on employee via three models was explained in [12]. Studying the linear stability of nonlinear couple model with two delays analysing characteristic equation [21] observed Hopf bifurcation when sum of delays crossed a critical value. The effect of employment relation and working condition on health inequalities through several psychological, behavioural and physio pathological path ways discussed in [2]. It was observed that management-employee relation in small firms were more satisfactory than large firms due to lower job satisfaction in large firms highlighting the relation of management-employee relation, firm size and job satisfaction [14]. The key factors of employee-employer relationship, its benefits and key role played by job satisfaction in development good employee-employer relation for growth of business was outlined in [18].

After the establishment of mathematical models based on human relation following an interdisciplinary approach in [15] the deviant behaviour observed in employees and employer's corresponding reaction to it was modelled. In this study the deviant behaviour theory and practices were observed by examining the behaviour of employees proposing a series of application to illustrate the usefulness of the mathematical model. In [13] using logistic regression and odd ratios analysed the conjunction of several indicators on employment of citizens in Republic of Macedonia to see the effect of gender, age, ethnicity, education, area of residence and number of family members on employment. At the same time various mathematical models used for studying problem of labour potential particularly describing the stages of process of creation of mathematical model for economic and social systems as whole were discussed in [19]. Recently in [17] it was explored that the organizational structure, efficiency and evolution in perspective of its relationship to bureaucracy are essential in order to construct a mathematical model. The approach used is reminiscent of non-mathematical treatment of organizational system complexity [20]. From the simulation it is revealed that through five stages of development organizations evolve. Marsden [9] explained the diffusion of different employment systems within national economies applying theory of evolutionary games studying their

interaction with established institutions at both national and sectoral levels. In [22] the dynamics of interaction between partners in a marital relation mediated by an intermediate was discussed and studied.

The interactions between the employee and employer mediated by intermediate employee has been modelled in this paper to study how the dynamics evolve between them and growth of mutual intolerance can push the employee-employer relation towards a chaotic phase. Using Lyapunov spectra Marshall and Sprott [10] studied the second-order autonomous and simple conservative chaotic complex variable systems. The significance of using computer simulation for building theories of organization was demonstrated by Lomi and Larsen in [8]. Using different techniques of nonlinear analysis different phases of employee-employer interaction dynamics considering presence of an intermedator have been analysed. The study is significant as in most office interaction system the interaction between the employee and employer are intermediated by some other colleague. It is interesting to see the effect of disappointment level on dynamics of the employee-employer relation in presence of an intermediating colleague.

2. Mathematical model

Let us consider x_e , x_E and x_i represent the emotions of employee, employer and the intermediate colleague in the employee-employer relation. The model is described as follows:

$$\begin{aligned} (1) \quad & \dot{x}_e = c_2x_e - d_2x_E, \\ (2) \quad & \dot{x}_E = c_1x_E - d_1x_e + E_1x_ex_i, \\ (3) \quad & \dot{x}_i = c_3x_i - E_2x_ex_E, \end{aligned}$$

where c_1 =coefficient of compromise of employee

c_2 =coefficient of compromise of employer

c_3 =coefficient of compromise of intermediate colleague

d_1 =coefficient of disappointment of employee

d_2 =coefficient of disappointment of employer

E_1 =coefficient of encounter between employee and intermediate colleague

E_2 =coefficient of encounter between intermediate colleague and employer

The employer and employees belonging to an urban educated working class background in corporate sector are being considered. The employment relation is Pluralist in nature as employment relation relations in corporate sector companies is being discussed where employee is both psychologically and economically complex being with equity and voice as stated by Budd (2004) [5]. Both employer and employee are educated and mature individuals with equal rights to voice their opinion following the official protocols. As individuals they are assumed to have had good brought up and moral upbringing. Ideally education brings self-awareness, realisation, maturity and sensitivity thus employer and employees considered in the system are assumed to possess these qualities however to what extent these quality effect these individuals may vary.

Being self-aware and holding self-esteem both employer and employee are encouraged by each other's emotion while they are more cautious about their own respective emotions. Education, maturity, compatibility and sensitivity restrain them from engaging in disputes. It is the emotions of both individuals which cast effect on each other's state while disputes lose their intensity and negligibly affect them by virtue of the compatibility they share as mature and cautious people. The self-esteem make critic of his or her opinions during compromise affect his/her emotional state negatively. Tolerance however casts positive impact on emotional state of the individual as it makes it easier to understand the emotions of other person. The emotional state of intermediary however is affected by the encounter between the employee and employer positively because it strengthens the discretion of intermediary to make his position stronger.

As every individual is different both the employer and employee have different or same level of tendency to compromise and tolerance for each other. The employer with lower tolerance or realisation is bothered and more casual in their consideration of employee's opinion. Due to this the employer acts as a dominant person while employee serves with commitment and respect. The schematic diagram of the system under study is shown in Figure 1.

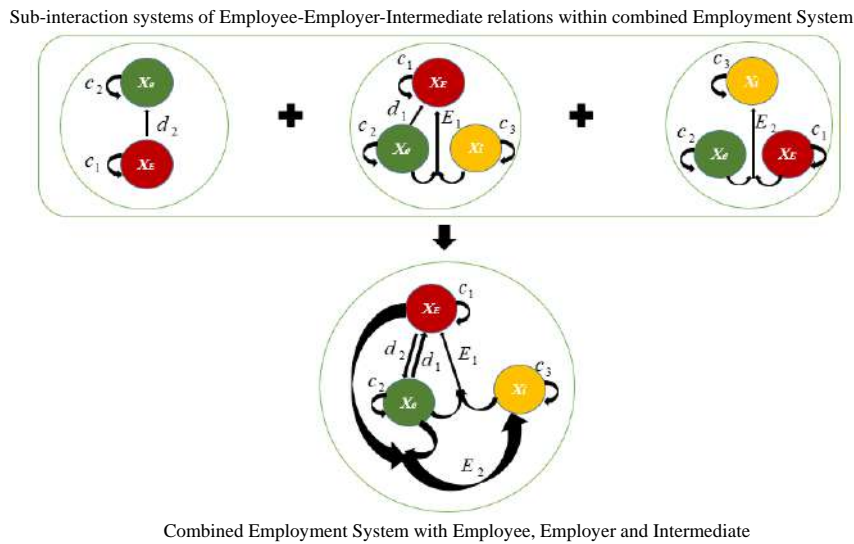


Figure 1: Schematic Diagram of the Employment Relation System under Study

3. Fixed point analysis

For the system $eq^n(1) - (3)$ three fixed points exists which are given as follows:

$$1) (x_e, x_E, x_i) = (0, 0, 0),$$

$$2) (x_e, x_E, x_i) = \left(\sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}}, \frac{c_2}{d_2} \sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}}, \frac{(d_1 d_2 - c_1 c_2)}{d_2 E_1} \right),$$

$$3) (x_e, x_E, x_i) = \left(-\sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}}, -\frac{c_2}{d_2} \sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}}, \frac{(d_1 d_2 - c_1 c_2)}{d_2 E_1} \right).$$

Jacobian of the system is as follows:

$$J = \begin{bmatrix} c_2 & -d_2 & 0 \\ -d_1 + E_1 x_i & c_1 & E_1 x_e \\ -E_2 x_E & -E_2 x_e & c_3 \end{bmatrix}.$$

For $(x_e, x_E, x_i) = (0, 0, 0)$ the Jacobian is as follows:

$$J = \begin{bmatrix} c_2 & -d_2 & 0 \\ -d_1 & c_1 & 0 \\ 0 & 0 & c_3 \end{bmatrix}.$$

For this the characteristic equation is as follows:

$$\lambda^3 + e_1 \lambda^2 + e_2 \lambda + e_3 = 0,$$

where

$$e_1 = -(c_1 + c_2 + c_3), e_2 = (c_1 c_2 + c_2 c_3 + c_1 c_3 - d_1 d_2), e_3 = -c_3 (d_1 d_2 - c_1 c_2).$$

From Routh-Hurwitz criteria for stability $e_1 > 0, e_3 > 0$ and $e_1 e_2 - e_3 > 0$. Thus, for stability of $(x_e, x_E, x_i) = (0, 0, 0)$ it is required that $d_1 < (\frac{c_1 c_2}{d_2}) = d_0$.

For fixed points

$$(x_e, x_E, x_i) = \left(\sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}}, \frac{c_2}{d_2} \sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}}, \frac{(d_1 d_2 - c_1 c_2)}{d_2 E_1} \right)$$

and

$$(x_e, x_E, x_i) = \left(-\sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}}, -\frac{c_2}{d_2} \sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}}, \frac{(d_1 d_2 - c_1 c_2)}{d_2 E_1} \right),$$

both show invariance and have same behaviour and conditions of stability. For them the Jacobian is as follows:

$$J = \begin{bmatrix} c_2 & -d_2 & 0 \\ -d_1 + E_1 \left(\frac{(d_1 d_2 - c_1 c_2)}{d_2 E_1} \right) & c_1 & E_1 \left(\sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}} \right) \\ -E_2 \left(\frac{c_2}{d_2} \sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}} \right) & -E_2 \left(\sqrt{\frac{(d_1 d_2 - c_1 c_2) c_3}{c_2 E_2 E_1}} \right) & c_3 \end{bmatrix}.$$

For this the characteristic equation is as follows:

$$\lambda^3 + e_1\lambda^2 + e_2\lambda + e_3 = 0,$$

where

$$e_1 = -(c_1 + c_2 + c_3), e_2 = \left(c_2c_3 + \frac{d_1d_2c_3}{c_2} \right), e_3 = -2c_3(d_1d_2 - c_1c_2).$$

Thus, for their stability it is required that

$$\left(\frac{c_1c_2}{d_2} \right) < d_1 < \left(\frac{2c_1c_2^2 + c_2^2(c_1 + c_2 + c_3)}{d_2(2c_2 - (c_1 + c_2 + c_3))} \right).$$

4. Results and discussion

Numerical simulation of the above system was carried out for different values of the parameters. The factors on which the parameter values depend upon and the relation through which they have been obtained are as follows:

1. Coefficient of compromise depends on ego and adjustability. The value of coefficient of compromise is determined by following relation:

$$c_i = ego \times W_{ego} - adjustability \times W_{adjustability}$$

2. Coefficient of disappointment depends on self-esteem, maturity and submissiveness of individual. The value of coefficient of disappointment is determined by following relation:

$$d_i = self - esteem \times W_{self - esteem} + maturity \times W_{maturity} \\ + intolerance \times W_{intolerance}$$

3. Coefficient of encounter depend on encounter intensity and given by following relation:

$$E_i = encounter\ intensity \times W_{encounter\ intensity}$$

The different weights (W) attain value as per the following Table1 where the levels of impact of the factors and their weight values are mentioned.

The coefficient of compromise for employee, employer and intermediary for the considered model are determined as follows:

1. The employee is benevolent and loyal to employer he/she has no ego. Employee's tendency to adjust affects his/her discretion up to level of consideration but self-respect restrains it from reaching the level of action.

$$c_2 = ego \times W_{ego} - adjustability \times W_{adjustability} \\ = 1 \times 0 - 1 \times 3 \\ = -3$$

Table 1: Levels of impact of the factors and their weight values

Level 1: Effect	Level 2: Influence	Level 3: Motivating Consideration	Level 4: Motivating Action	Weight Value
No	No	No	No	0
Yes	No	No	No	1
Yes	Yes	No	No	2
Yes	Yes	Yes	No	3
Yes	Yes	Yes	Yes	4

2. The employer being at the top position has ego up to the level of affecting his/her discretion and has lower adjustability as compared to employee.

$$\begin{aligned}
 c_1 &= ego \times W_{ego} - adjustability \times W_{adjustability} \\
 &= 1 \times 1 - 1 \times 2 \\
 &= -1
 \end{aligned}$$

3. The intermediate colleague has no ego as he or she is not involved in the relation directly but mediate externally by advising. But being an intermediate employee he/she has adjustability up to the level of effecting his/her emotions.

$$\begin{aligned}
 c_3 &= ego \times W_{ego} - adjustability \times W_{adjustability} \\
 &= 1 \times 0 - 1 \times 1 \\
 &= -1
 \end{aligned}$$

The employee and employer both has education and so their self-esteem motivate actions. Three cases may arise depending on how maturity and intolerance affects employee mentioned as follows:

Case 1. Both employee and employer hold self-esteem and their maturity affects their emotion but none is intolerant at the time of argument and give equal weightage to each other's opinion.

$$\begin{aligned}
 d_{i=1,2} = d &= self - esteem \times W_{self-esteem} + maturity \times W_{maturity} \\
 &\quad + intolerance \times W_{intolerance} \\
 &= 1 \times 4 + 1 \times 1 + 1 \times 0 \\
 &= 5
 \end{aligned}$$

Case 2. Both employee and employer are submissive but their intolerance start affecting their emotions. Thus despite of giving space to each other's opinion

but they present their outlook firmly without accepting much change.

$$\begin{aligned}
 d_{i=1,2} = d &= self - esteem \times W_{self-esteem} + maturity \times W_{maturity} \\
 &\quad + intolerance \times W_{intolerance} \\
 &= 1 \times 4 + 1 \times 1 + 1 \times 1 \\
 &= 6
 \end{aligned}$$

Case 3. The intolerance of both is at peak affecting his/her action and thus there are disputes, misunderstanding and grievance.

$$\begin{aligned}
 d_{i=1,2} = d &= self - esteem \times W_{self-esteem} + maturity \times W_{maturity} \\
 &\quad + intolerance \times W_{intolerance} \\
 &= 1 \times 4 + 1 \times 1 + 1 \times 4 \\
 &= 9
 \end{aligned}$$

The value of coefficient of interaction are as follows:

1. The encounter between both the employee and employer positively influence the intermediate colleague's emotion to make his position stronger in institution.

$$\begin{aligned}
 E_2 &= encounter\ intensity \times W_{encounter\ intensity} \\
 &= 1 \times 1 \\
 &= 1
 \end{aligned}$$

2. The encounter between the intermediate colleague and employee negatively affects the emotions of employer who desires his/her employees to work with efficiency and not involve in disputes wasting time.

$$\begin{aligned}
 E_1 &= encounter\ intensity \times W_{encounter\ intensity} \\
 &= 1 \times 2 \\
 &= 2
 \end{aligned}$$

The phase portrait, time series and plot of Lyapunov exponent for:

- Case 1 ($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 5, d_2 = 5, E_1 = 2, E_2 = 1$):
- Case 2 ($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 6, d_2 = 6, E_1 = 2, E_2 = 1$);
- Case 3 ($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 9, d_2 = 9, E_1 = 2, E_2 = 1$)

are shown in Figure 2, 3 and 4 respectively. In Figure 5 and 6 the bifurcation diagrams for variation in and have been shown.

Case 1. ($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 5, d_2 = 5, E_1 = 2, E_2 = 1$). When both employee and employer display zero level of intolerance by virtue of education the stable phase of employee-employer relation exists. This is the starting phase of the dynamics between the employer and employee where the education plays significant role in determining the level of understanding they display to one another. As it is the starting era maturity affect both the employer and employee. Thus none of them is intolerant to others view instead they give equal weightage to each other's opinion. Both share equity and have positive emotion levels despite of encounters and mediation by intermediate colleague which doesn't affect the dynamics much.

Case 2. ($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 6, d_2 = 6, E_1 = 2, E_2 = 1$). When both the employer and employee begin to get affected by intolerance towards each other's opinion their relation enter critical phase. The employer being dominant and at the top most position no more give weightage to the opinion of employee even if he/she allows employee to present their opinion without hesitation. The compromising employee on the other hand starts getting affected by this treatment from the employer and thus in return begins disregarding the employer's decision. This leads to continuous oscillations in the emotions of the employer and employee. Development of grudge or grievance between the employee and employer begin to occur which doesn't allow restoration of stability. This is the middle phase of the employee-employer relation dynamics where both start getting affected by intolerance towards each other's opinion leading to misunderstanding and thus the stability in the relation doesn't tend to restore. While the employee and employer undergo oscillations in their emotions in negative domain the intermediate continue to have emotions in positive domains. The intermediate thus continues to maintain his/her position with aspirations to make it stronger with the weakening of employee's stature.

Case 3. ($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 9, d_2 = 9, E_1 = 2, E_2 = 1$). When the mutual intolerance of employee and employer further extend to the level of motivating their action then disputes and misunderstanding occurs causing grievance to both of them. Thus the oscillations in emotions become chaotic for employer and employer with their relation enter chaotic phase. The emotions of the intermediate continue to be positive and he/she now holds stronger position than employee with the employer and employee turning completely intolerant towards each other. From the bifurcation plot in Figure 5 for variation in $d_1 = d_2 = d$ parameter all the three stages of employment dynamics are clearly observed. The critical value observed through bifurcation diagram for variation in $d_1 = d_2 = d$ is 5.26 while the value obtained from fixed point analysis is also 5.26 as per the relation

$$d_1 < \left(\frac{2c_1c_2^2 + c_2^2(c_1 + c_2 + c_3)}{d_2(2c_2 - (c_1 + c_2 + c_3))} \right).$$

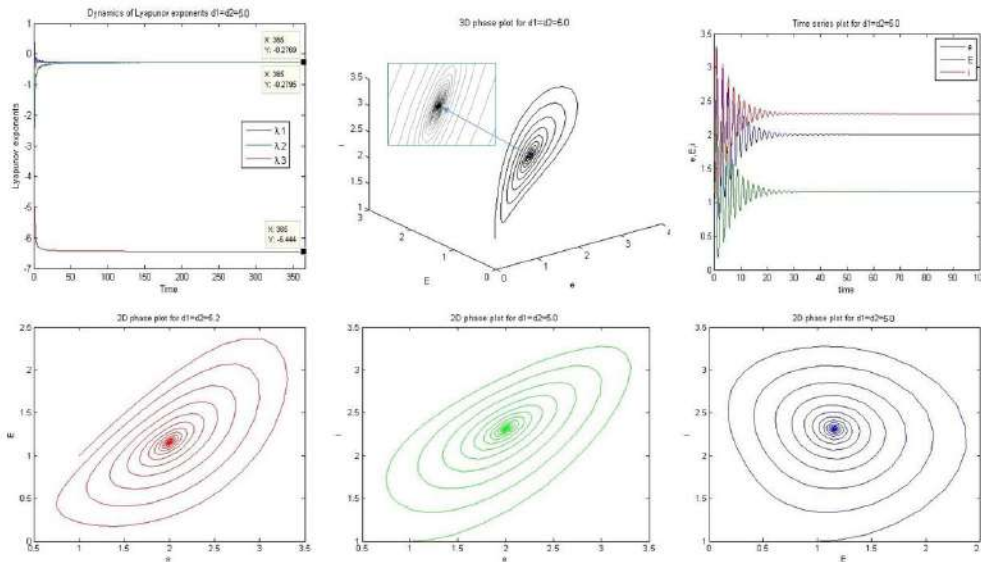


Figure 2: 3D and 2D Phase Plots, Time series Plot, Lyapunov Exponent Plot for Case 1($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 5, d_2 = 5, E_1 = 2, E_2 = 1$), Stable Phase

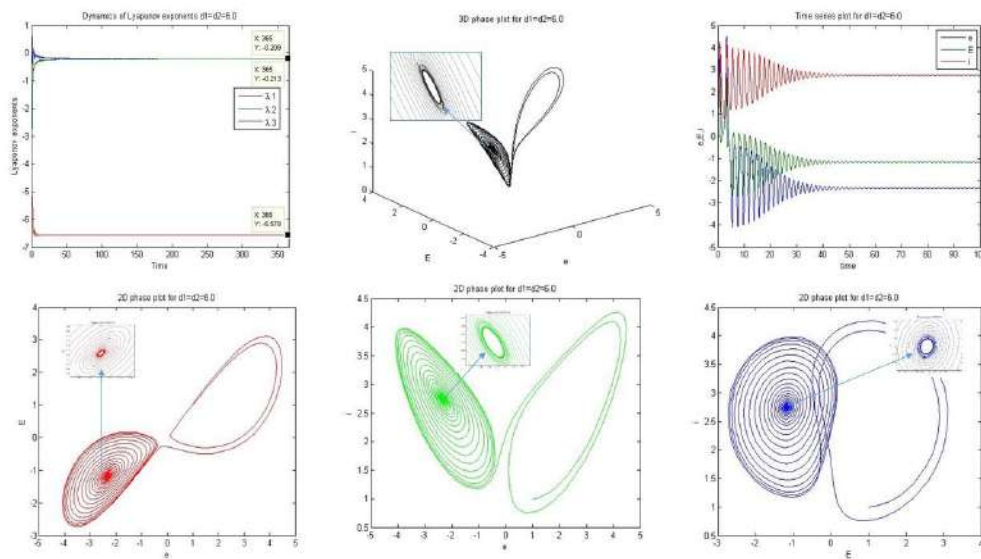


Figure 3: 3D and 2D Phase Plots, Time series Plot, Lyapunov Exponent Plot for Case 1($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 6, d_2 = 6, E_1 = 2, E_2 = 1$), Critical Phase

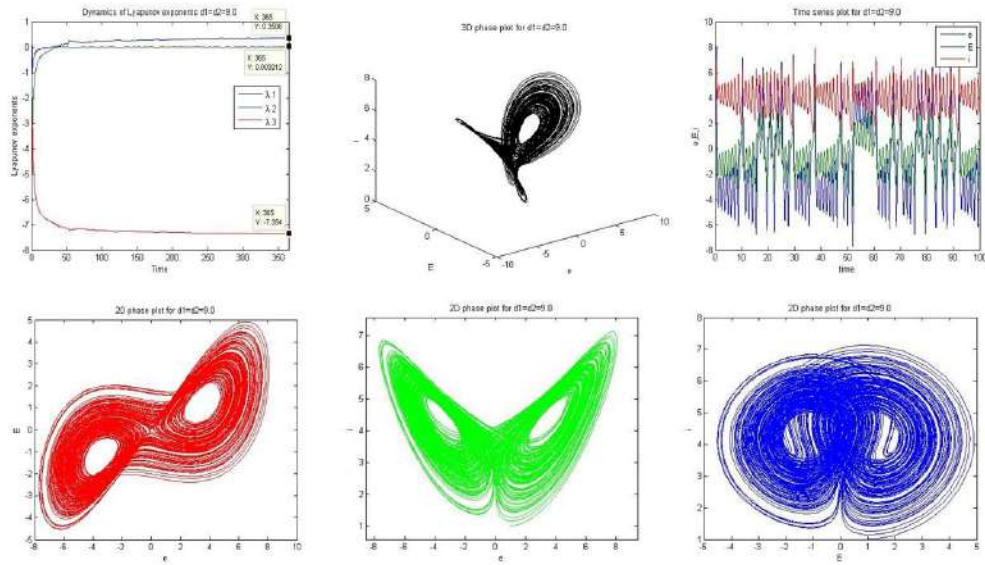


Figure 4: 3D and 2D Phase Plots, Time series Plot, Lyapunov Exponent Plot for Case 1($c_1 = -1, c_2 = -3, c_3 = -1, d_1 = 9, d_2 = 9, E_1 = 2, E_2 = 1$),, Chaotic Phase

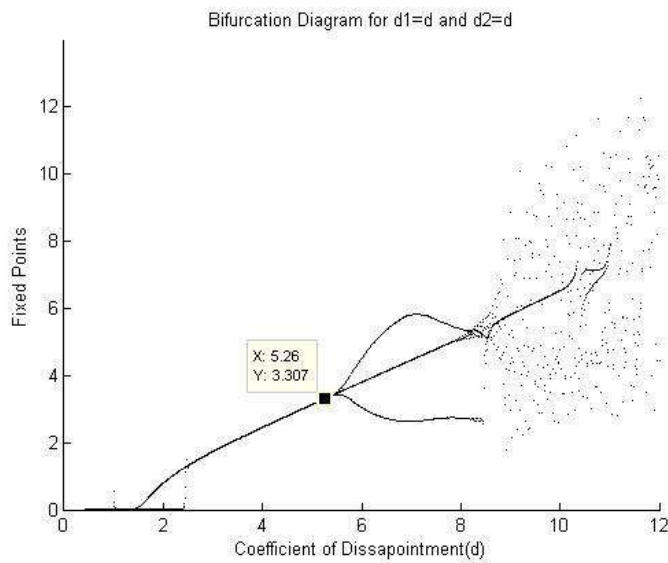


Figure 5: Bifurcation diagram for variation in $d_1=d_2=d$ parameter

In case of employee and employer having unequal level of disappointment and intolerance then it is observed that if employee has more intolerance then system enters chaotic phase faster as evident from bifurcation plot in Figure 6.

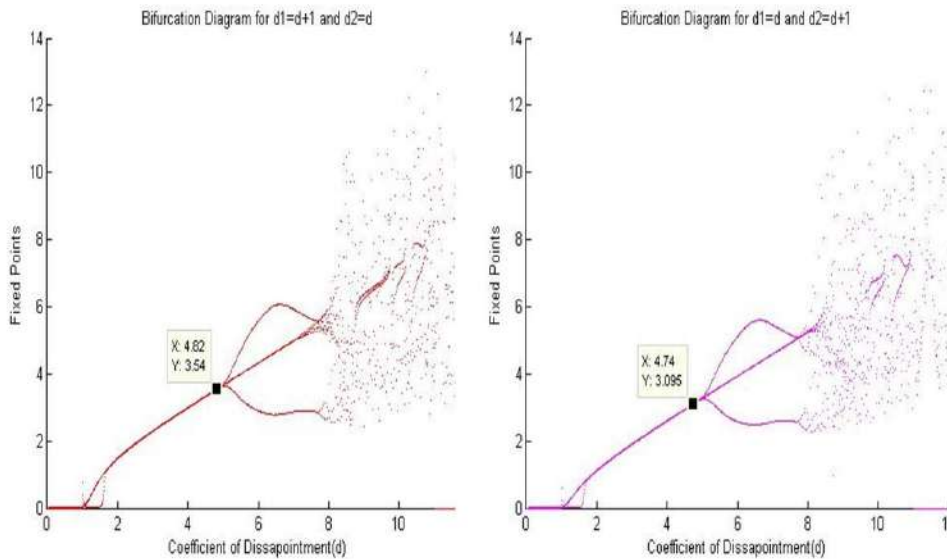


Figure 6: Bifurcation diagram for variation in unequal level of coefficient of disappointment

5. Conclusion

In this paper the pluralist employment relation in a corporate system has been modelled. From stability analysis the conditions between the parameters for the stability of system has been determined. The validity of the condition has been verified from Phase plots, Lyapunov plots and Bifurcation plots obtained from simulation of system at different parameter values. The stable, critical and chaotic stages has been observed with variation in levels of disappointment level of both the employee and employer. When employee and employer hold unequal amount of disappointment then the system transits to chaos faster if employee has more disappointment than employer. It is concluded that if employee holds more tolerance then the relation between employee and employer sustain despite of intermediate colleague mediating their interactions.

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