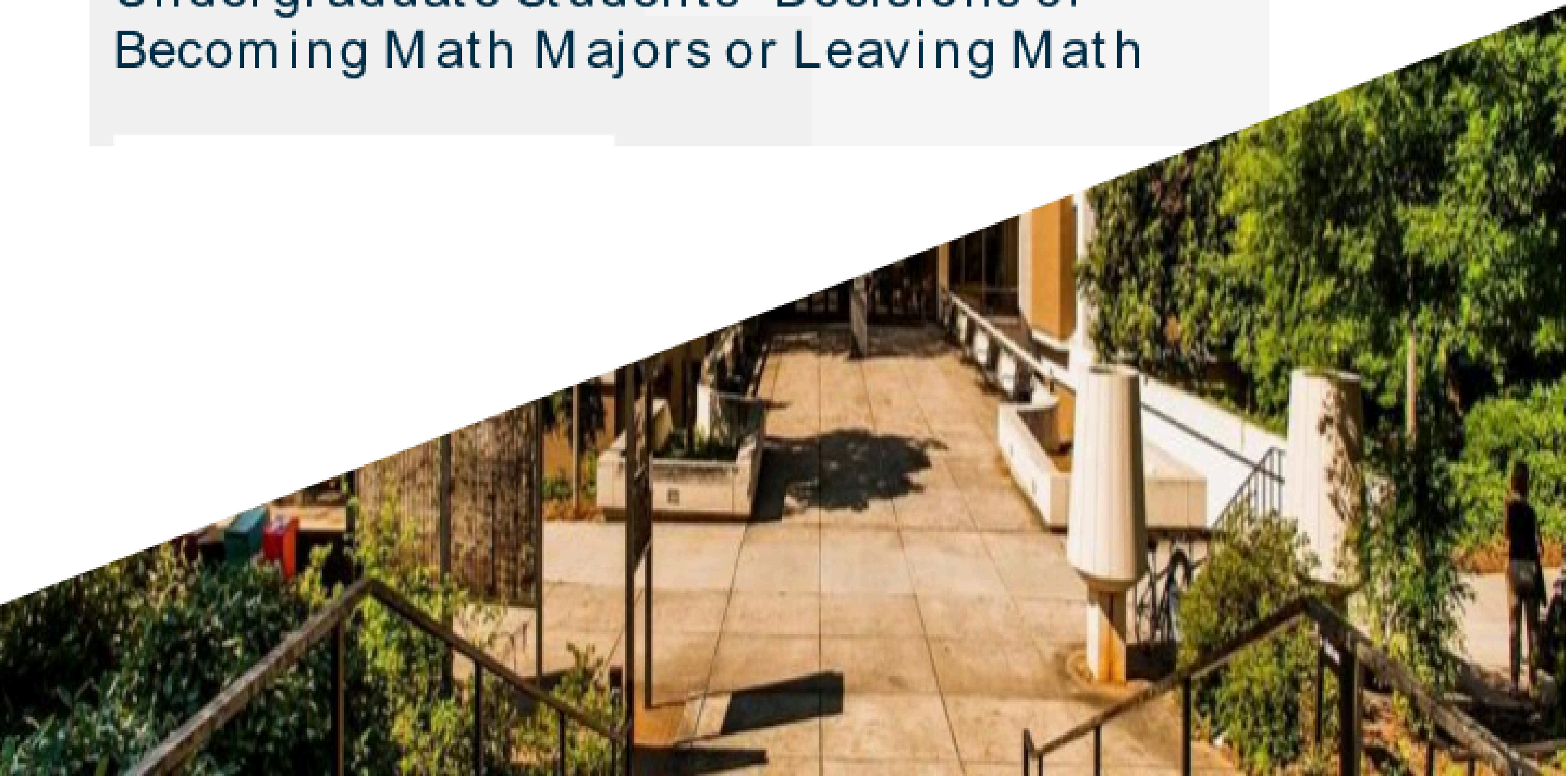
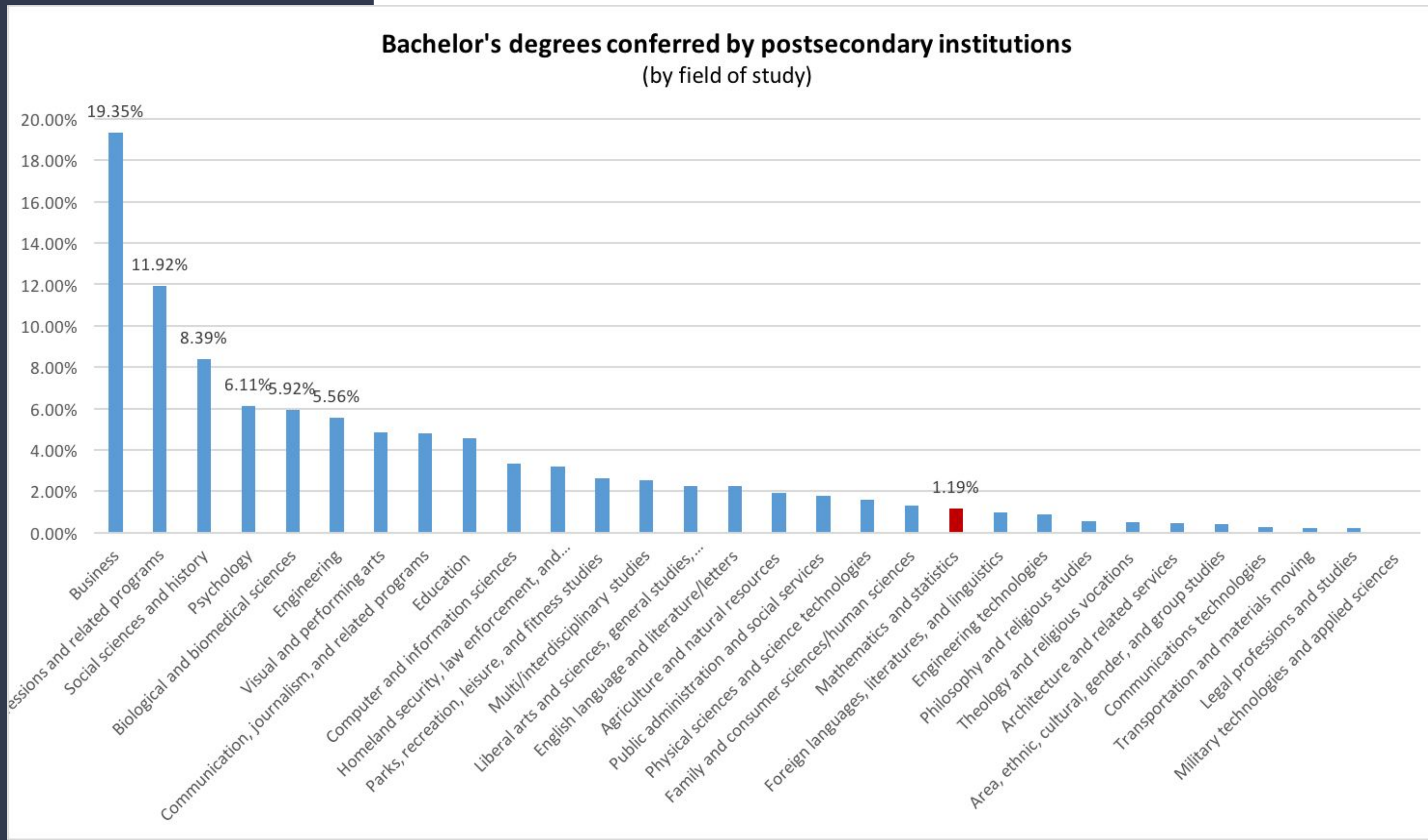
The Dynamic Effects of Peer Influences on Undergraduate Students' Decisions of Becoming Math Majors or Leaving Math



Motivation

Approximately 22,000 college students graduate each year with bachelor's degrees in mathematics and/or statistics, verus:

- 370,000 Business
- 161,000 Social Science
- 117,000 Psychology
- 110,000 Biology
- 106,000 Engineering

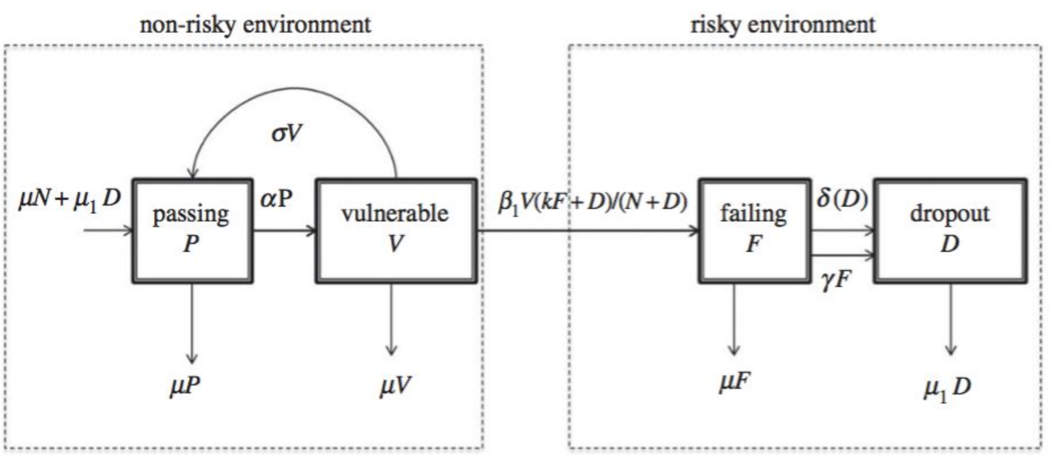


Learning from a previous model (Amdouni, Paredes, Kribs, & Mubayi, 2017)

Last year, the Royal Society of London published a paper by Bechir Amdouni, Marlio Paredes, Christopher Kribs, and Anuj Mubayi, entitled **“Why do students quit school? Implications from a dynamical modelling study.”**

The study aims at modelling the dynamics of high school student dropout populations. Specifically, they looked at **how parental involvement and social interactions with peers affect students’ academic performance**.

They had already established that **the positive or negative social influences of students’ peers grades and opinions about school could be modelled with parameters**.

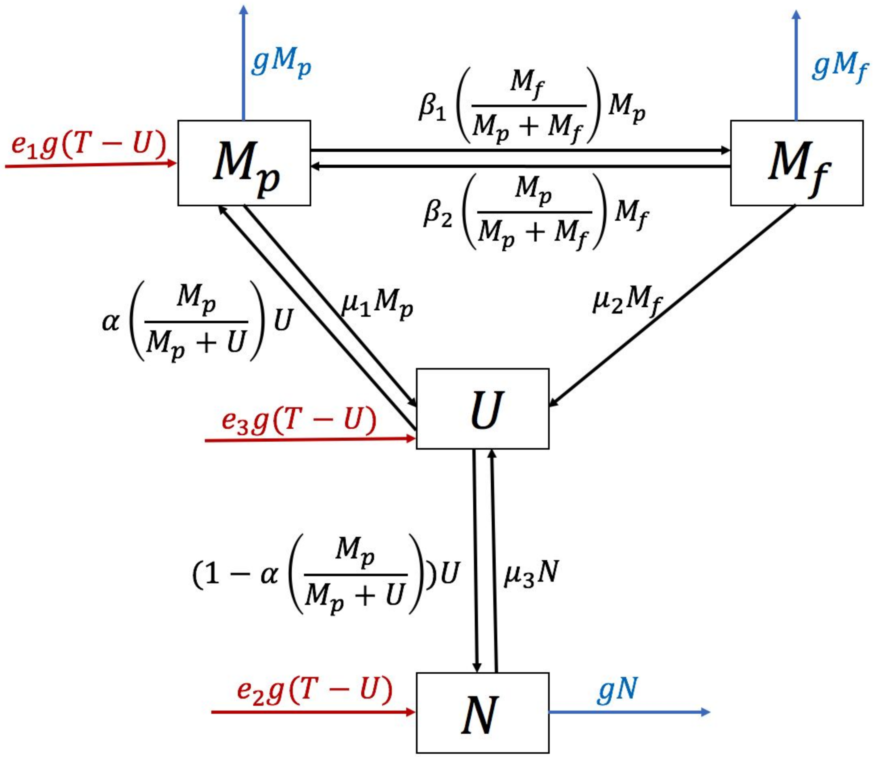


Our Research Question

How do peer interactions in college influence undergraduate students' decisions to join or leave a mathematics degree program?

Our Model: Variables

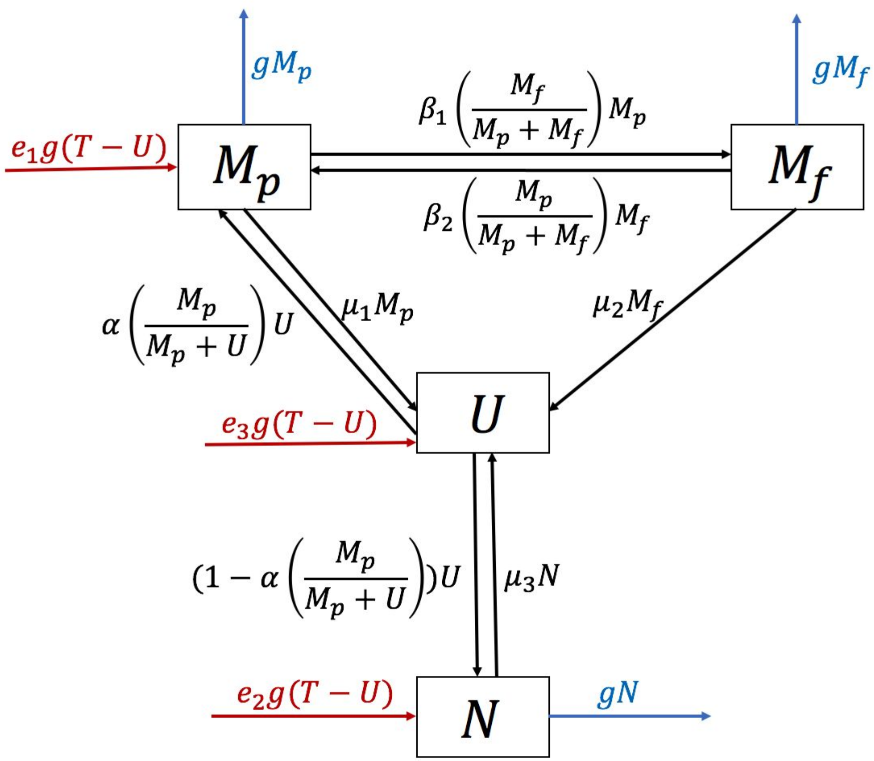
Variable	Definition
T	Total number of UGA undergraduate students (constant; T≈28,000)
M	Number of UGA undergraduate students majoring in mathematics
Mp	Number of mathematics majors who pass all math courses
Mf	Number of mathematics majors who fail at least one math course
U	Number of UGA undergraduate students with unspecified major or students who are thinking about leaving their original program
N	Number of UGA undergraduate students majoring in other subjects (i.e., non-math majors)



Our Model: Parameters

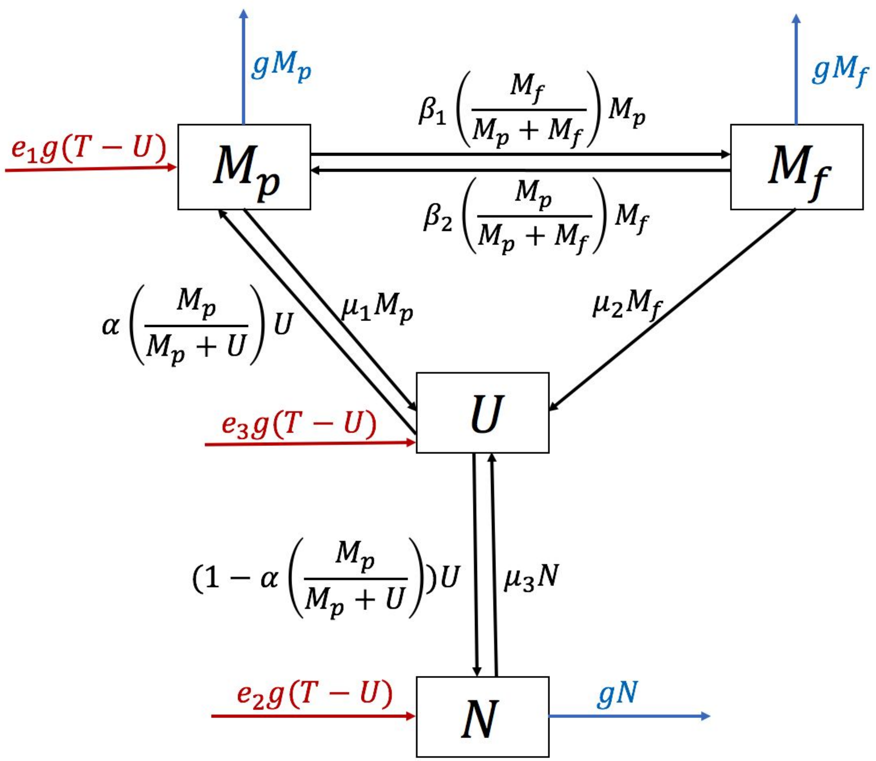
	Definition	Unit	Value
1/g	average number of years a typical college student stay in the school	year	4
e1	probability of freshmen deciding to major in mathematics	dim.-less	0.03
e2	probability of freshmen having unspecified majors	dim.-less	0.84
e3	probability of freshmen deciding to major in non-math subjects	dim.-less	0.13

g(T-U)=g(Mp+Mf+N)
e1+e2+e3=1



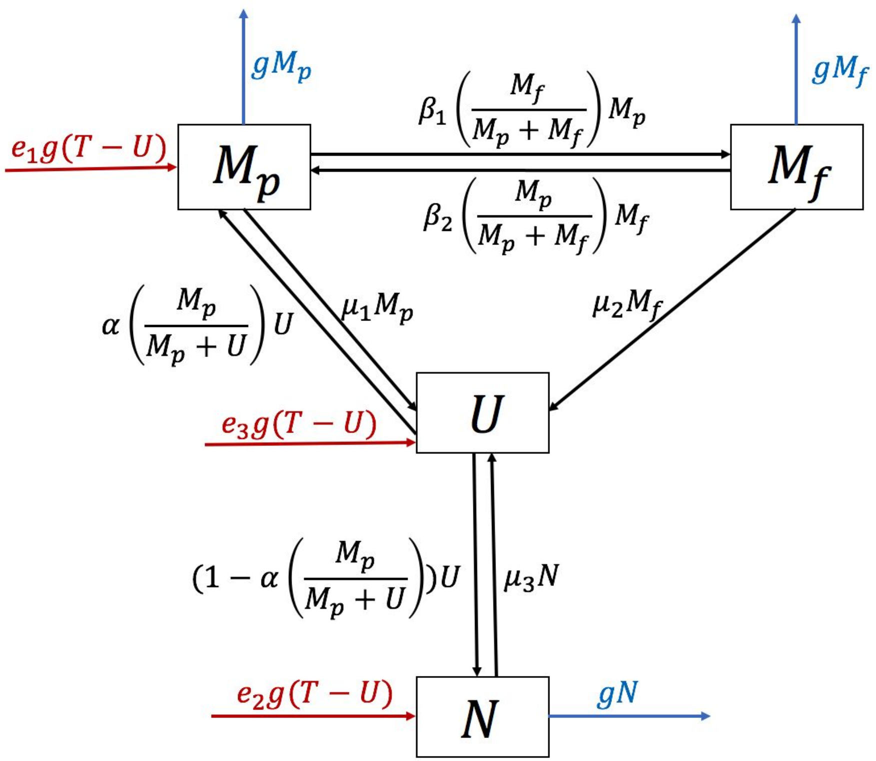
Our Model: Parameters

	Definition	Unit	Value
μ1	per capita rate of math passing students who are thinking about leaving math majors due to personal reasons	1/year	0.013
μ2	per capita rate of math failing students who are thinking about leaving math majors due to personal reasons	1/year	0.125
μ3	per capita rate of thinking about leaving non-math majors due to personal reasons	1/year	0.02



Our Model: Parameters

	Definition	Unit	Value
α	transmission efficiency (i.e., average effective social influences) of math passing students (Mp) on undecided students (U)	1/year	0.4
β1	transmission efficiency (i.e., average effective negative influences) of math failing students (Mf) on math passing students (Mp)	1/year	0.75
β2	transmission efficiency (i.e., average effective positive influences) of math passing students (Mp) on math failing students (Mf)	1/year	0.3



Our Model: The ODE System

$$\frac{dM_p}{dt} = e_1 g(1-U) + \alpha \frac{M_p}{M_p+U} U + \beta_2 \frac{M_p}{M_p+M_f} M_f - (gM_p + \beta_1 \frac{M_f}{M_p+M_f} M_p + \mu_1 M_p)$$

$$\frac{dM_f}{dt} = \beta_1 \frac{M_f}{M_p+M_f} M_p - (gM_f + \beta_2 \frac{M_p}{M_p+M_f} M_f + \mu_2 M_f)$$

$$\frac{dN}{dt} = e_2 g(1-U) + (1 - \alpha \frac{M_p}{M_p+U}) U - (\mu_3 N + gN)$$

$$\frac{dU}{dt} = e_3 g(1-U) + \mu_1 M_p + \mu_2 M_f + \mu_3 N - U$$

Initial Conditions

Mp(t=0)=.7e1=0.021

Mf(t=0)=.3e1=0.009

N(t=0)=e2=0.84

U(t=0)=e3=0.13

Fixed Point and Stability Analysis

After assigning the estimated parameter values, we found the following fixed points:

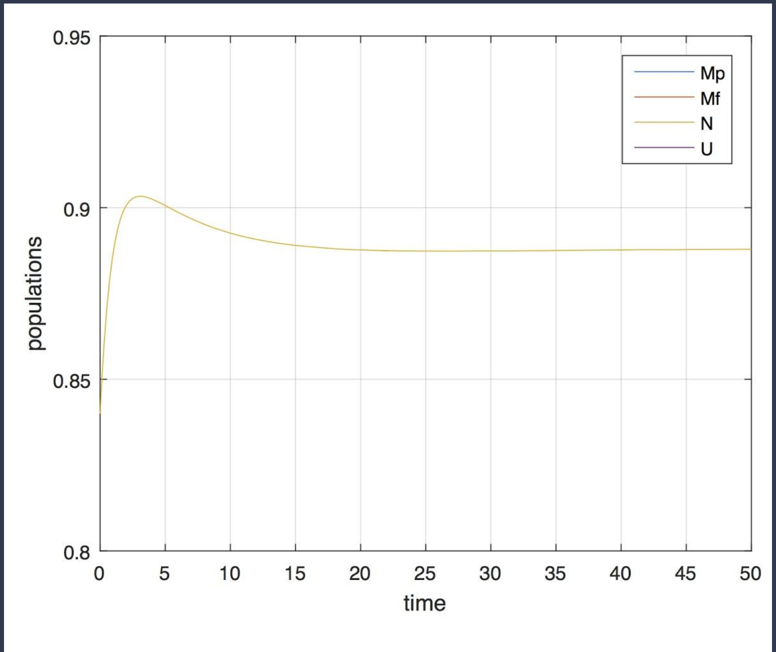
(Mp*, Mf*,N*,U*)=
(0.0716, 0, 0.8790, 0.0494),
(-0.0188, 0, 0.9688, 0.05),
(-0.0206, -0.0041,0.9751, 0.0496),
(0.0512, 0.0102, 0.8880, 0.0506)

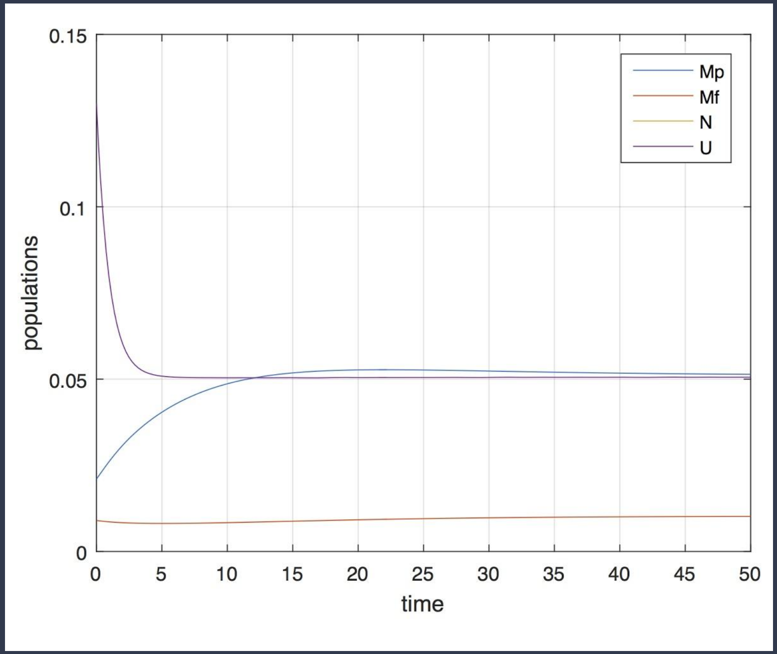
By using the Jacobian matrix of our ODE, we calculated the eigenvalues and determined the fixed point stability:

(Mp*, Mf*,N*,U*)=(0.0716, 0, 0.8790, 0.0494) is unstable.

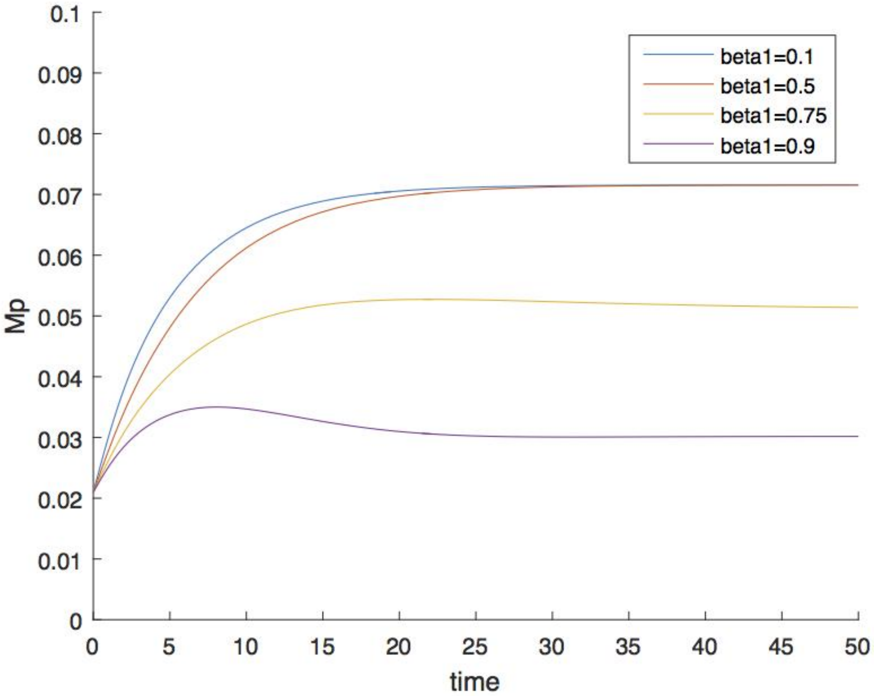
(Mp*, Mf*,N*,U*)=(0.0512, 0.0102, 0.8880, 0.0506) is stable.

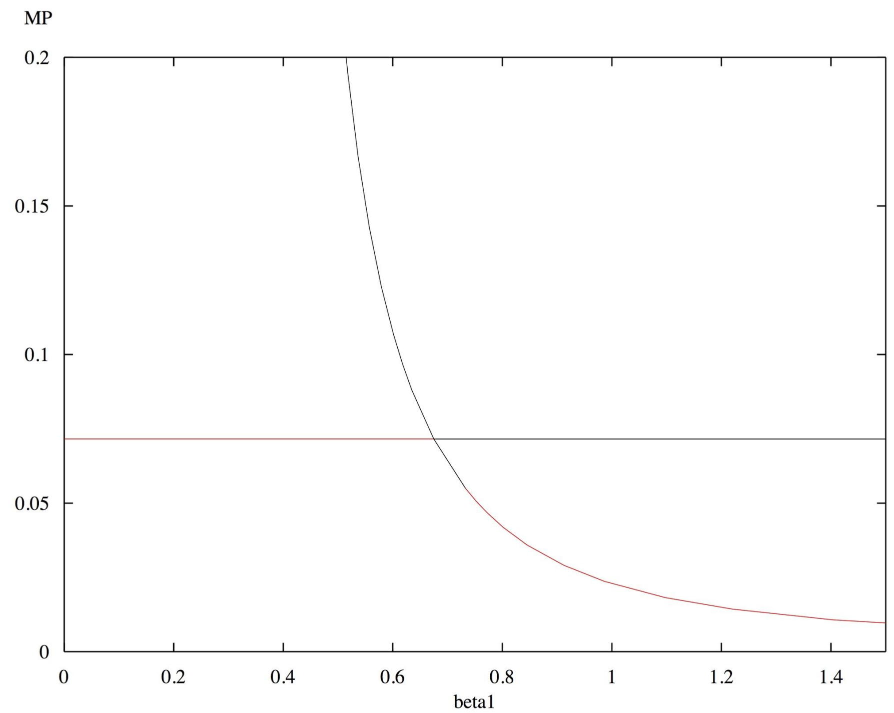
Simulation


0.95
0.9
0.85
0.8
populations
0
5
10
15
20
25
30
35
40
45
50
time
Mp
Mf
N
U


0.15
0.1
0.05
0
populations
0
5
10
15
20
25
30
35
40
45
50
time
Mp
Mf
N
U

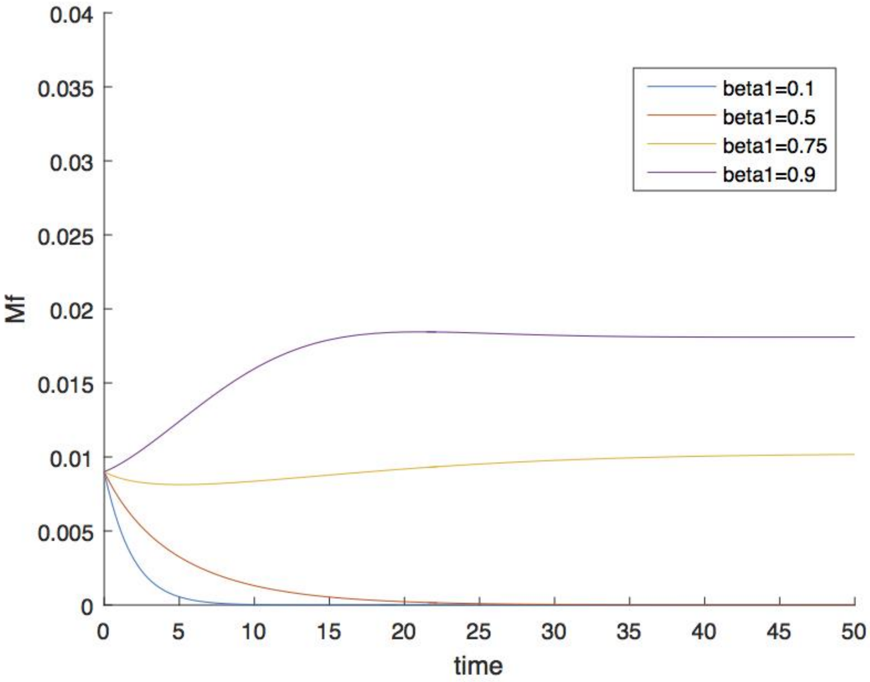
Effects of Beta1 (i.e., negative influences of Mf on Mp)

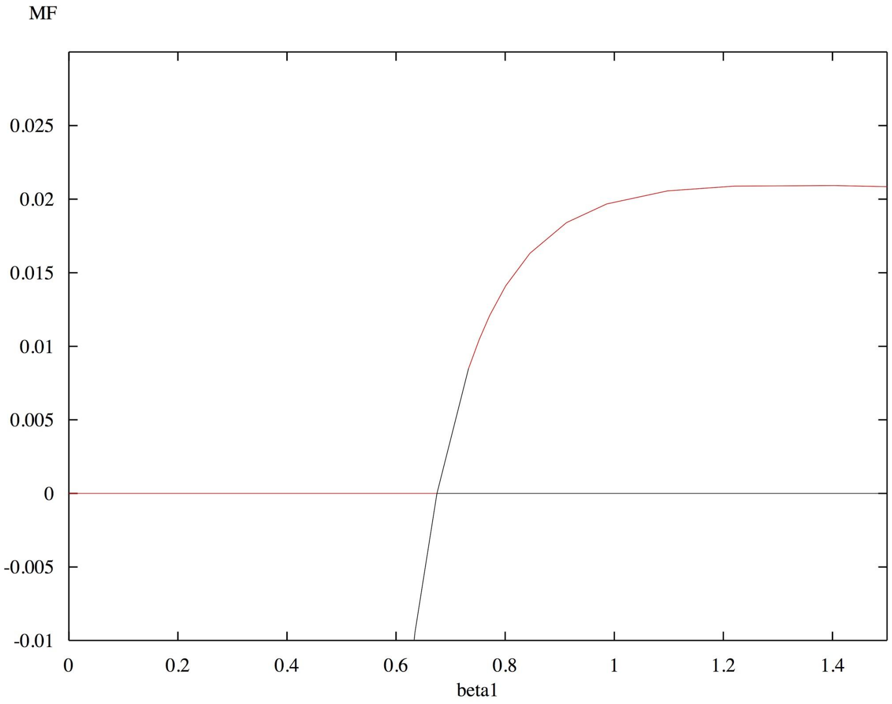




Time plot of Mp vs. time and bifurcation diagram of Mp vs. beta 1 (transmission efficiency of math failing students (Mf) on math passing students (Mp))

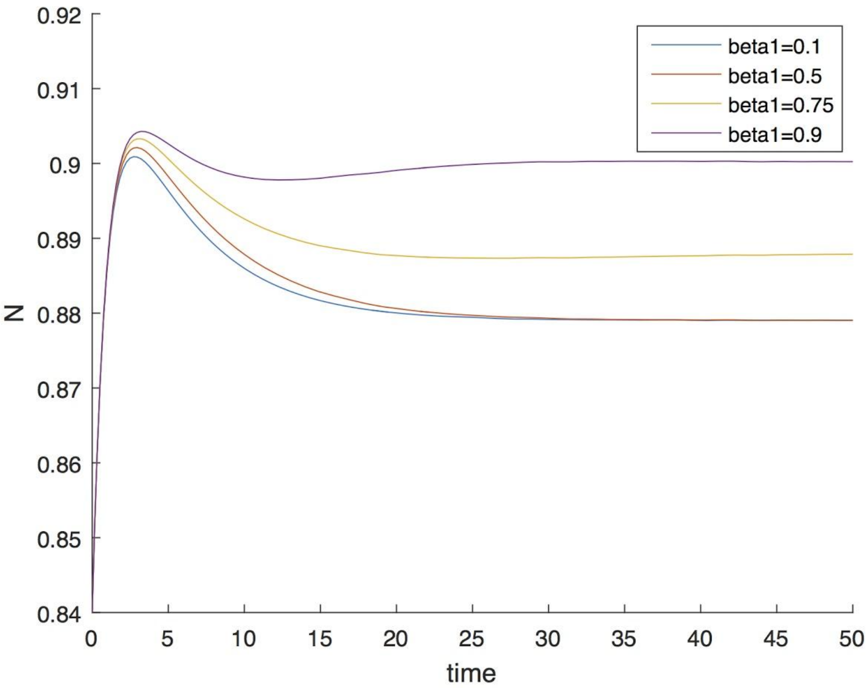
Effects of Beta1 (i.e., negative influences of Mf on Mp)

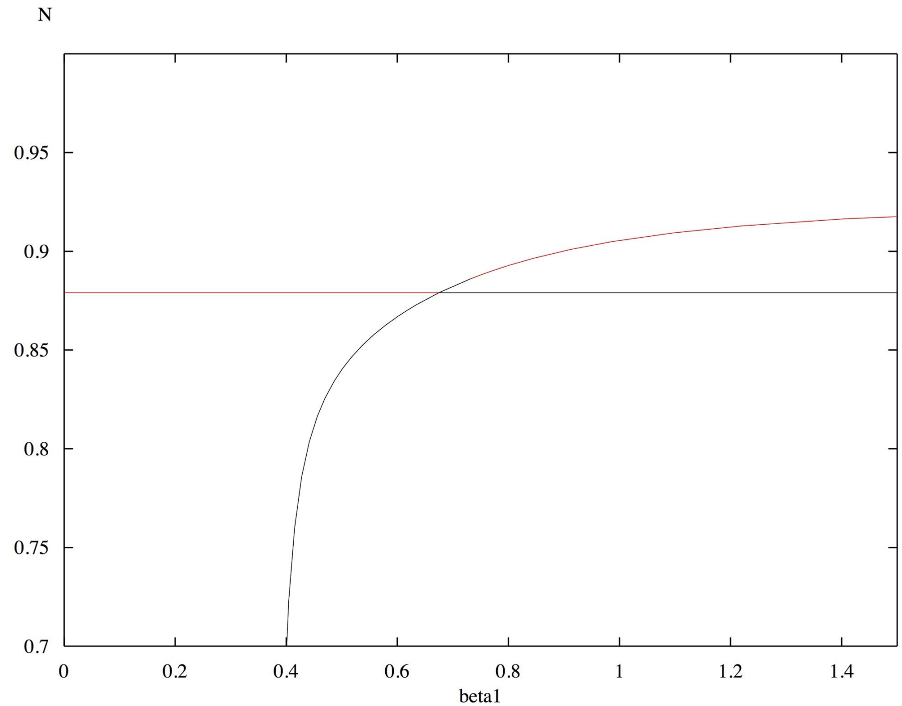




Time plot of Mf vs. time and bifurcation diagram of Mf vs. beta 1.

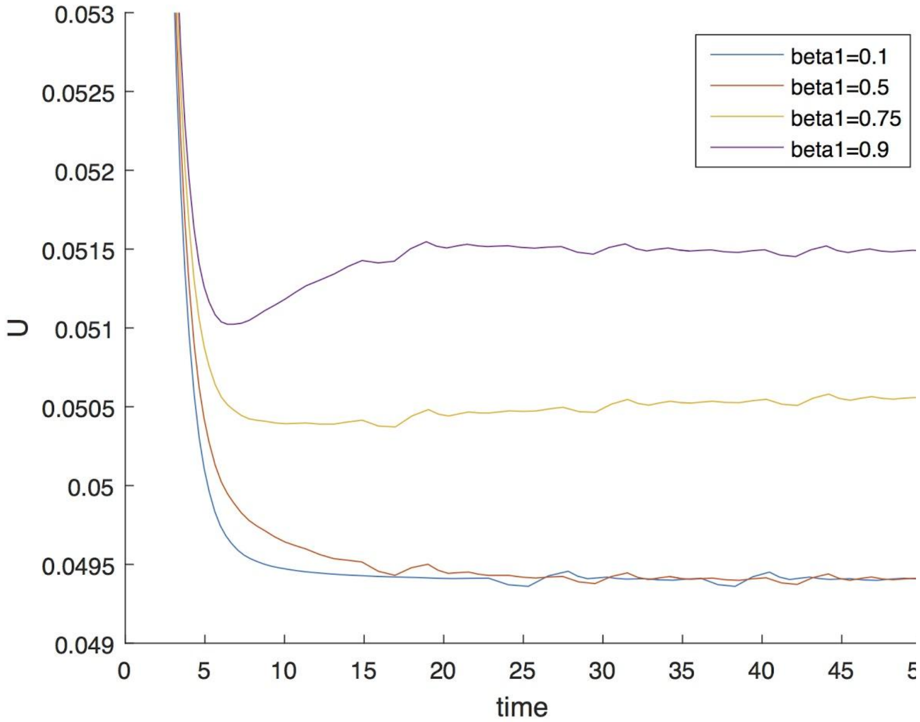
Effects of Beta1 (i.e., negative influences of Mf on Mp)

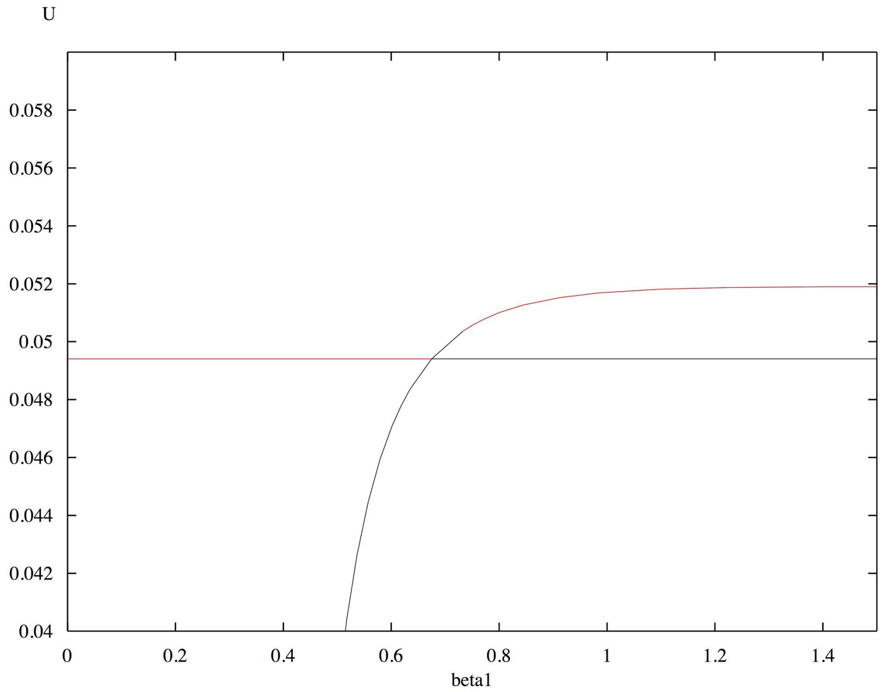




Time plot of N vs. time and bifurcation diagram of N vs. beta 1.

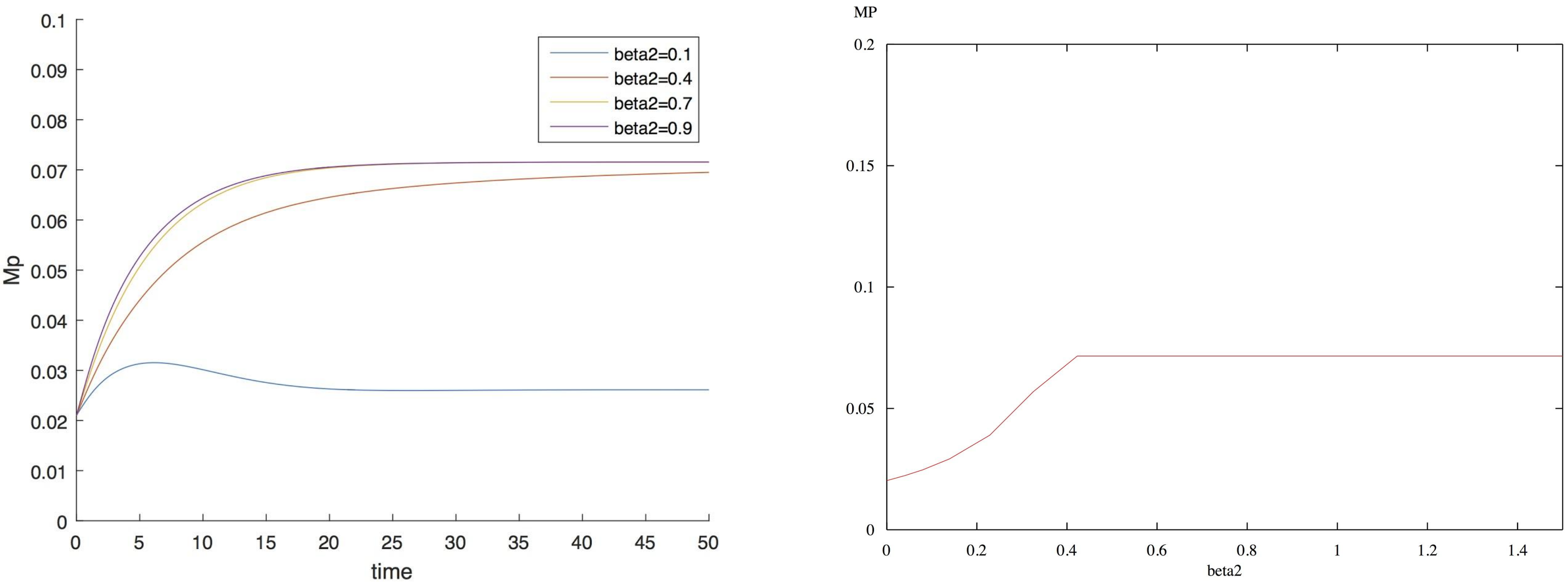
Effects of Beta1 (i.e., negative influences of Mf on Mp)





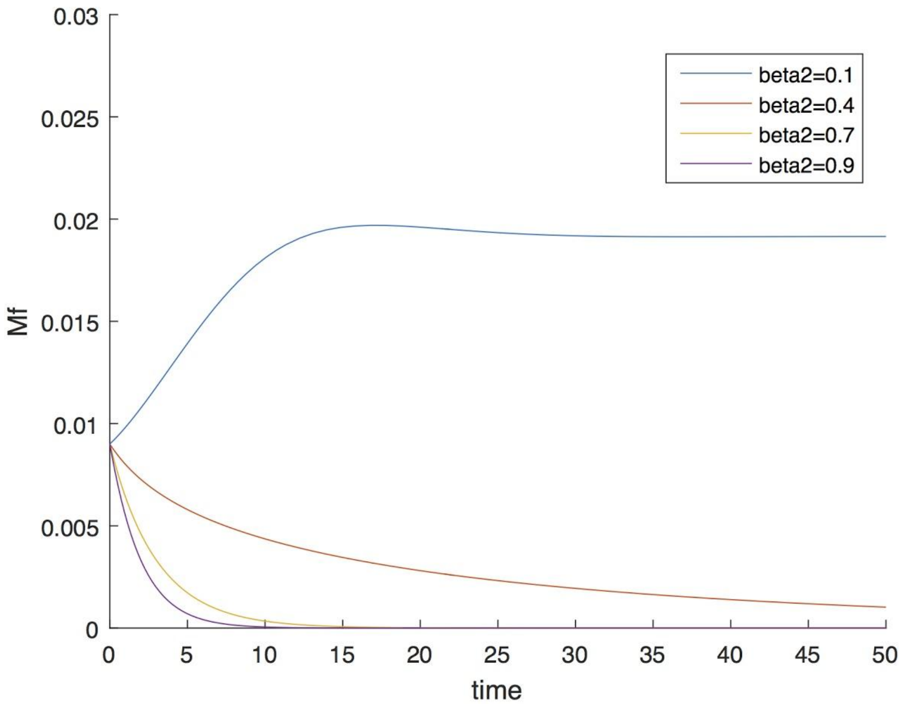
Time plot of U vs. time and bifurcation diagram of U vs. beta 1.

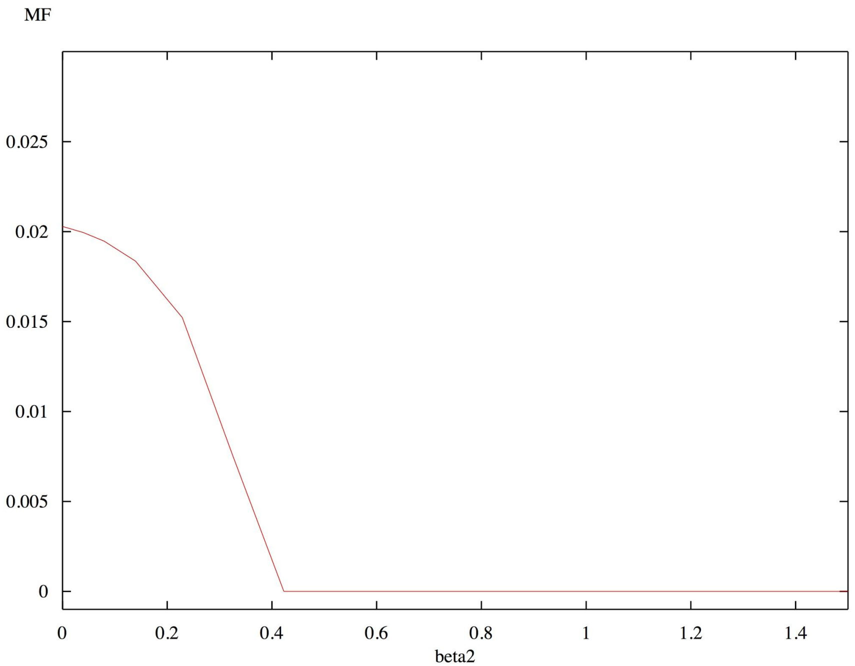
Effects of Beta2 (i.e., positive influences of Mp on Mf)



Time plot of Mp vs. time and bifurcation diagram of Mp vs. beta 2 (transmission efficiency of math passing students (Mp) on math failing students (Mf))

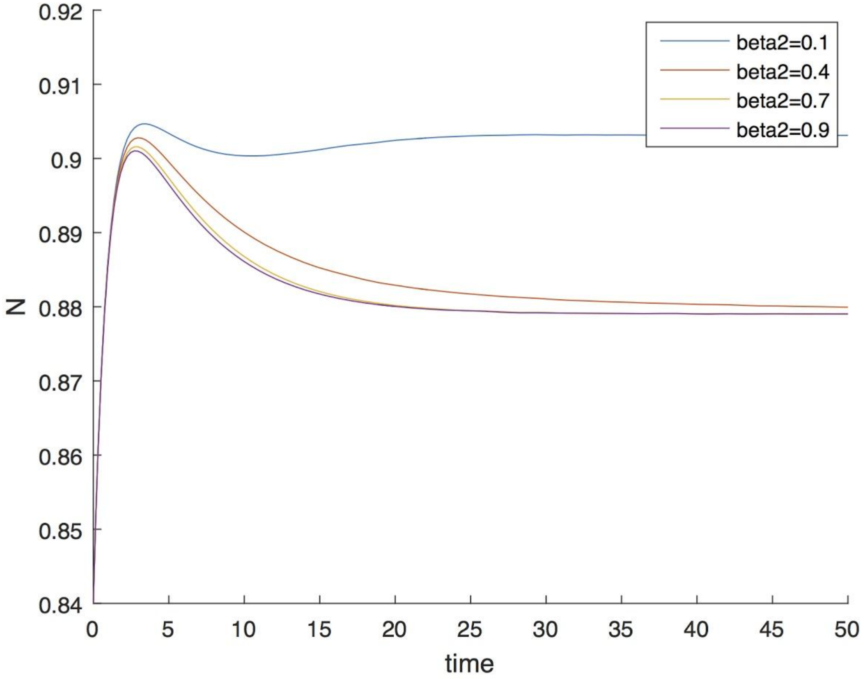
Effects of Beta2 (i.e., positive influences of Mp on Mf)

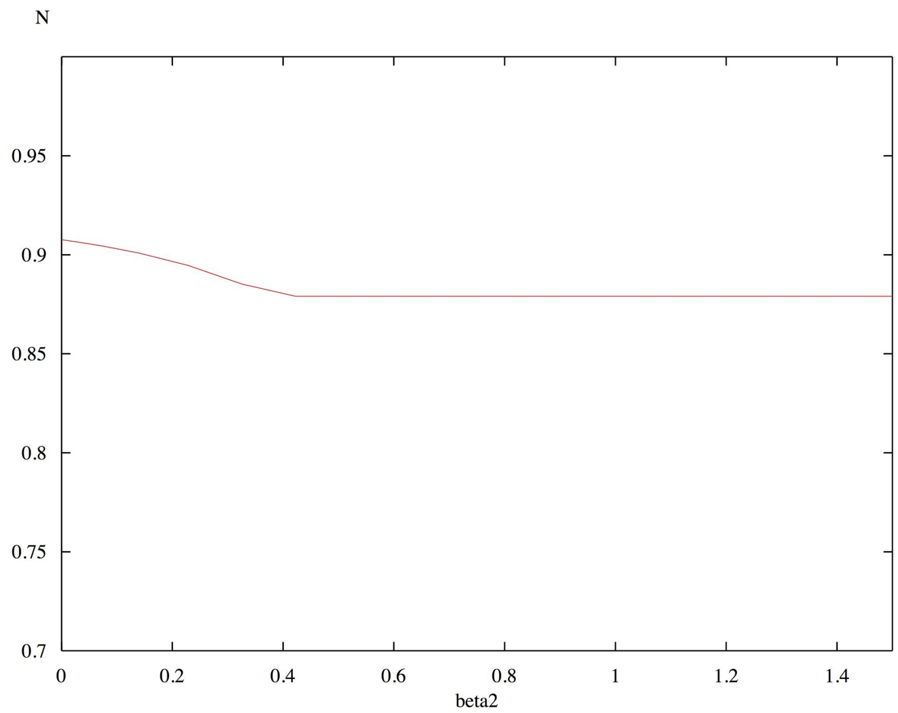




Time plot of Mf vs. time and bifurcation diagram of Mf vs. beta 2..

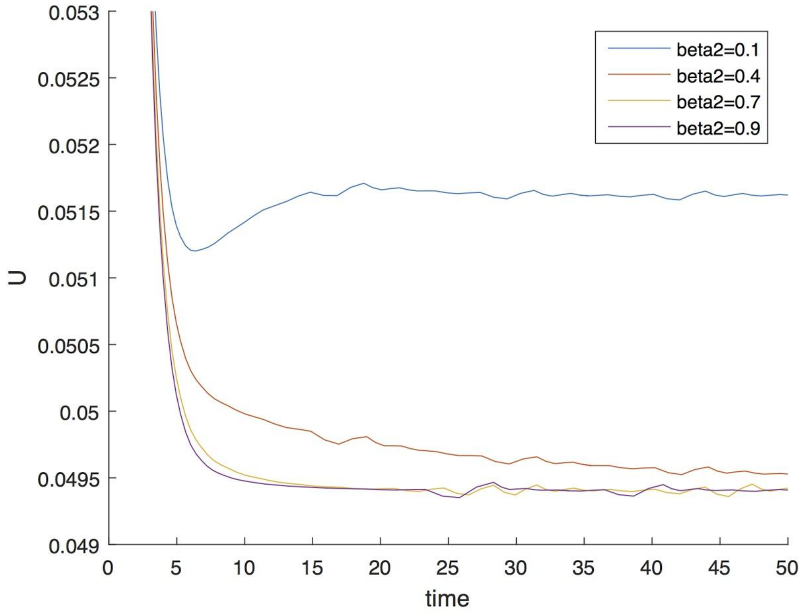
Effects of Beta2 (i.e., positive influences of Mp on Mf)

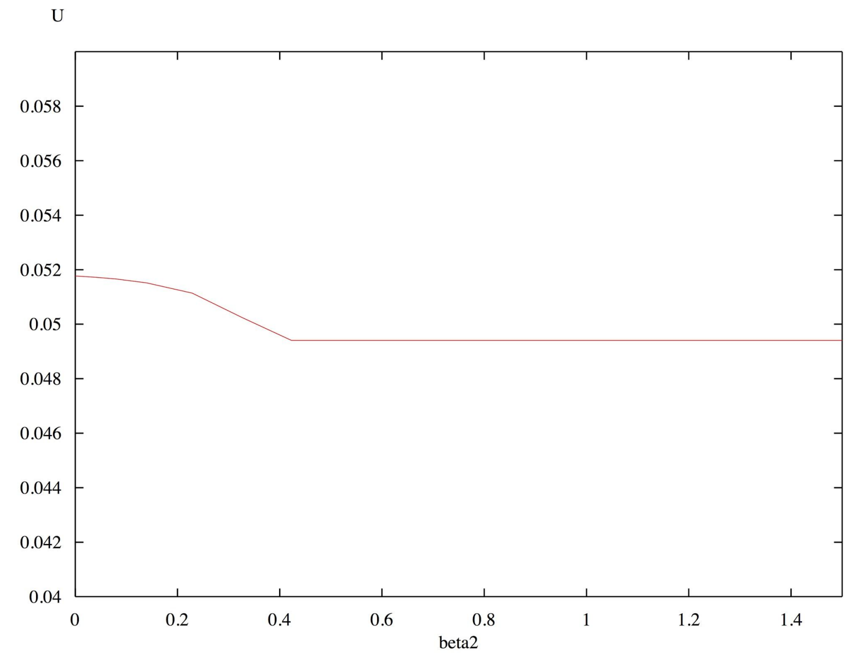




Time plot of N vs. time and bifurcation diagram of N vs. beta 2.

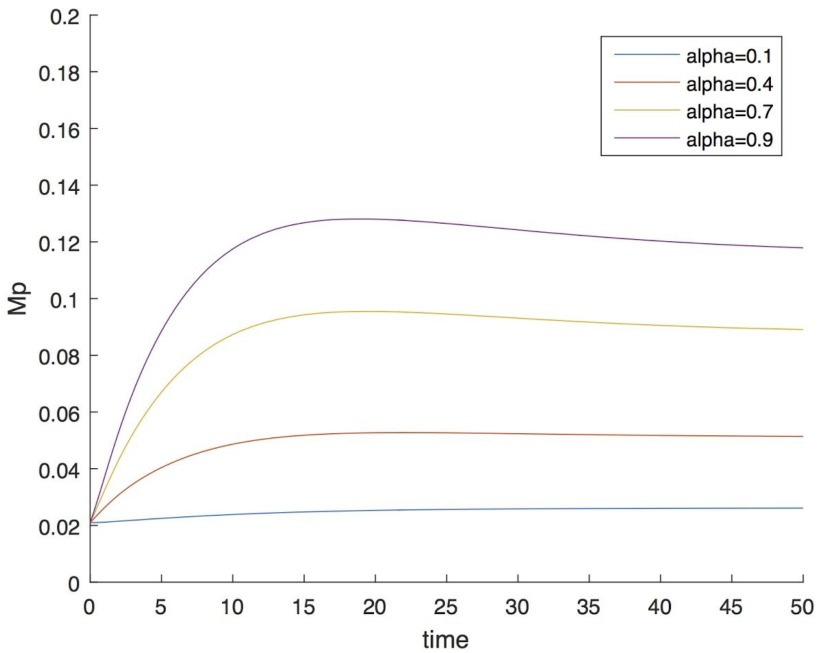
Effects of Beta2 (i.e., positive influences of Mp on Mf)

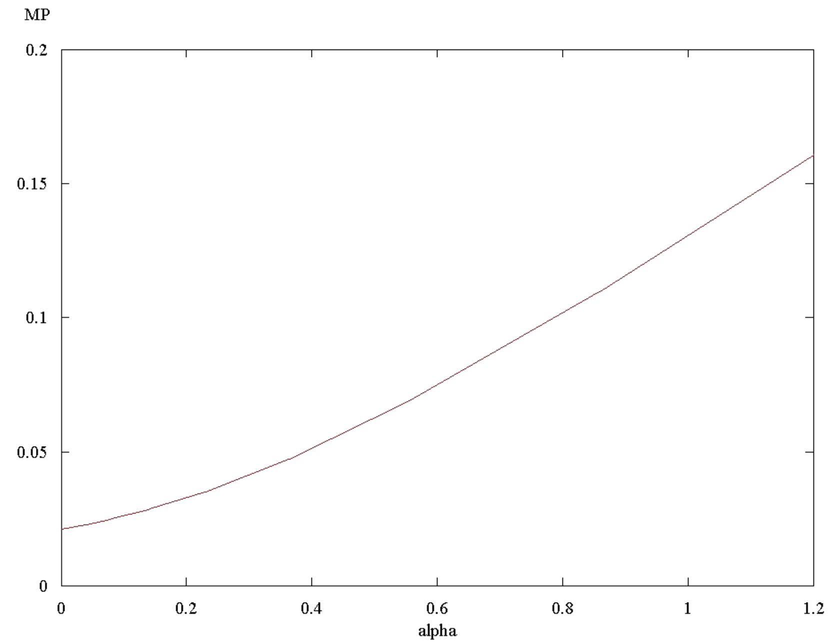




Time plot of U vs. time and bifurcation diagram of U vs. beta 2.

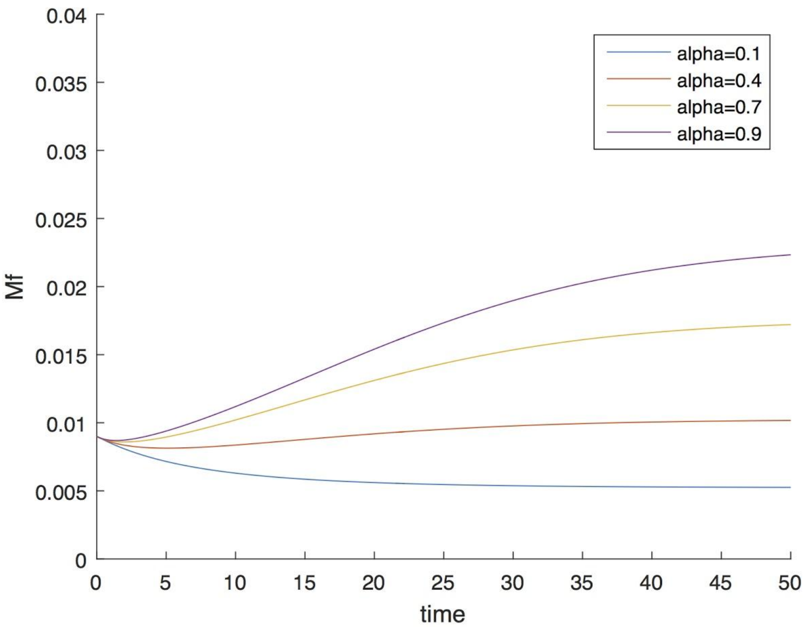
Effects of Alpha (i.e., positive influences of Mp on U)

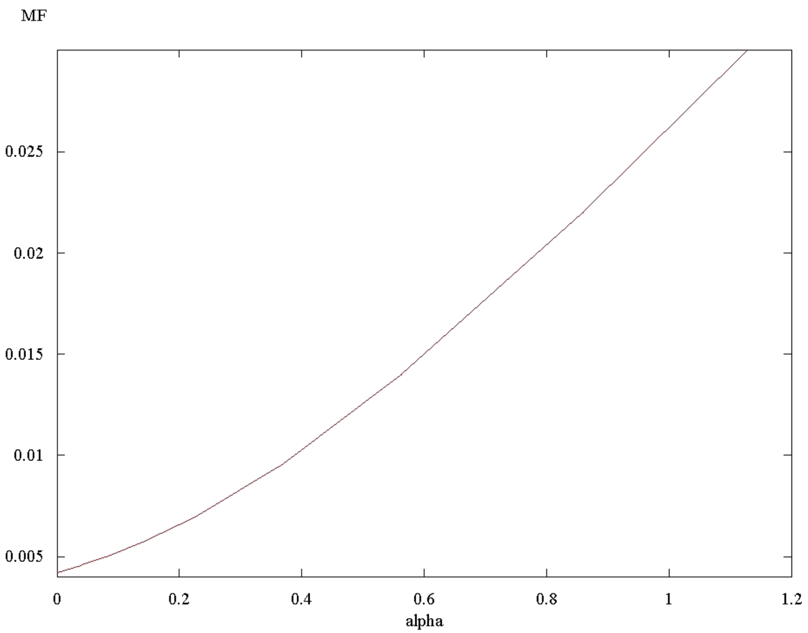




Time plot of Mp vs. time and bifurcation diagram of Mp vs. alpha (transmission efficiency of math passing students (Mp) on undecided students (U)

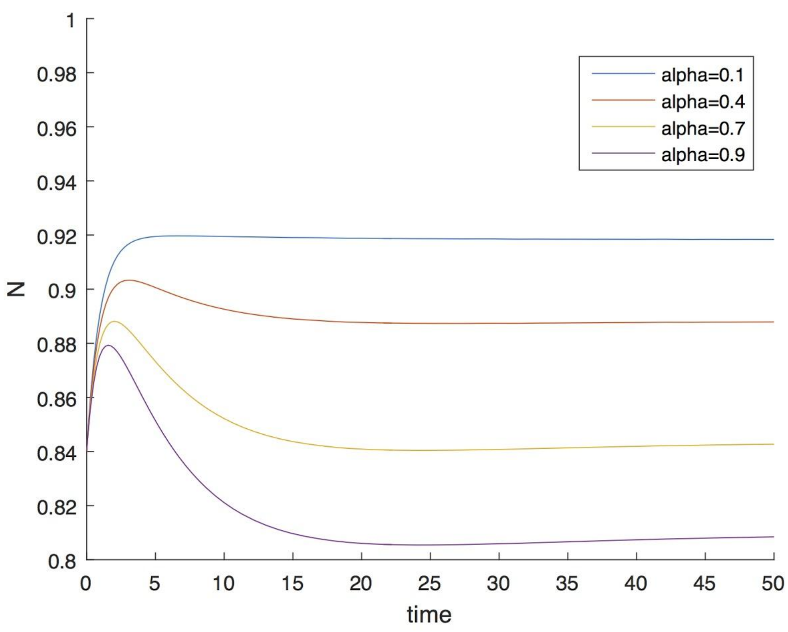
Effects of Alpha (i.e., positive influences of Mp on U)

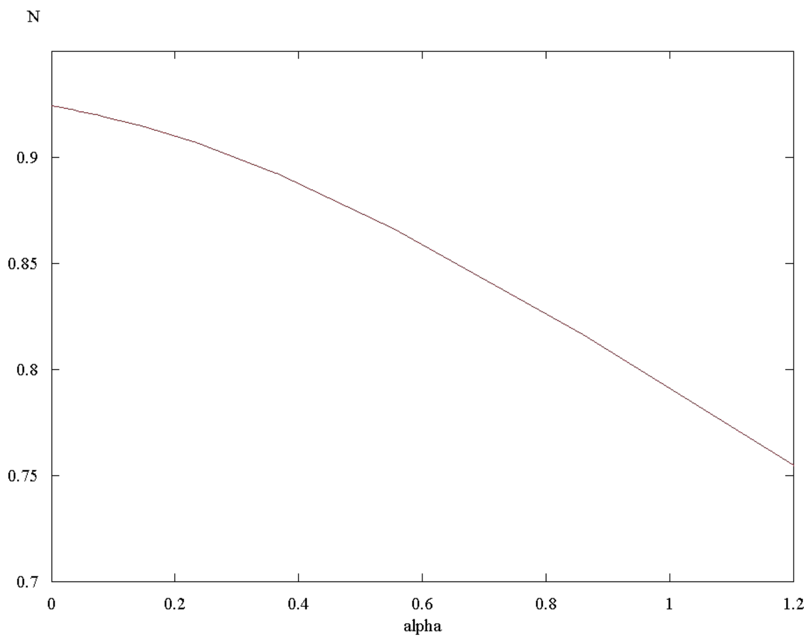




Time plot of Mf vs. time and bifurcation diagram of Mf vs. alpha

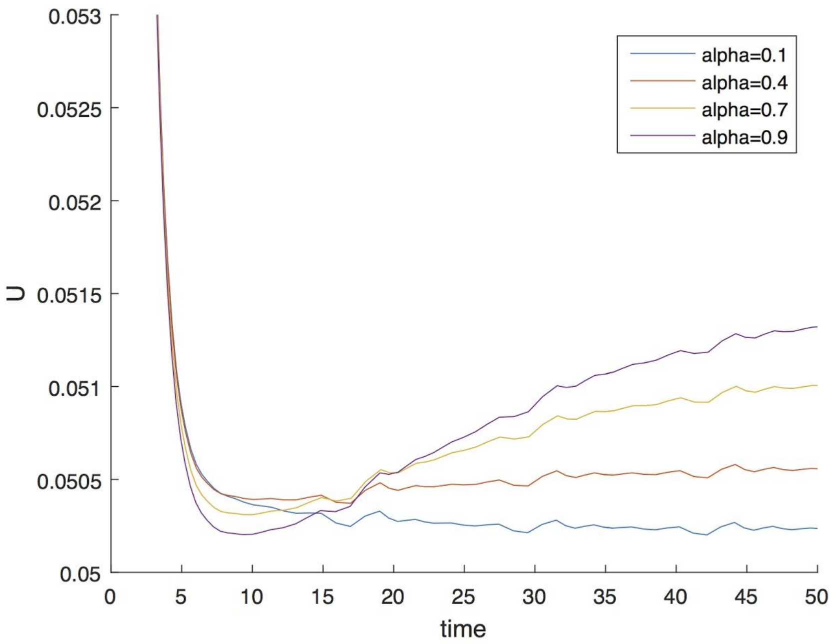
Effects of Alpha (i.e., positive influences of Mp on U)

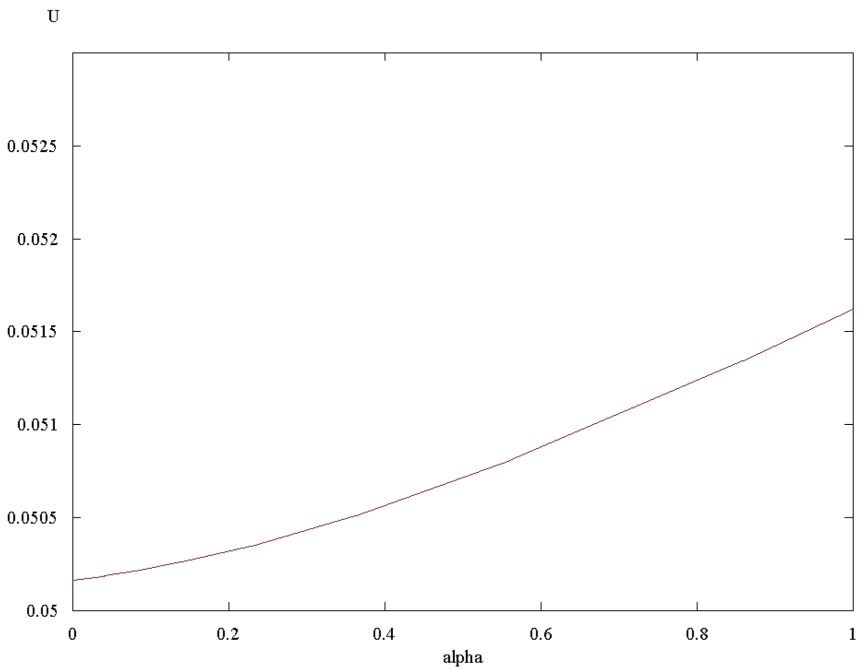




Time plot of N vs. time and bifurcation diagram of N vs. alpha

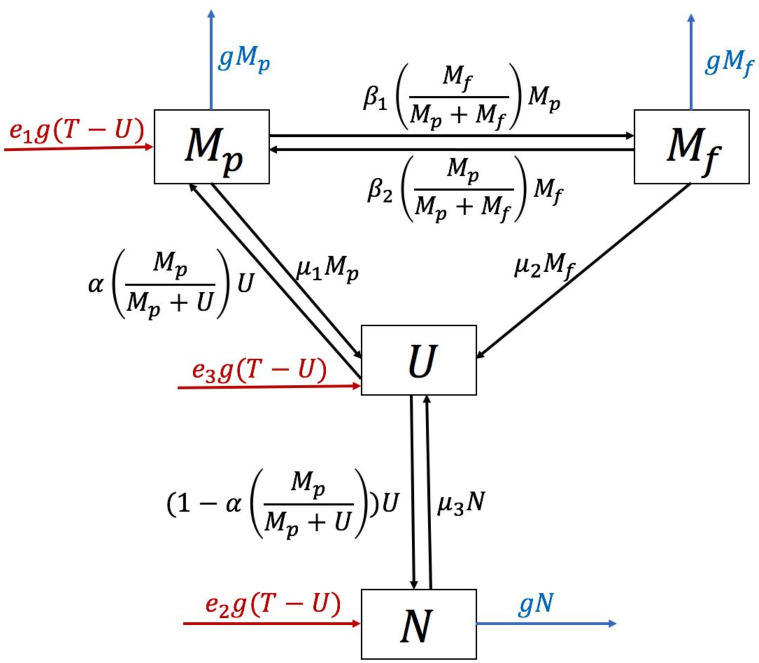
Effects of Alpha (i.e., positive influences of Mp on U)





Time plot of U vs. time and bifurcation diagram of U vs. alpha

Conclusion



After a few years, our system **reaches a stable fixed point**—within a reasonable range of variations in the parameters describing transmission efficiency of attitudes between populations of passing and failing math students and undecided students.

We did not observe any bifurcations in alpha (positive influences of passing math students on undecided students) **or beta 2** (positive influences of passing math students on failing math students).

There is a bifurcation of all four population variables for beta 1 that occurs around 0.7. At this value of beta 1, the stable steady state of the passing math students shifts from a fixed value to gradually decreasing values while the stable steady states of the failing math students, undecided students, and non-math students change from a fixed value to gradually increasing values.

This implies that **when the negative influences of math failing students are smaller than 0.7, they do not affect the four populations in a long run. However, once they are bigger than 0.7, smaller number of students will decide to major in math.**

References

Amdouni, B., Paredes, M., Kribs, C., & Mubayi, A. (2017). Why do students quit school? Implications from a dynamical modelling study. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Science, 473*(2197).

"Bachelor's Degrees Conferred by Postsecondary Institutions, by Field of Study: Selected Years, 1970-71 through 2015-16." *National Center for Education Statistics (NCES) Home Page, a Part of the U.S. Department of Education*, Institute of Education Sciences, nces.ed.gov/programs/digest/d17/tables/dt17_322.10.asp?current=yes.