Robustifying "The Generalized Taylor Rule": Three Period Regime Switching and Spillovers

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Abstract

This papers attempts to generalize the results obtained by Davig and Leeper (2007) by introducing a third regime. The third regime can be thought as a "Transitory State" through which policy rule switches from "more active" regime to "passive" regime. The third regime can also be thought as a "highly implausible/unexpected" short period yet very dramatic regime like September 9/11 or world war II. An introduction of the third regime generally reduces the determinacy region. The more passive the third regime is, the larger is the reduction. Inflation volatility depends on the nature of the third regime. With some modest transition from other regimes, regime 3 significantly reduces inflation volatility

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1 Introduction

Davig and Leeper(2007) demonstrated that with the introduction of Regime Switching in an 'Inflation Determination Model', indeterminanacy of equilibrium under various empirically plausible value of the taylor rule coefficient can be resolved. Their paper argued that in a two-period regime switching policy rule, "Spillover" from one regime to another can result in *equilibrium* with taylor coefficients that previous literature have argued results in *indeterminancy* under "Fixed Regime Rule". This paper attempts to generalize their results by introducing a third regime. The introduction of the third regime can be motivated in two ways. First, the third regime can be thought as a "Transitory State" through which policy rule switches from "more active" regime to "passive" regime. In that case, analyzing the spillovers of this third regime over other two regimes can shed more light as to how spillovers in regime switching effects the equilibrium outcome. Second, the third regime may be thought as a "highly implausible/unexpected" short period yet very dramatic regime like September 9/11 or world war II, which effects agent's expectation about future regime in a very significant way and might expand/contract the determinacy frontier. I will call this type of state as the 'Shock State'. I will try to decompose these two effects and analyze them separately. The paper is organized the following. We will first outline the model. Then we will carry out two experiments each of which will be subdivided into two

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parts. The first experiment will look at the effect of the third regime on the determinacy frontier. The second experiment will analyze the effect of the third regime on the relative volatility of inflation. Each experiment will look at the "spillover" effect and the "Shock" effect of the third regime. All these experiments will be conducted in similar spirit of Davig and Leeper(2007)

2 Model of Inflation Determination

2.1 Basic Setup

Similar to Davig and Leeper(2005), we have an observed policy regime s_t which can have three different values 1,2,3. Regime follows a three period markov process with $p\left(s_t = j / s_{t-1} = i\right) = p_{ij}$ and $\sum_{j=1}^{3} p_{ij} = 1$, where,

$$P = \begin{bmatrix} \\ p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}.$$

The model of inflation determination involves a system of two equations similar to Davig and Leeper(2007), which are as follows:

$$i_t = E_t \pi_{t+1} + E_t r_{t+1} \tag{1}$$

$$r_t = \rho . r_{t-1} + v_t \tag{2}$$

Where i_t is the nominal and r_t is the real interest rate , $|\rho| \prec 1$ and v_t is an iid random variable, $E\left(v_t\right) = 0$. Monetary policy follows a very simplified Taylor rule:

$$i_t = \alpha\left(s_t\right).\pi_t$$

Where $\alpha\left(s_t\right) = \begin{matrix} \alpha_1 \; iff \;\; s_t = 1 \\ \alpha_2 \; iff \;\; s_t = 2 \\ \alpha_3 \; iff \;\; s_t = 3 \end{matrix}$

Combining all the above equations, we get ,

$$\alpha\left(s_t\right) \pi_t = E_t . \pi_{t+1} + \rho . r_t \tag{3}$$

Equation(3) will be our main equation for analysis. Similar to Davig and Leeper(2005), let us define the information set available to agents at time t as, $\Omega_t = \Omega_t^{-1} \cup \{s_t\}$, where, $\Omega_t^{-1} = \{r_t, r_{t-1}, ..., s_t, s_{t-1}, ...\}$. Now the expectation about inflation is given by $E\left[\pi_{t+1}\left(s_{t+1} = i \;\mid s_t = j\right) \mid \;\Omega_t\right].$

Therefore, equation(3) can be written for $s_t = 1, 2, 3$ as follows:

$$\begin{gathered} \alpha\left(s_t = 1\right).\pi_t\left(s_t = 1\right) = \\ p_{11} E\left[\pi_{t+1}\left(s_{t+1} = 1, s_t = 1\right) \;\mid \Omega_t^{-1}\right] + p_{12} E\left[\pi_{t+1}\left(s_{t+1} = 2, s_t = 1\right) \;\mid \Omega_t^{-1}\right] \\ + p_{13} E\left[\pi_{t+1}\left(s_{t+1} = 3, s_t = 1\right) \;\mid \Omega_t^{-1}\right] \\ \alpha\left(s_t = 2\right).\pi_t\left(s_t = 2\right) = \\ p_{21} E\left[\pi_{t+1}\left(s_{t+1} = 1, s_t = 2\right) \;\mid \Omega_t^{-1}\right] + p_{22} E\left[\pi_{t+1}\left(s_{t+1} = 2, s_t = 2\right) \;\mid \Omega_t^{-1}\right] \\ + p_{23} E\left[\pi_{t+1}\left(s_{t+1} = 3, s_t = 2\right) \;\mid \Omega_t^{-1}\right] \end{gathered}$$

$$\begin{gathered}\alpha\left(s_t=3\right).\pi_t\left(s_t=3\right)= \\ p_{31}E\left[\pi_{t+1}\left(s_{t+1}=1,s_t=3\right) \quad \mid \Omega_t^{-1}\right]+p_{32}E\left[\pi_{t+1}\left(s_{t+1}=2,s_t=3\right) \quad \mid \Omega_t^{-1}\right] \\ +p_{33}E\left[\pi_{t+1}\left(s_{t+1}=3,s_t=3\right) \quad \mid \Omega_t^{-1}\right]\end{gathered}$$

Since we have integrated out the current state s_t, we can write the above equations as follows:

$$\alpha\left(s_t=1\right).\pi_t\left(s_t=1\right)=p_{11}E\left[\pi_{t+1}\left(s_{t+1}=1\right) \quad \mid \Omega_t^{-1}\right]+p_{12}E\left[\pi_{t+1}\left(s_{t+1}=2\right) \quad \mid \Omega_t^{-1}\right]$$

$$+p_{13}E\left[\pi_{t+1}\left(s_{t+1}=3\right) \quad \mid \Omega_t^{-1}\right]+\rho.r_t \tag{4}$$

$$\alpha\left(s_t=2\right).\pi_t\left(s_t=2\right)=p_{21}E\left[\pi_{t+1}\left(s_{t+1}=1\right) \quad \mid \Omega_t^{-1}\right]+p_{22}E\left[\pi_{t+1}\left(s_{t+1}=2\right) \quad \mid \Omega_t^{-1}\right]$$

$$+p_{23}E\left[\pi_{t+1}\left(s_{t+1}=3\right) \quad \mid \Omega_t^{-1}\right]+\rho.r_t \tag{5}$$

$$\alpha\left(s_t=3\right).\pi_t\left(s_t=3\right)=p_{31}E\left[\pi_{t+1}\left(s_{t+1}=1\right) \quad \mid \Omega_t^{-1}\right]+p_{32}E\left[\pi_{t+1}\left(s_{t+1}=2\right) \quad \mid \Omega_t^{-1}\right]$$

$$+p_{33}E\left[\pi_{t+1}\left(s_{t+1}=3\right) \quad \mid \Omega_t^{-1}\right]+\rho.r_t \tag{6}$$

Define $\pi_{it}=\pi_t\left(s_t=i\right)$. Also let,

$$\begin{gathered}E_t\pi_{1t+1}= \\ p_{11}E\left[\pi_{t+1}\left(s_{t+1}=1\right) \quad \mid \Omega_t^{-1}\right]+p_{12}E\left[\pi_{t+1}\left(s_{t+1}=2\right) \quad \mid \Omega_t^{-1}\right]+p_{13}E\left[\pi_{t+1}\left(s_{t+1}=3\right) \quad \mid \Omega_t^{-1}\right] \\ E_t\pi_{2t+1}= \\ p_{21}E\left[\pi_{t+1}\left(s_{t+1}=1\right) \quad \mid \Omega_t^{-1}\right]+p_{22}E\left[\pi_{t+1}\left(s_{t+1}=2\right) \quad \mid \Omega_t^{-1}\right]+p_{23}E\left[\pi_{t+1}\left(s_{t+1}=3\right) \quad \mid \Omega_t^{-1}\right] \\ E_t\pi_{3t+1}= \\ p_{31}E\left[\pi_{t+1}\left(s_{t+1}=1\right) \quad \mid \Omega_t^{-1}\right]+p_{32}E\left[\pi_{t+1}\left(s_{t+1}=2\right) \quad \mid \Omega_t^{-1}\right]+p_{33}E\left[\pi_{t+1}\left(s_{t+1}=3\right) \quad \mid \Omega_t^{-1}\right]\end{gathered}$$

Also define the forecast errors as,

$$\begin{aligned}\eta_{1t+1}&=\pi_{1t+1}-E_t\left(\pi_{1t+1}\right) \\ \eta_{2t+1}&=\pi_{2t+1}-E_t\left(\pi_{2t+1}\right) \\ \eta_{3t+1}&=\pi_{3t+1}-E_t\left(\pi_{3t+1}\right)\end{aligned}$$

Then equation 4, 5, 6 can be written as:

$$\begin{aligned}\alpha_1.\pi_{1t}&=p_{11}\left(\pi_{1t+1}-\eta_{1t+1}\right)+p_{12}\left(\pi_{2t+1}-\eta_{2t+1}\right)+p_{13}\left(\pi_{3t+1}-\eta_{3t+1}\right)+\rho.r_t \\ \alpha_2.\pi_{2t}&=p_{21}\left(\pi_{1t+1}-\eta_{1t+1}\right)+p_{22}\left(\pi_{2t+1}-\eta_{2t+1}\right)+p_{23}\left(\pi_{3t+1}-\eta_{3t+1}\right)+\rho.r_t \\ \alpha_3.\pi_{3t}&=p_{31}\left(\pi_{1t+1}-\eta_{1t+1}\right)+p_{32}\left(\pi_{2t+1}-\eta_{2t+1}\right)+p_{33}\left(\pi_{3t+1}-\eta_{3t+1}\right)+\rho.r_t\end{aligned}$$

In matrix form,

$$\begin{gathered}\begin{bmatrix}\alpha_1 & 0 & 0 \\ 0 & \alpha_2 & 0 \\ 0 & 0 & \alpha_3\end{bmatrix}\begin{bmatrix}\pi_{1t} \\ \pi_{2t} \\ \pi_{3t}\end{bmatrix}=\begin{bmatrix}p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33}\end{bmatrix}\begin{bmatrix}\pi_{1t+1} \\ \pi_{2t+1} \\ \pi_{3t+1}\end{bmatrix}+\begin{bmatrix}\rho \\ \rho \\ \rho\end{bmatrix}.r_t \\ -\begin{bmatrix}p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33}\end{bmatrix}\begin{bmatrix}\eta_{1t+1} \\ \eta_{2t+1} \\ \eta_{3t+1}\end{bmatrix}\end{gathered}$$

Reorganizing the above equation gives us,

$$\begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}^{-1} \begin{bmatrix} \alpha_1 & 0 & 0 \\ 0 & \alpha_2 & 0 \\ 0 & 0 & \alpha_3 \end{bmatrix} \begin{bmatrix} \pi_{1t} \\ \pi_{2t} \\ \pi_{3t} \end{bmatrix} = \begin{bmatrix} \pi_{1t+1} \\ \pi_{2t+1} \\ \pi_{3t+1} \end{bmatrix} + \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}^{-1} \begin{bmatrix} \rho \\ \rho \\ \rho \end{bmatrix} .r_t$$

$$- \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}^{-1} \begin{bmatrix} \eta_{1t+1} \\ \eta_{2t+1} \\ \eta_{3t+1} \end{bmatrix} \tag{7}$$

Thus the roots of the system are the eigen values of

$$\begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}_D^{-1} \begin{bmatrix} \alpha_1 & 0 & 0 \\ 0 & \alpha_2 & 0 \\ 0 & 0 & \alpha_3 \end{bmatrix}$$

The uniqueness of the equilibrium will require all the three roots exceed 1. Since the eigen values will be very difficult to solve analytically, we will use numerical methods to calculate when we carry out our experiments.

2.2 Solution of the Model

Similar to Davig and Leeper(2007),we will use the *method of undeterminant coefficients* to solve the model. We therefore posit a similar solution of the model,

$$\pi_t = a(s_t).r_t$$

where,

$$\begin{aligned} a(s_t) = \; & a_1 \; for \; s_t = 1 \\ & a_2 \; for \; s_t = 2 \\ & a_3 \; for \; s_t = 2 \end{aligned}$$

Substituting this into (3),

$$\alpha(s_t)\pi_t = E_t.\pi_{t+1} + \rho.r_t = \rho.r_t E[a(s_{t+1}) \mid s_t, r_t] + \rho.r_t \tag{8}$$

Now,

$$\begin{aligned} E[\pi_{t+1} \mid s_t = 1, r_t] &= p_{11}.a_1 + p_{12}.a_2 + p_{13}.a_3 \\ E[\pi_{t+1} \mid s_t = 2, r_t] &= p_{21}.a_1 + p_{22}.a_2 + p_{23}.a_3 \\ E[\pi_{t+1} \mid s_t = 3, r_t] &= p_{31}.a_1 + p_{32}.a_2 + p_{33}.a_3 \end{aligned}$$

Substituting this and the assumed solution into (7), we get,

$$\begin{aligned} \alpha_1.a_1.r_t &= [p_{11}.a_1 + p_{12}.a_2 + p_{13}.a_3 + 1].\rho.r_t \\ \alpha_2.a_2.r_t &= [p_{21}.a_1 + p_{22}.a_2 + p_{23}.a_3 + 1].\rho.r_t \\ \alpha_3.a_3.r_t &= [p_{31}.a_1 + p_{32}.a_2 + p_{33}.a_3 + 1].\rho.r_t \end{aligned}$$

Now using method of undeterminant coefficient, we can set,

$$\begin{aligned}\alpha_1.a_1. &= [p_{11}.a_1 + p_{12}.a_2 + p_{13}.a_3 + 1].\rho \\ \alpha_2.a_2. &= [p_{21}.a_1 + p_{22}.a_2 + p_{23}.a_3 + 1].\rho \\ \alpha_3.a_3. &= [p_{31}.a_1 + p_{32}.a_2 + p_{33}.a_3 + 1].\rho\end{aligned}$$

In matrix form, the solution of the model looks like,

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} = \overbrace{\begin{bmatrix} \alpha_1 - \rho.p_{11} & -\rho.p_{12} & -\rho.p_{13} \\ -\rho.p_{21} & \alpha_2 - \rho.p_{22} & -\rho.p_{23} \\ -\rho.p_{31} & -\rho.p_{32} & \alpha_3 - \rho.p_{33} \end{bmatrix}}^{A}{}^{-1} \begin{bmatrix} \rho \\ \rho \\ \rho \end{bmatrix}$$

We can show that $Det\,(A) \neq 0$.Hence the matrix is invertible and we can get solutions for a_1, a_2, a_3.The expressions for a_1, a_2, a_3 are very lengthy and complicated and are not specified here.

Following Hamilton(1994), we can also calculate the ergodic probability of each regime. For exposition, the method is briefly explained here.

Given,

$$P = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}, \text{define, } F = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \\ 1 & 1 & 1 \end{bmatrix} \text{ and } E = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix}'$$

Then the ergodic probability is given by the following column matrix,

$$Ergodic\Pr obability = \left(F'.F\right)^{-1} F'.E$$

3 Experiments

I would like to analyze the effect of the third regime in terms of its "Transitory effect" and its "Shock Effect". Design of the experiments would be carried out very carefully to analyze these two effects separately. Attempt would be made to separate these effects by assigning different values of the elements of our P matrix. It should be mentioned that determinacy of equilibrium or more precisely invertibility of the P matrix in the D term gets effected by the different values of the transitional probabilities. As a result, it is not possible to completely decompose these two effects. Despite that, attempt would be made to minimize the one effect while trying to analyze the other one.We will compare our results with Davig and Leeper(2007) and also with the fixed regime determinacy frontier which, if otherwise specified, would always be specified as the lighter gray area of each of the graph. The extension of the determinacy frontier due to flexible regime would be the sum of the darker area and the lighter area. In order to avoid confusion, the determinacy frontier would always be the area above the level curve that defines the lower bound of the determinacy frontier

3.1 Third Regime as a Transitory State

In order to analyze how the spillover of the third regime as a 'Transitory state', we assume from the outset that $p_{13} = p_{31} = 0$. The motivation is that by doing so, we are assuming that the only way regime-3 can effect regime-1 is through regime-2. The value of p_{23} would then be very crucial because it will determine whether regime-2 gets a one way or both way spillover from regime-3 which would eventually also effect the spillover that regime-1 receives from regime-3.

3.1.1 Analyzing the Determinacy frontier

Appendix-1 outlines the simulations results for analyzing the determinacy frontier. Values of α_1, α_2,the coefficient for regime-1 and regime-2 varies from 0.8 to 1.5. We will assume different value for α_3 from very passive to passive. Appendix-1 shows the baseline results when we have assumed $\alpha_3 = 0.8, p_{32} = p_{33} = 0.5$ and $p_{23} = 0$.The motivation was to allow equal amount of time for our economy to stay in regime-2 and regime-3 if the economy starts from regime-3. Other values of the P matrix are specified in graph. We notice that the determinacy region looks very similar to Davig and Leeper(2007)'s two regime case. But when $p\_11 = p\_22 = 0$,there is a reduction in determinacy frontier compared to Davig and Leeper(2007). Therefore, when the regimes are all transitory and there is only one way spillover, this reduces determinacy.

Appendix-2 assumes everything above but now assume $p_{23} = 0.1$.In this case, when all regimes are transitory(lower panel), determinacy region even losses some area of the fixed regime frontier. Appendix-3 strengthens this observation. For a larger value of $p_{23}(0.85)$, and a lower value of $p_{22}(0.1)$,the determinacy frontier shrinks down to some mere points(upper panel, right).Appendix-4, also reports some interesting results. It also points out that for a moderate value of p_{23}, (0.5),the smaller the value of p_{11} or p_{22}, the smaller the determinacy region, even compared to the fixed regime setup. But in each case, a moderate value of p_23 would result in a reduction of the determinacy region even compared to a fixed regime. Therefore, we conclude that the larger the spillover or the more transitory each of the states are, the more dramatic is the reduction of the determinacy region.

Appendix-5,6,7,8 assumes $p_{33} = 0.01$ to allow maximum possible spillover of regime-3 over regime-2 without violating the invertibility of P matrix. They point out the same set of conclusions in Appendix2-4 with more dramatic reduction of the determinacy region with larger value of p_{23} or smaller value of p_{11}or p_{22}.

Appendix-9, 10, 11, 12 assumes $p_{33} = 0.99$. They report that for various values of p_{23}, p_{22}, p_{11}, the determinacy region looks like a fixed regime setup.This is understandable because if the regime-3 is absorbing, then economy evolves around this regime like a fixed one.

3.1.2 Analyzing the Volatility of Inflation

The analysis of the volatility of inflation is carried out in the similar spirit of Davig and Leeper(2007). The volatility in each regime is analyzed with setting $\alpha_3 = 1.5, \alpha_3 = 0.8$ and varying the value of α_2.Appendix-13, 14, 15 reports inflation volatility similar to Davig and Leeper(2007)for smaller values of p_{23}. Appendix -13, 14 reports similar results as Davig and Leeper(2007) with one difference for different active policy in regime-1. Inflation volatility in each regime and for all active level appears to be very similar. But the convergence of the inflation volatility is smoother and faster than Davig and Leeper(2007). Interestingly, Inflation volatility in each regime converges to zero for bigger values of α_2, even for the regime-3.In Appendix-15,however tracing out the transitory effect would be a little harder in these cases because the value of p_{33} has also been changed. But comparing Appendix-15 with Appendix-14, both of which assumes $p_{23} = 0.01$, a decrease in the value of p_{33} from 0.5 to 0.01 leaves the inflation volatility in regime-1 and 2 unchanged but dramatically increases the volatility of regime-3. Appendix-16 only reports 1%

active policy in regime-1 and assumes $p_{23} = 0.1$ with $p_{32} = p_{33} = 0.5$. The results are very much comparable to Davig and Leeper(2005). However, no experiment has been conducted with the value of p_{33} larger than 0.1. They need to be done to analyze the full transitory effect of regime-3.

Despite that we can conclude that for smaller values of p_{23} or only one way of spillover will not dramatically modify the inflation volatility in regime-2 or regime-1. With larger both way spillover, we will see that the volatility of inflation might go up or go down. But will be explained when we Look at the "Shocking state" effect of regime-3.

Table-1_1 and Table-1_2 reports a deeper look at the inflation volatility. As was explained in the previous appendices, table-1 shows that with $p_{23} = 0$, results can be comparable with Davig and Leeper(2007)'s table-1. Table-1_3 does not provide any additional information when$p_{23} = 0.01$. The only interesting thing to note here is that regime-3 is much more volatile than regime-1 or even regime-2.

Table-1_4 however reports interesting results when $p_{23} = 0.2$. Volatility in both regime-1 and regime-2 goes down significantly. With regime-3 almost transitory,the larger the value of P_{11}, the smaller the volatility of inflation in regime-1, which also reduces the volatility in regime-2. For larger value of α_2,the volatility in regime-2 is smaller and for larger value of p_{23}, the volatility is larger. However, the volatility of inflation in regime-3 is larger than regime-2.

Table-1_5 reports even more dramatic results. When the third regime is a very active regime(2.0), the dampening effect of regime-3 is more significant. This time the volatility of inflation in regime-2 goes down significantly. The volatility of inflation in regime-1 also shows even more dampening trend.In addition to that, with regime-3 being almost transitory, the volatility of inflation in regime-3 now goes down is now smaller than regime-2

We can then conclude that passive regime-3 with little or no transition from other regimes plays no significant role in reducing inflation volatility compared to two regime case. But with some modest transition from other regimes, regime-3 significantly reduces inflation volatility. Finally with a very active regime-3, the reduction in inflation volatility is both dramatic and significant.

3.2 Third Regime as a "Shocking" State

In this section, we would like to analyze how the third regime-3 as "Shock" state effects the other two regimes. We therefore would vary both the transitional probability of regime-3 to regime-2 and regime-1 as well as the size of the coefficient for regime-3. This effect would be very difficult to analyze because we cannot set p_{21}, p_{12} equal to zero because of the loss of invertibility of the P matrix.

3.2.1 Analyzing the Determinacy frontier

Appendix-17, 18, 19 reports the determinacy frontier for different values of α_3 and also for different specification of the probabilities. We notice two things. First, going from very passive(0.1) to very active(1.5), there is tremendous gain in determinacy. Second, there is almost a symmetric tradeoff between α_1 and α_2. Analyzing Appendix-18 column wise, where we assumed $\alpha_3 = 0.8$,a reductions in p_{13} (second column, top to bottom) or p_{23}(first column, top to bottom) results in a larger reduction of the determinacy frontier. Alternatively, the more transitory the regimes are, the larger is the determinacy frontier. Similar results are seen in Appendix-19 where $\alpha_3 = 1.5$.Here, if we again analyze the graphs column wise, it seems like the more transitory are the regimes, the larger are the determinacy region. One possible explanation would be that the existence of a very active regime changes peoples expectation about future regime such that they are optimistic about the "activeness" of regimes and therefore, accommodate even less active(even passive) behavior.

Appendix-20 reports some additional insights. Here, the third regime is very active(1.5). Going from left to right on the top panel, we see the determinacy region is quite insensitive to transitional probabilities from the third regime to the other regime. The system also appears to be insensitive to the "absorbing" nature of regime-3 in the sense that as p_{33} goes from 0.90 to 0.45 in the top panel, determinacy frontier completely uneffected.Similar trend is noticed at the bottom panel. But Appendix-21 reports different results. Here third regime is mildly passive(0.8). With a slight increase in the transitional probability from regime-3 to regime-1, or with a significant decline in the "Absorbing" nature of regime-3(p_{33} going from 0.90 to 0.45), there is dramatic decline in the determinacy region even compared to the fixed regime setup. In the bottom panel, a minor decline in the transitional probability from regime-3 to regime-2(p_{32} going from 0.2 to 0.25), or a decline in the transitional probability from regime-2 to regime-3(p_{23} going from 0.45 to 0.25) , or a change in the absorbing nature of regime-2(p_{22} going from 0.1 to 0.50) results in a symmetric change in the determinacy frontier leaving it unaffected, although there is a reduction in determinacy frontier in both case. Since, for bottom panel all the above things occurred once, it is not clear the distinction between the transitory and the "shock" effect of regime-3. Appendix-22, 23,24 just robustify the observations made in Appendix-20 and 21.

3.2.2 Analyzing the Volatility of Inflation

Appendix-25 to Appendix-28 report the volatility of inflation under various specifications. Here the graphs should be analyzed a little bit differently than Davig and Leeper(2007) because now we are analyzing only one type of active policy in the regime-1. Appendix-25 assumes $\alpha_3 = 0.8$ and shows compared with the base line specification in Appendix-16, an increase in the transitional probability from regime-3 to regime-1(p_{31}going from 0 to 0.70) reduces the inflation volatility in regime-1. Compared with the baseline, a reduction in the absorbing nature of regime-3(p_{33} going from 0.5 to 0.05) also reduces the inflation volatility in regime-3. Comparing Appendix-26 with Appendix-25, we see a decline in p_{11} increases inflation volatility in regime-1. The surprising result is that this change in specification also raises the inflation volatility in regime-3. This is probably an evidence that there is spillovers from regime-1 to regime-3. An increase in the spillover from regime-1 to regime-2(p_{12} going from 0.15 to 0.25) also raises the inflation volatility in regime-2.

Appendix-27 and 28 reports results when the "shock" state is active(1.5). We see when the shock regime is completely transitory, The volatility in its own regime goes down almost to zero. In addition, the spillovers from regime-3 to regime-1,2 significantly reduces the inflation volatility.

We can therefore conclude that increase in direct spillover from the shock state reduces inflation volatility in regime-1,2. This reduction is very dramatic if the shock state is active. Also absorbing nature of each also plays a role in the inflation volatility. The more absorbing each states are, the more volatile inflation in that regime is.

Table-1_6 and 1_7 reports similar intuition of the role of the third regime as a shock state in terms of the inflation volatility. Table-1_6 reports results for $\alpha_3 = 0.8$. With regime-3 being completely transitory and allowing for significant transition from regime-3 to other regimes and modest to mild transition of other regimes to regime-3, the results are significant. Here attempt has been made to reduce the gradual transmission of regime-3 to regime-2 and regime-1, so that we can analyze the "shock" effect of regime-3. For larger value of p_{11},larger value of α_2, and smaller value of p_{23}, volatility of inflation goes down. In each of these cases, volatility of inflation in regime-3 is smaller than regime-2. But the "shock" effect of regime-3 becomes pronounced when the third regime is very active. Table-1_7 reports this when $\alpha_3 = 2.0$.Inflation volatility goes down for regime-1 almost to zero. Inflation volatility in regime-2 is reduced significantly. Finally, regime-3 now exhibit much lower volatility of inflation than regime-3.

By comparing results from table-1_1-1_5 with table1_6 and table-1_7, we can conclude that the shock effect of a third regime plays a more drastic role in terms of reducing inflation volatility. This effect is further intensified the more the third regime is.

4 Summary of Findings

We have tried to carry out experiments to analyze the effect of a third regime on the determinacy frontier and inflation volatility. We have carried the experiments while trying to decompose the effect of the third regime into "transitory" effect and "shock"effect. The experiments reveal interesting results. We would summarize them as follows. First, An introduction of third regime generally reduces the determinacy region. While analyzing the Transitory effect,the more transitory are the regimes, the dramatic are the reduction. Also the more passive the third regime, the larger is the reduction. While analyzing the "Shock" effect, the more transitory are the regimes, the smaller reduction is in the determinacy region. With a significantly active regime-3, the determinacy frontier is quite insensitive to transitional probabilities. Therefore, Transitory and "Shock" effect operates in opposite direction. Second, Inflation volatility depends on the nature of the effect being analyzed and also the nature of the regime-3. While analyzing the "transitory" effect, a passive regime-3 with little or no transition from other regimes plays no significant role in reducing inflation volatility compared to two regime case. But with some modest transition from other regimes, regime-3 significantly reduces inflation volatility. Finally with a very active regime-3, the reduction in inflation volatility is both dramatic and significant. While analyzing the "Shock" effect,we see that increase in direct spillover from the shock state reduces inflation volatility in regime-1,2. This reduction is very dramatic if the shock state is active. Also absorbing nature of each also plays a role in the inflation volatility. The more absorbing each states are, the more volatile inflation in that regime is.

5 Conclusion

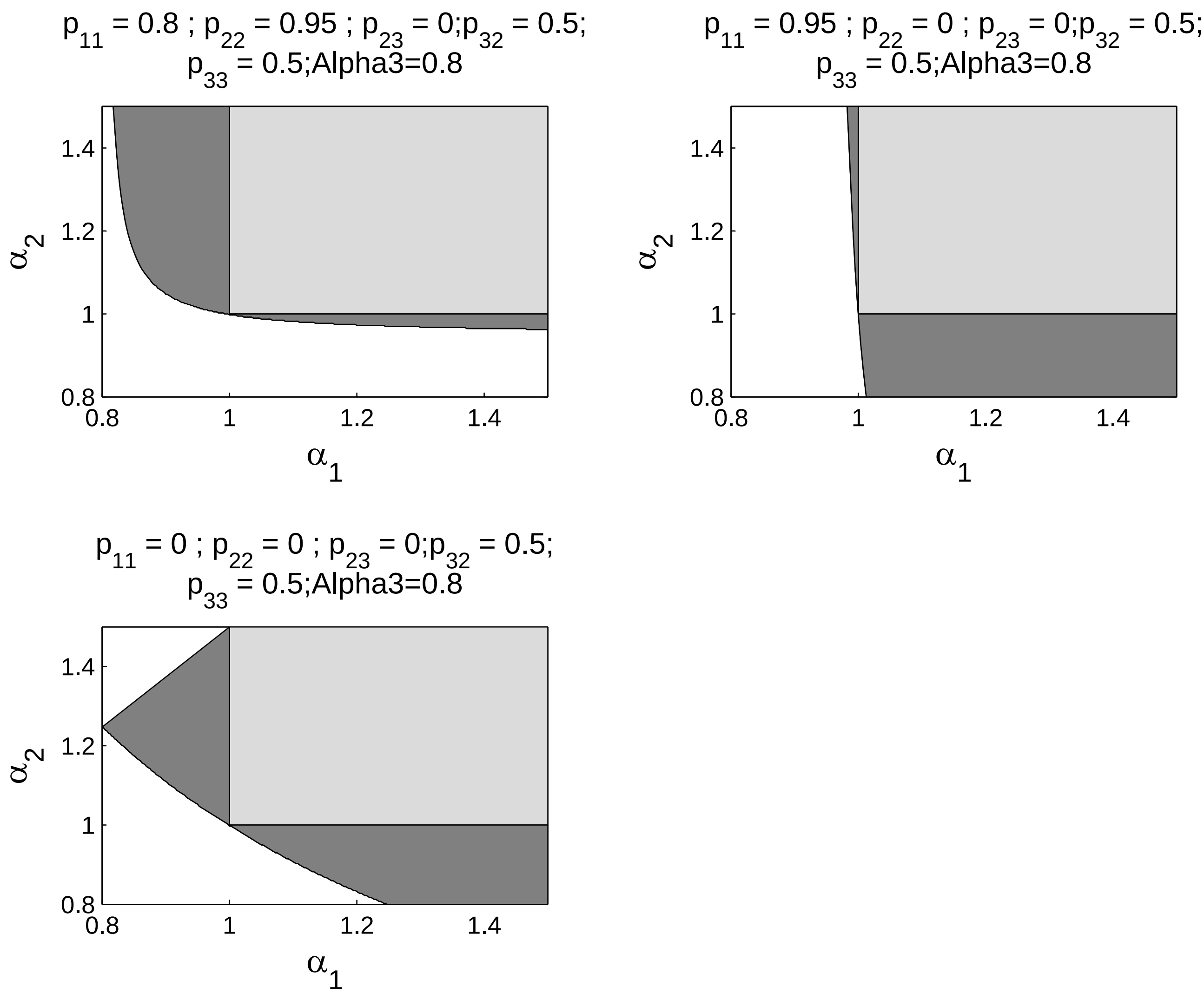
In this paper attempt has been made to robustify the results obtained by Davig and Leeper(2007) by subjecting the solution of the model to various parameter specification. Attempt has been to decompose the effect of an additional regime. The results reflect mixed results.Further experiments needs to be carried out to have a better gauge of the effect of a third regime.

References

[1] Davig, Troy, and Eric Leeper(2007): "Generalizing the Taylor Principle,"American Economic Review 97(3): 607-635.

[2] Hamilton, James(1994):"Time Series Analysis". Mcgrawhill.

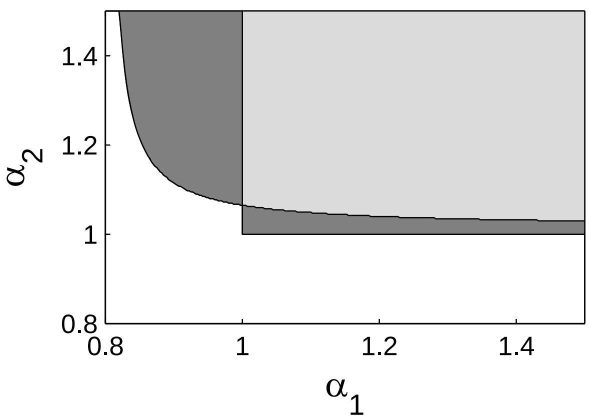
Appendix-1



Appendix-1

Appendix-2

$p_{11} = 0.8$; $p_{22} = 0.85$; $p_{23} = 0.1$;$p_{32} = 0.5$;$p_{33} = 0.5$;Alpha3=0.8



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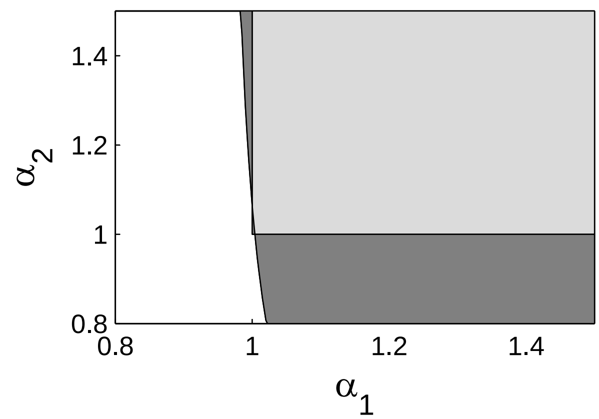

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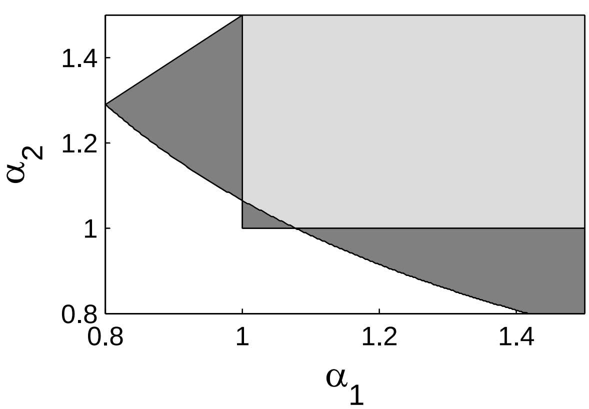
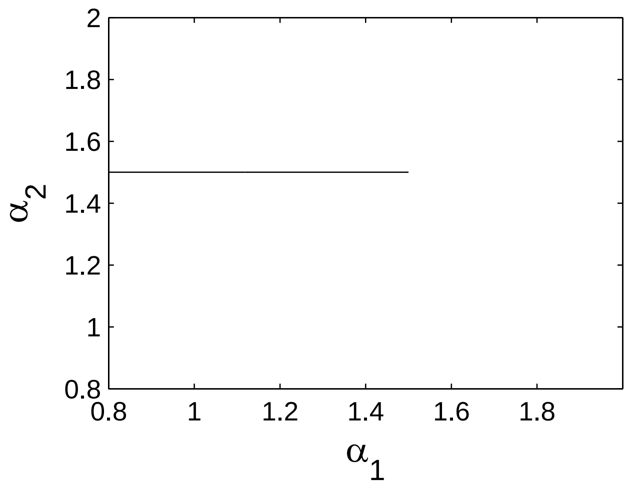


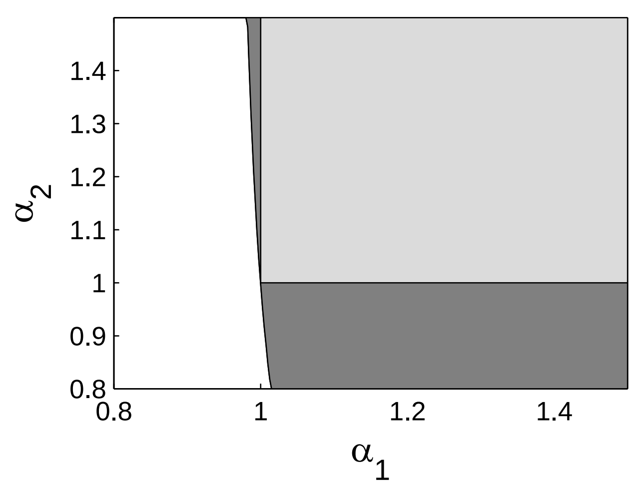
Appendix-2

Appendix-3

$p_{11} = 0.8$; $p_{22} = 0.1$; $p_{23} = 0.85$;$p_{32} = 0.5$; $p_{33} = 0.5$;Alpha3=0.8



;$p_{32} = 0.5$;$p_{33} = 0.5$;Alpha3=0.8$p_{11} = 0.95$; $p_{22} = 0.1$; $p_{23} = 0$



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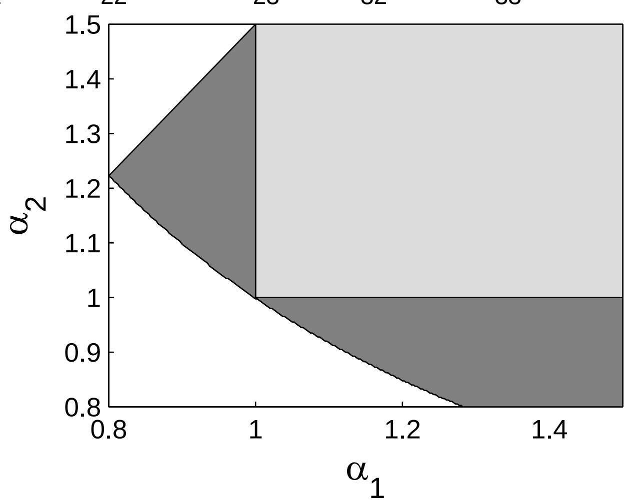
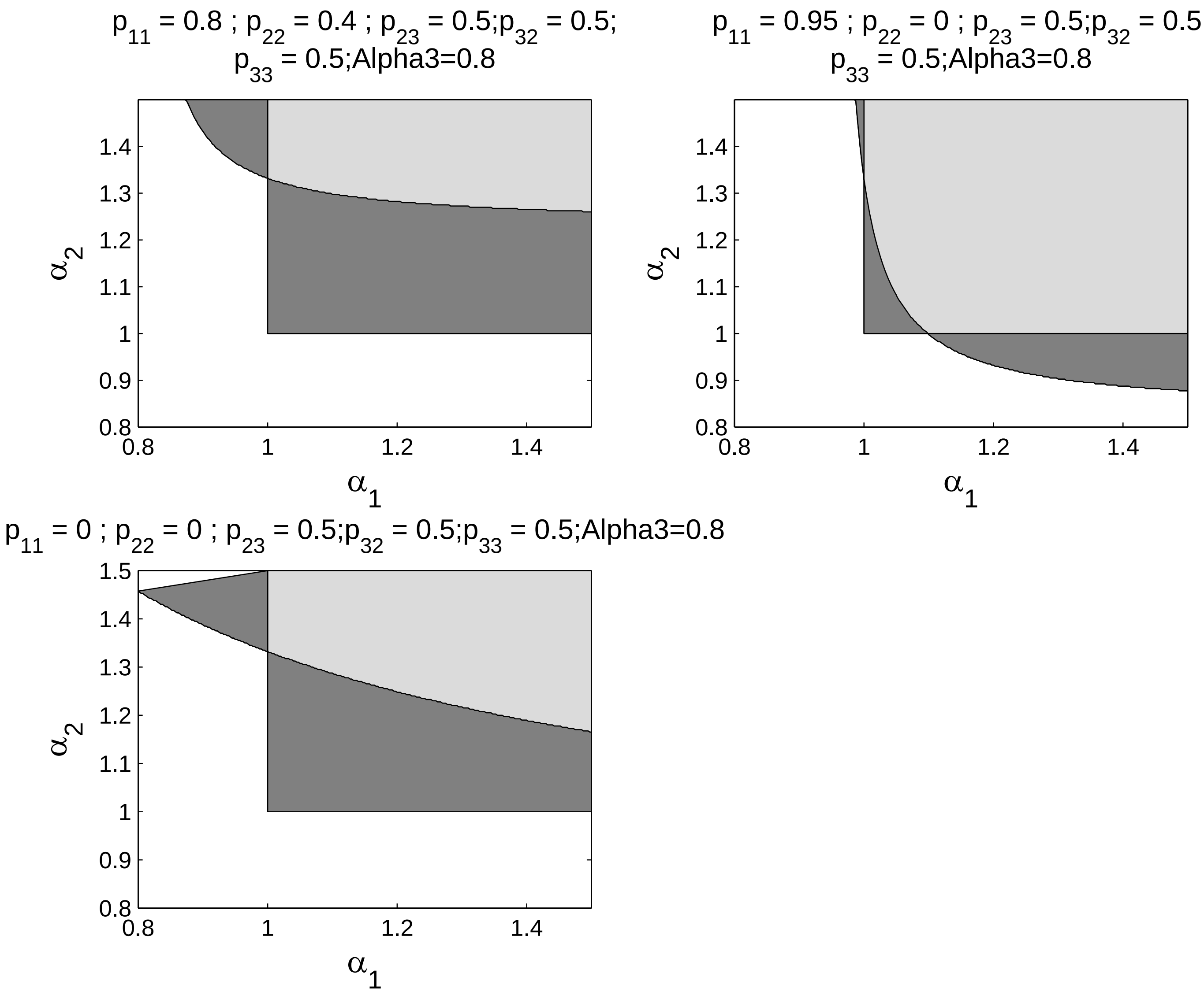


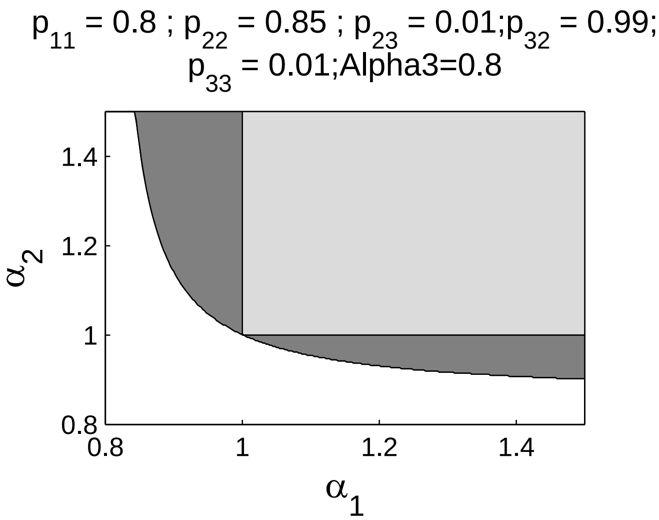
Appendix-3

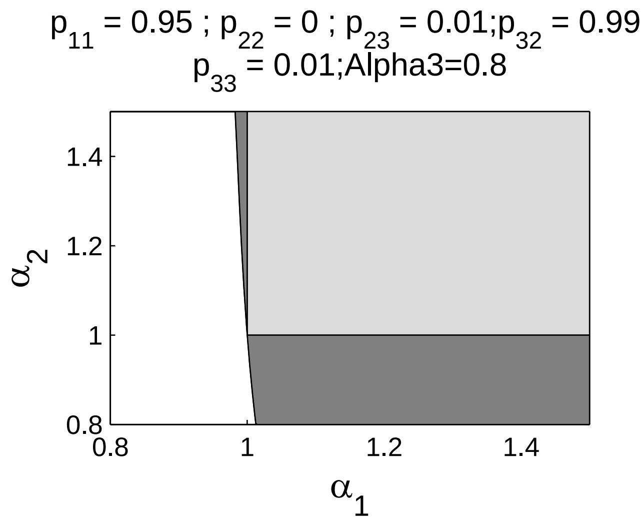
Appendix-4

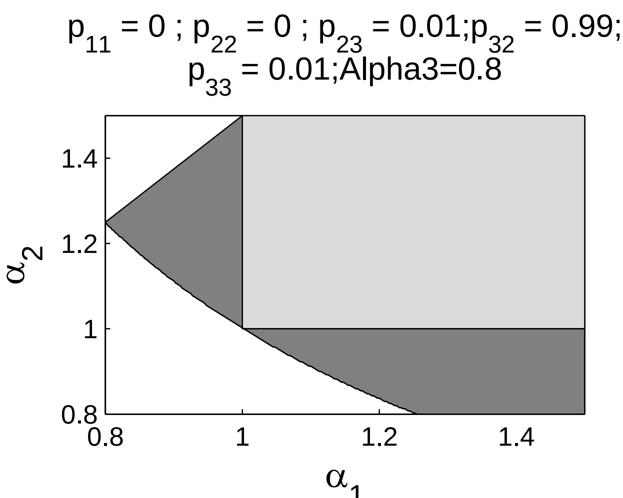


Appendix-4

Appendix-5







Appendix-5

Appendix-6

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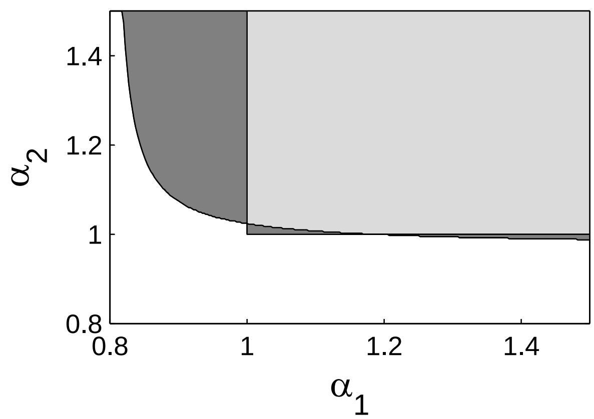
$p_{33} = 0.01$;Alpha3=0.8



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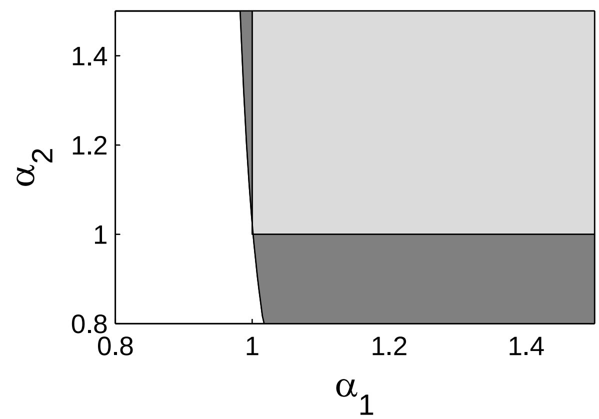

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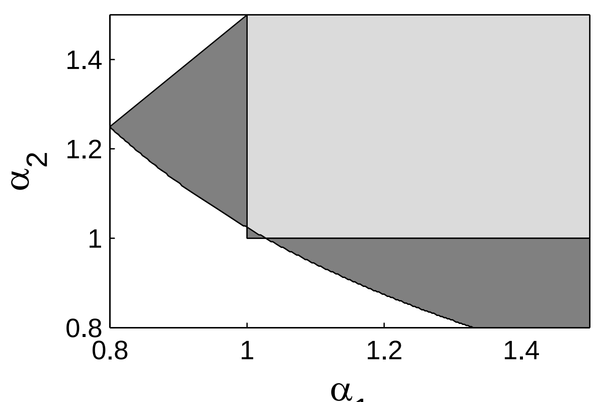

Appendix-6

Appendix-7

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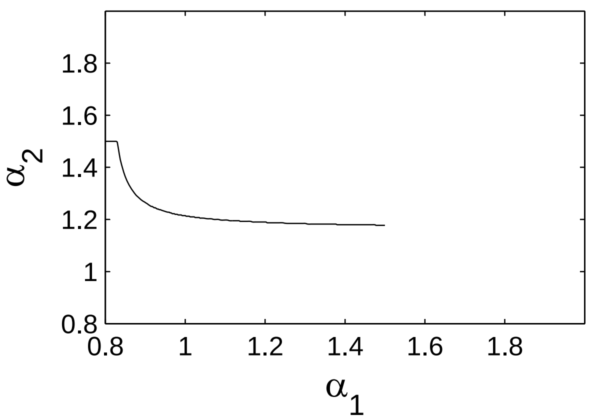

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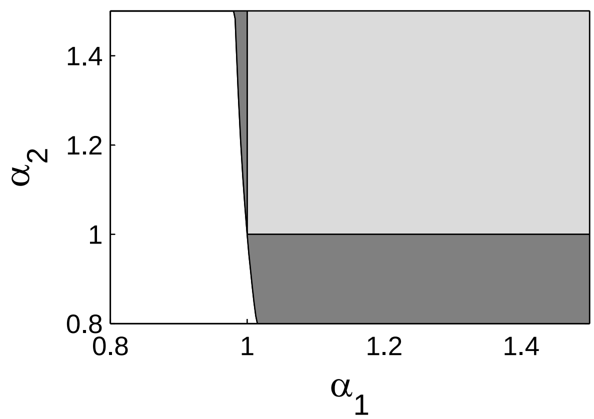

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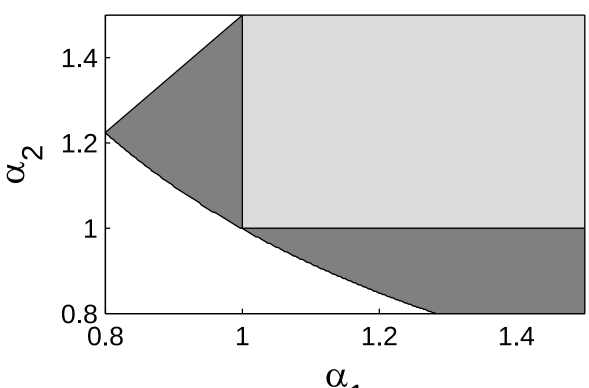

Appendix-7

Appendix-8

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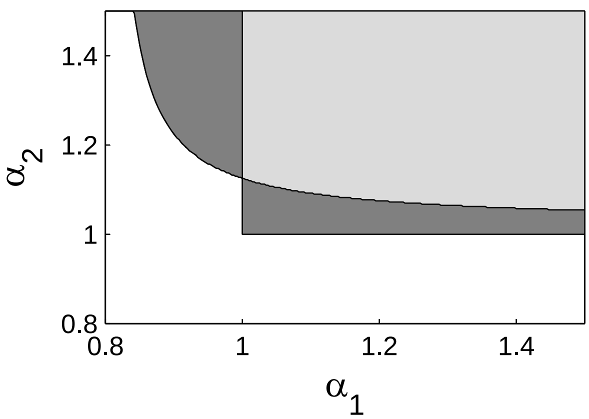

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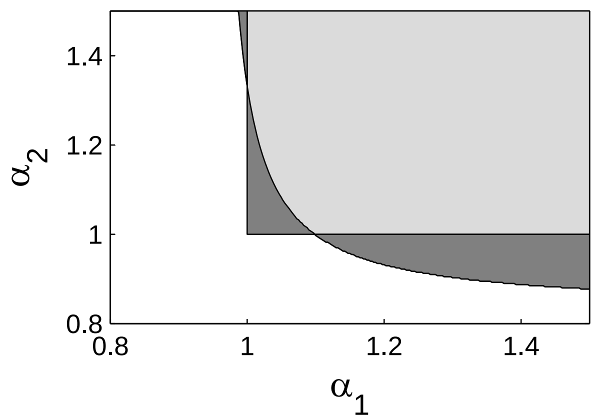

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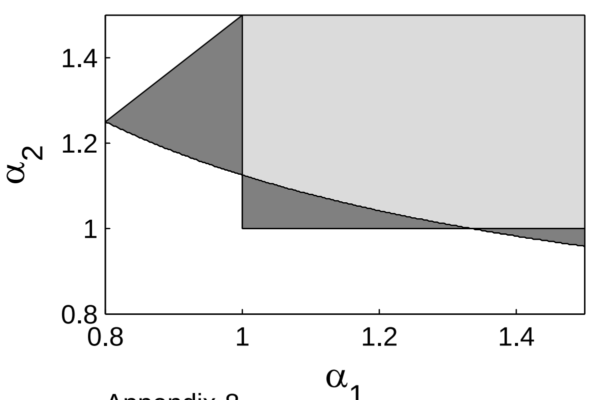
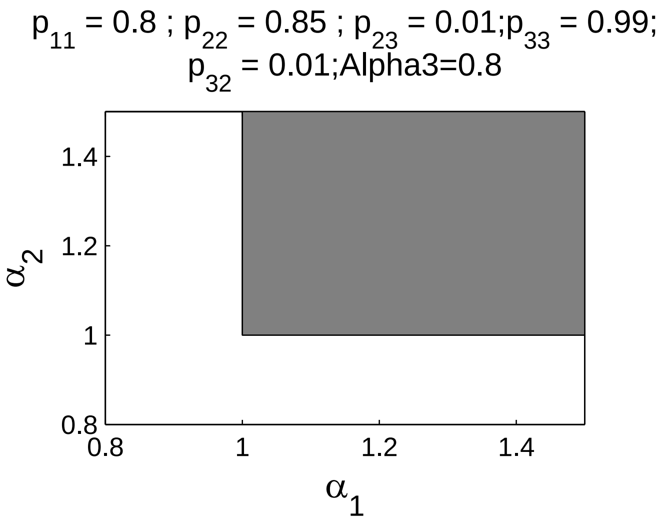
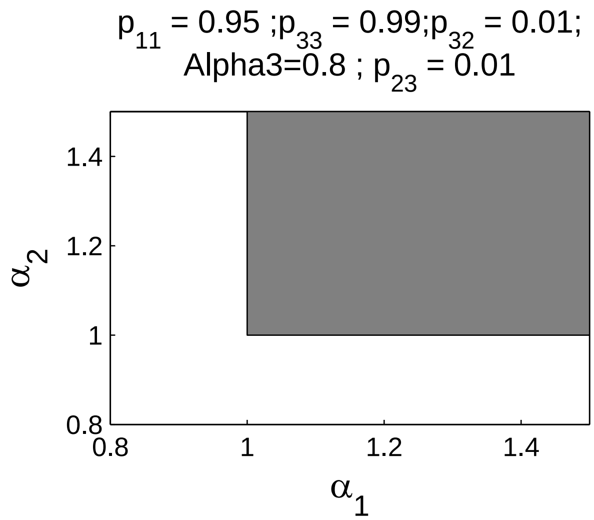
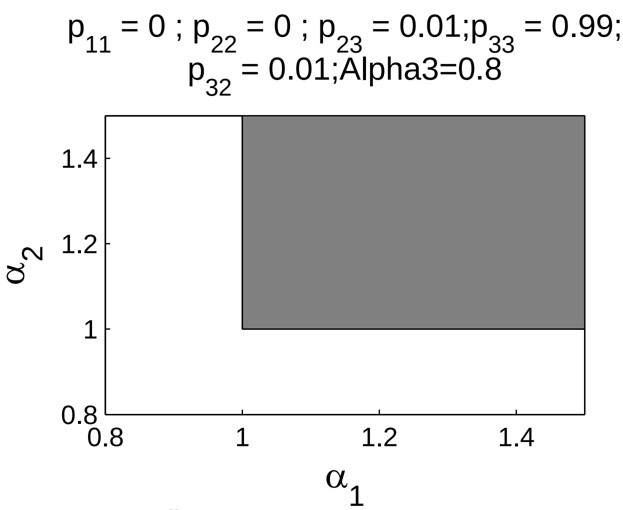


Appendix-8

Appendix-9







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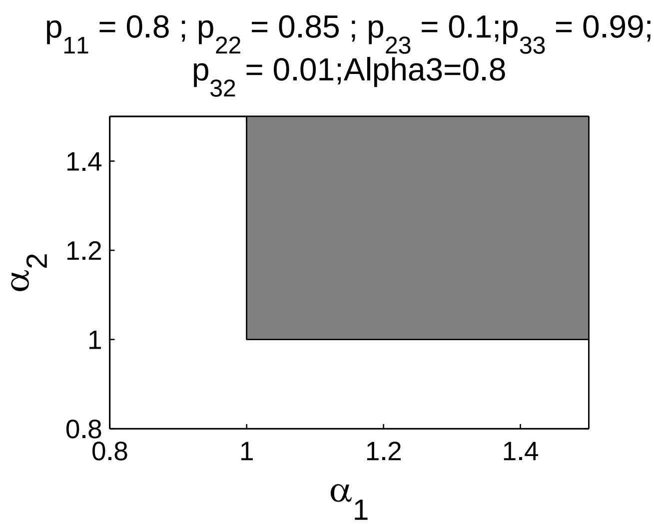
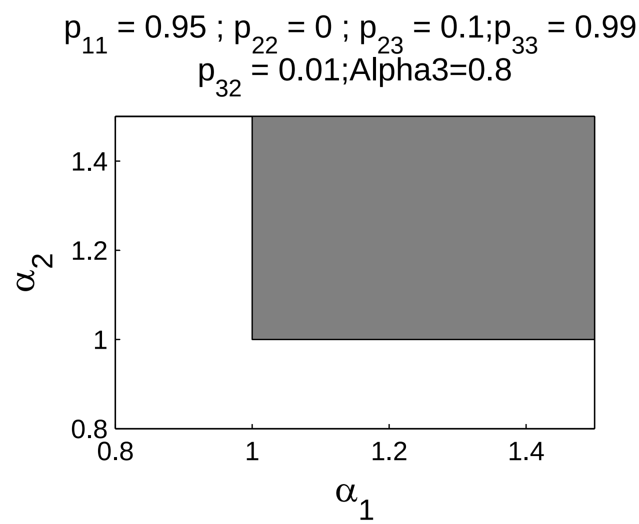
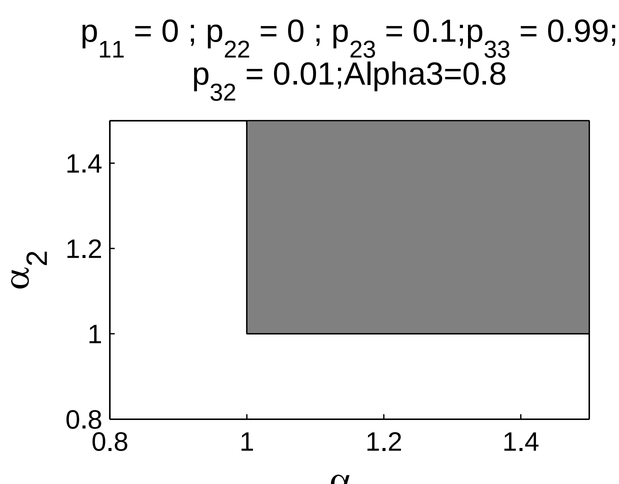
Appendix-10

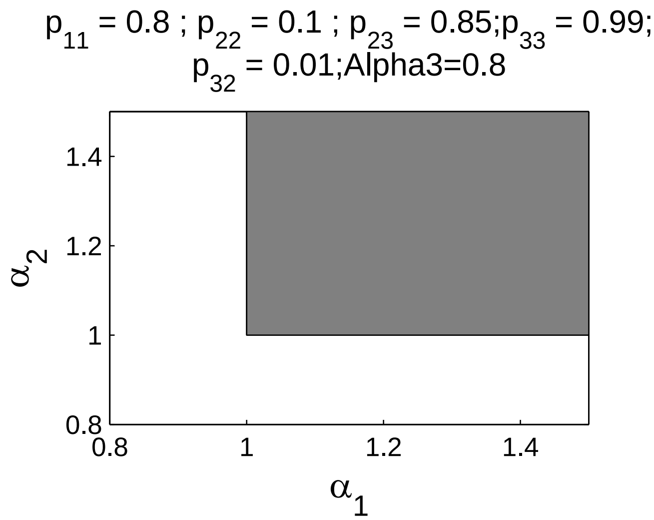


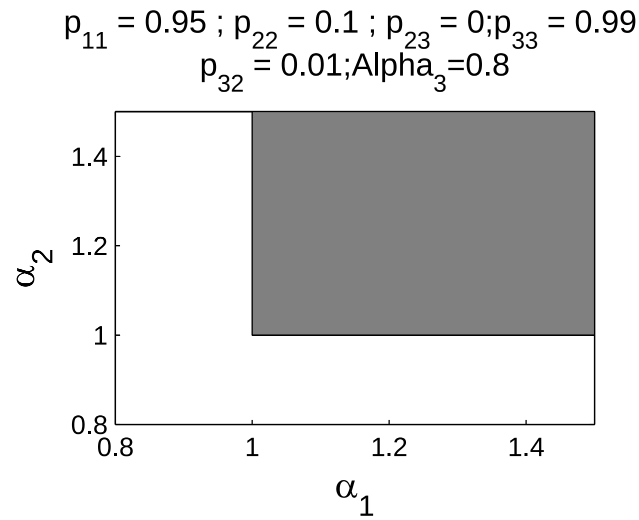


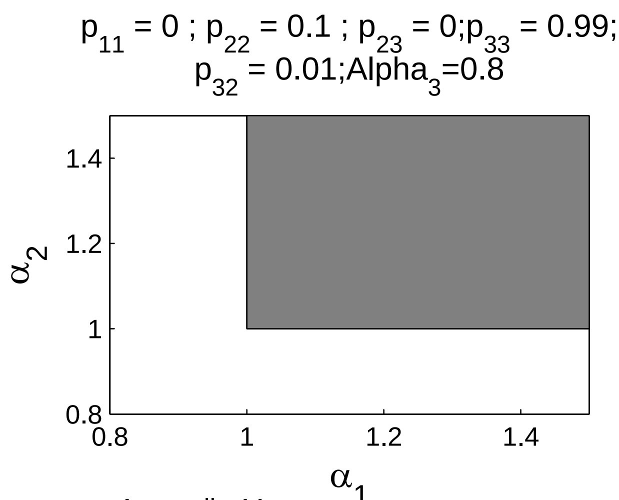


Appendix-10

Appendix-11







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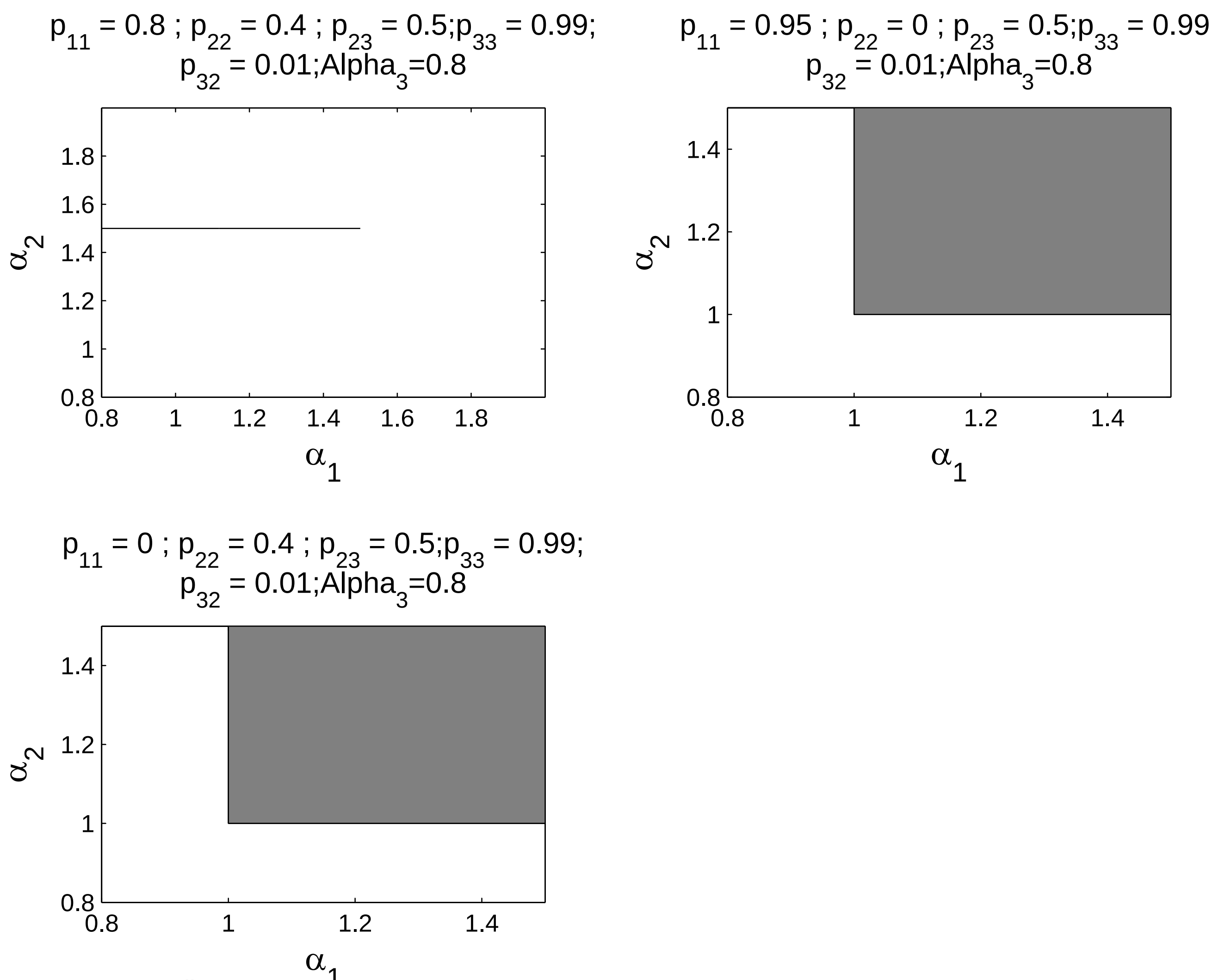
Appendix-12



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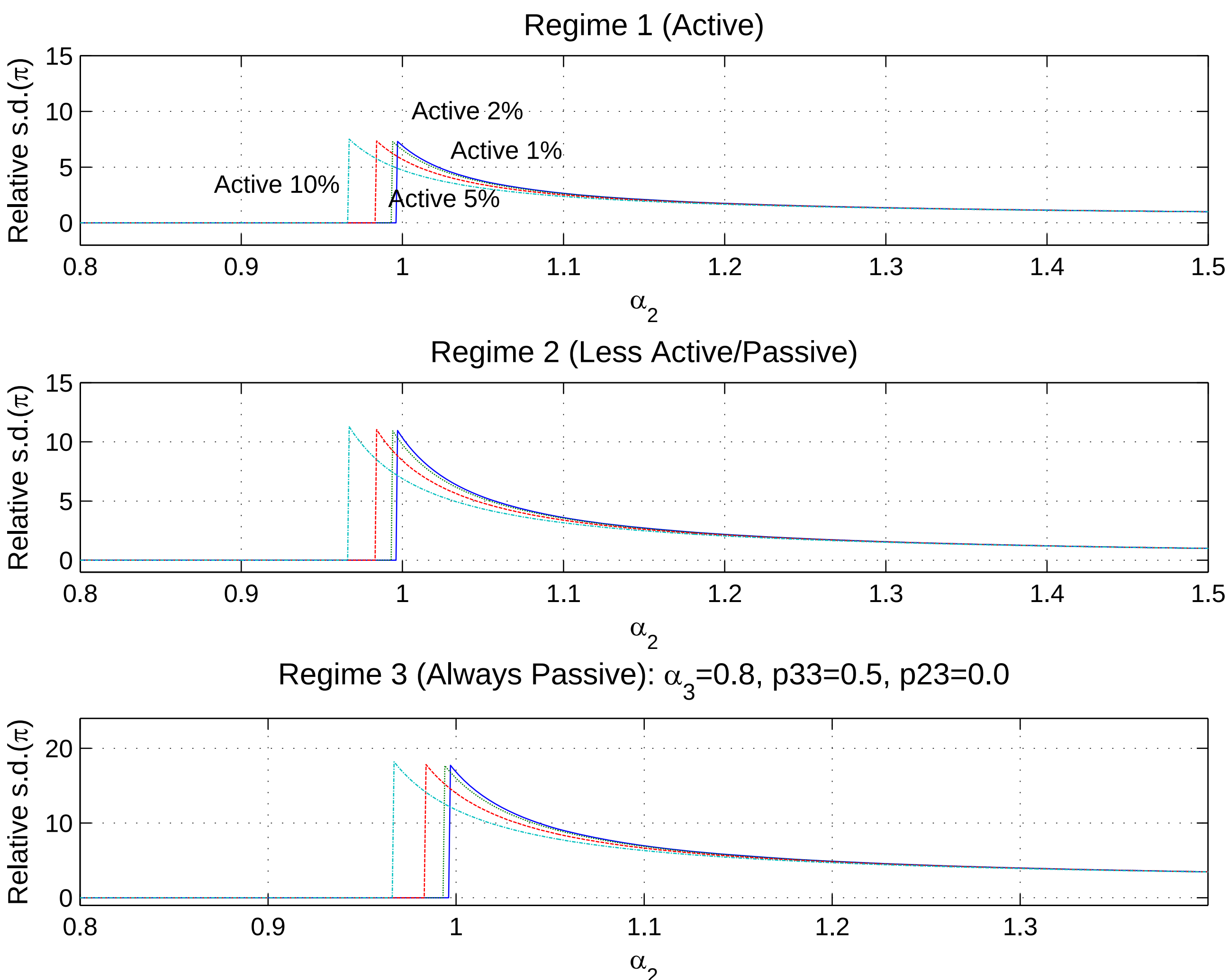
Appendix-13



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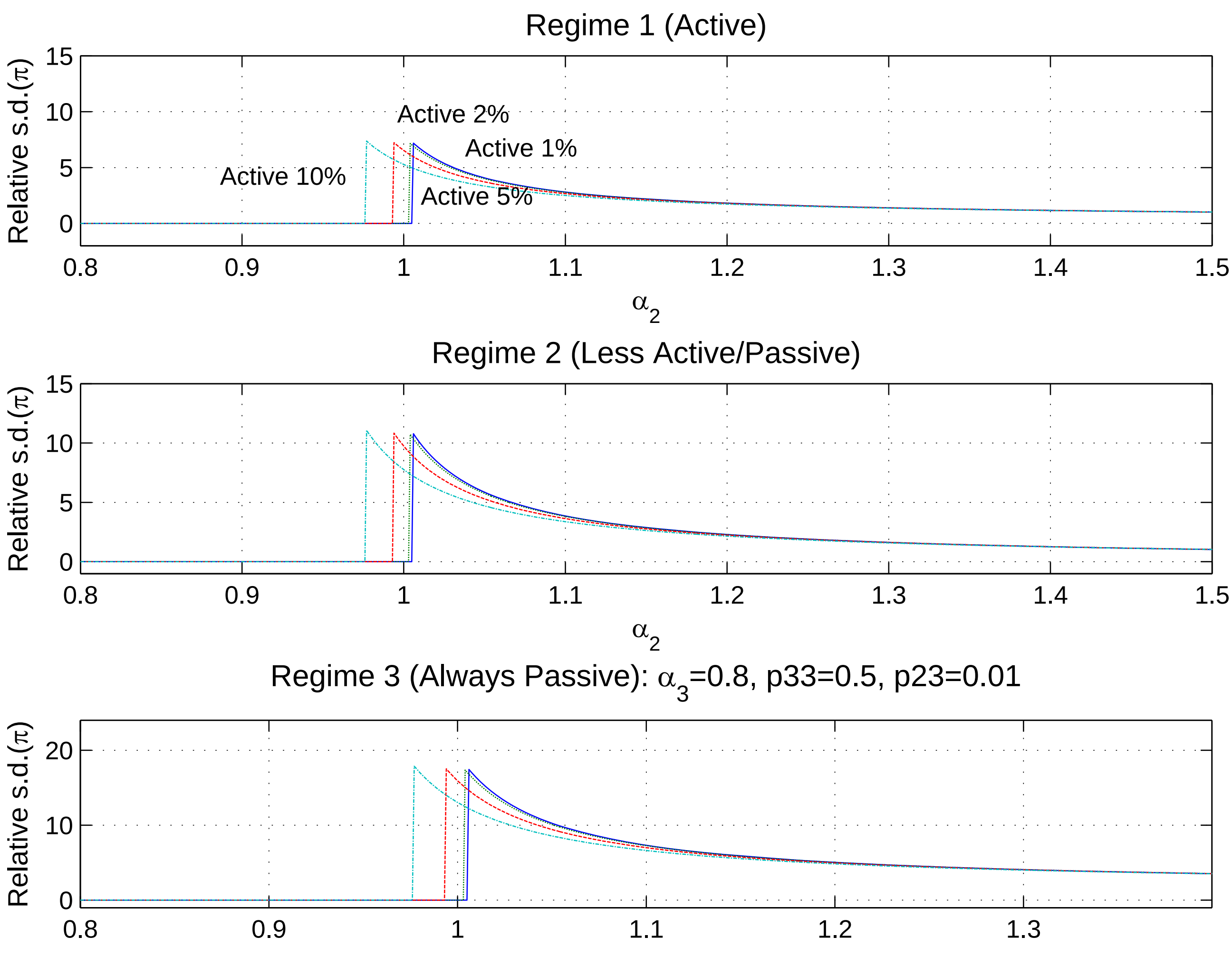
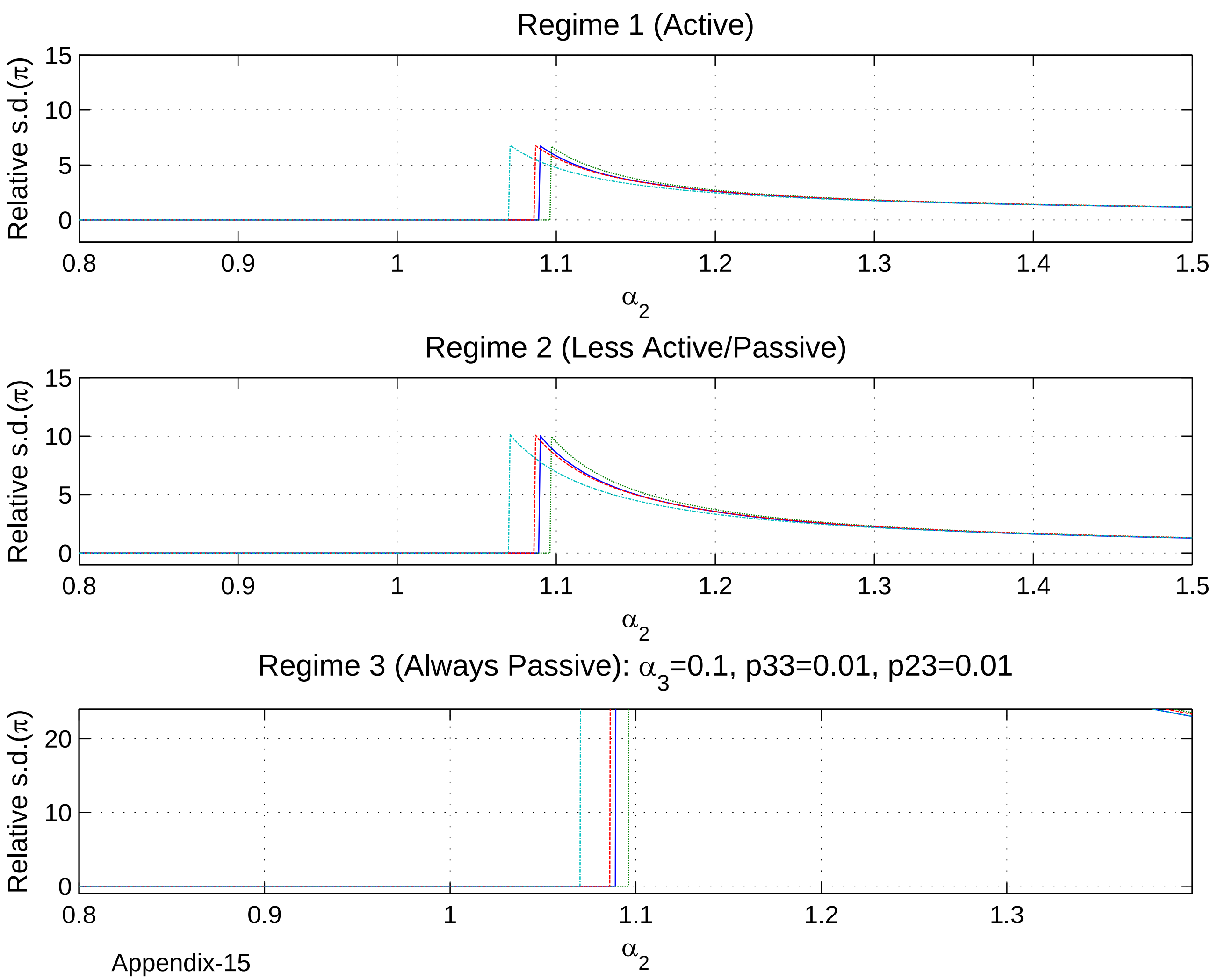
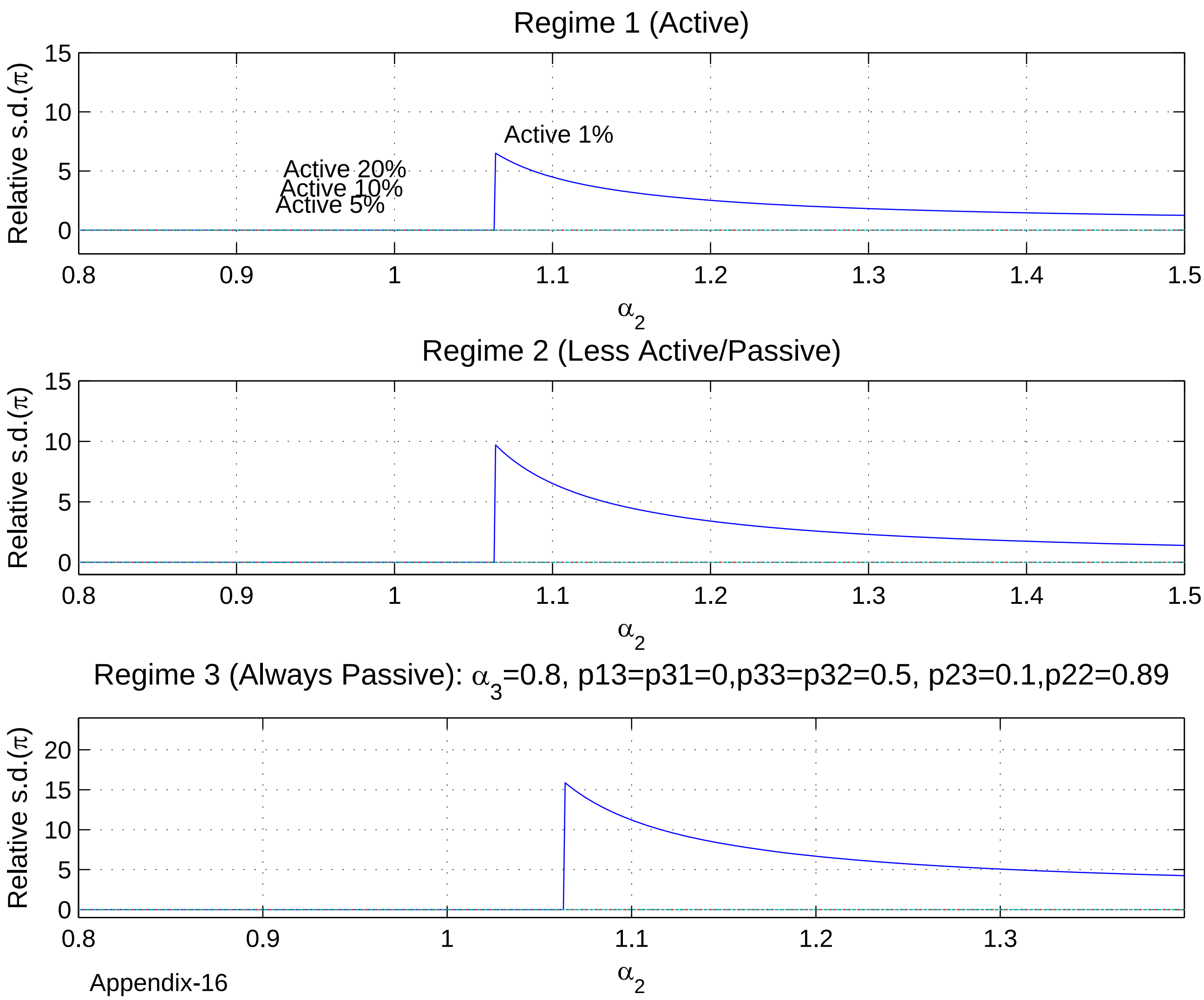


Regime 1 (Active)
Relative s.d.(π)
15
10
5
0
Active 2%
Active 1%
Active 10%
Active 5%
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
α2
Regime 2 (Less Active/Passive)
Relative s.d.(π)
15
10
5
0
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
α2
Regime 3 (Always Passive): α3=0.8, p33=0.5, p23=0.01
Relative s.d.(π)
20
10
0
0.8
0.9
1
1.1
1.2
1.3
α2

Appendix-15


Regime 1 (Active)
Relative s.d.(π)
15
10
5
0
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
α2
Regime 2 (Less Active/Passive)
Relative s.d.(π)
15
10
5
0
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
α2
Regime 3 (Always Passive): α3=0.1, p33=0.01, p23=0.01
Relative s.d.(π)
20
10
0
0.8
0.9
1
1.1
1.2
1.3
α2
Appendix-15

Appendix-16



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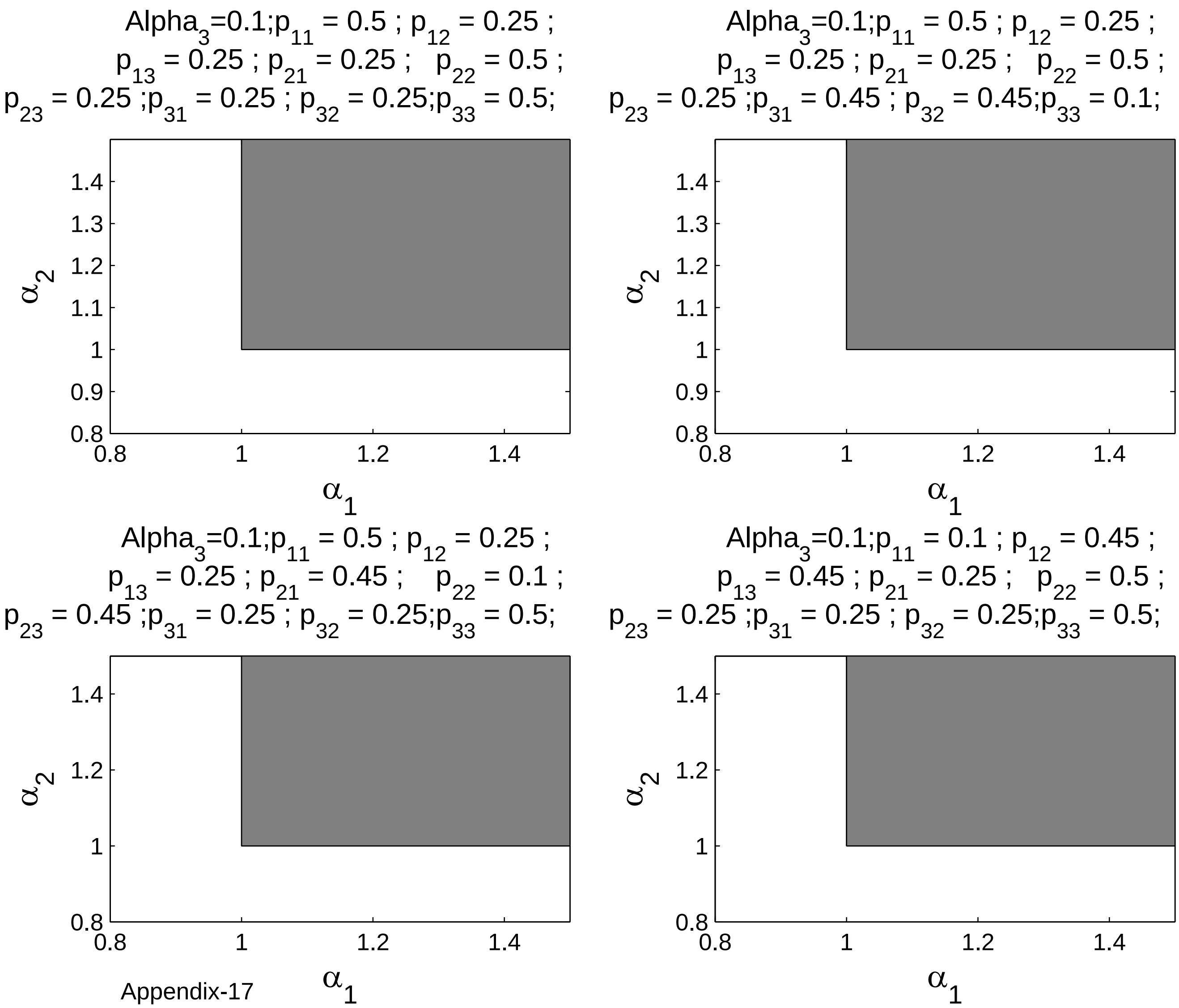
Appendix-17



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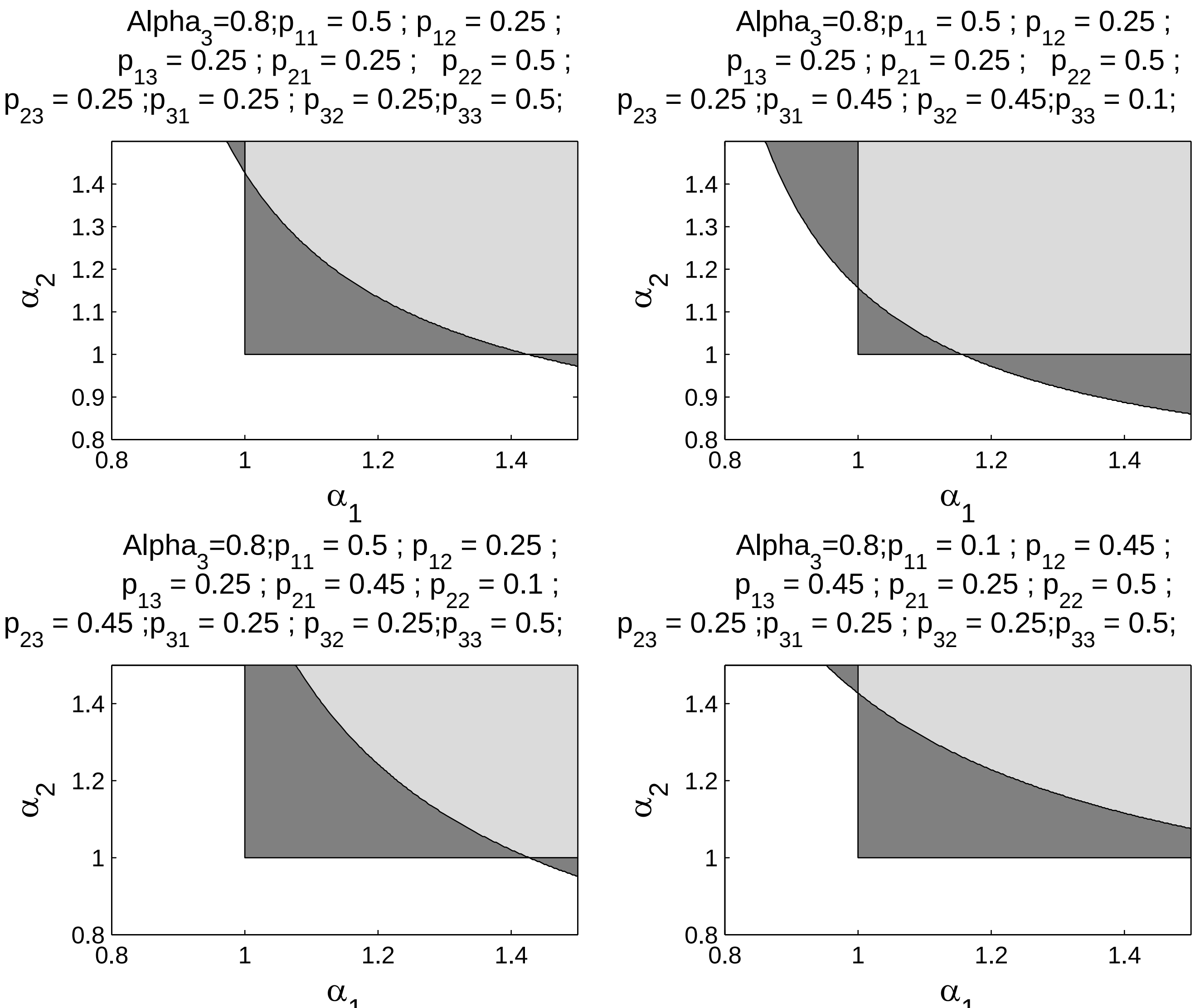
α_1
α_2
Appendix-17

Appendix-18



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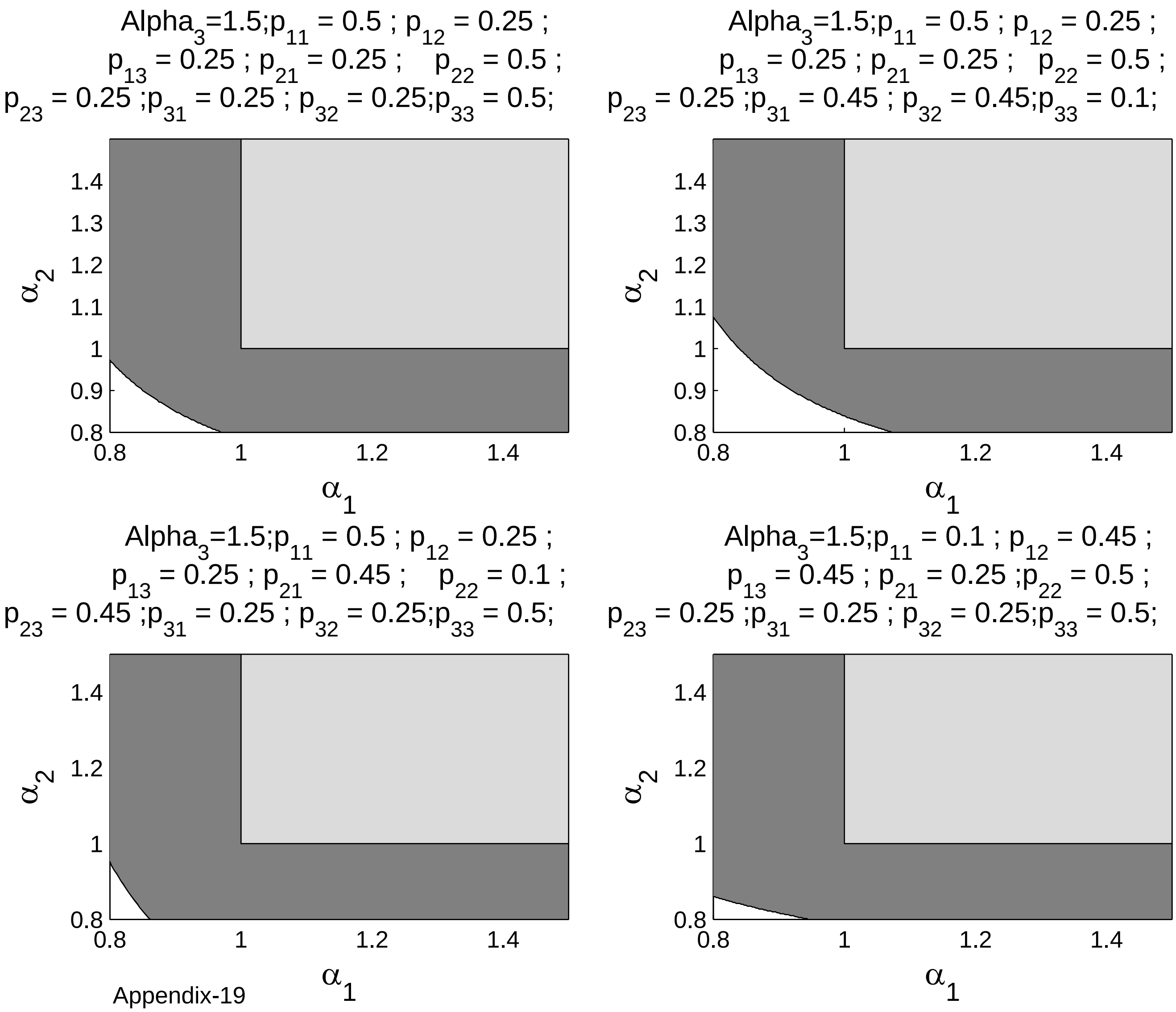
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α_2
α_1
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α_2
α_1
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α_2
α_1
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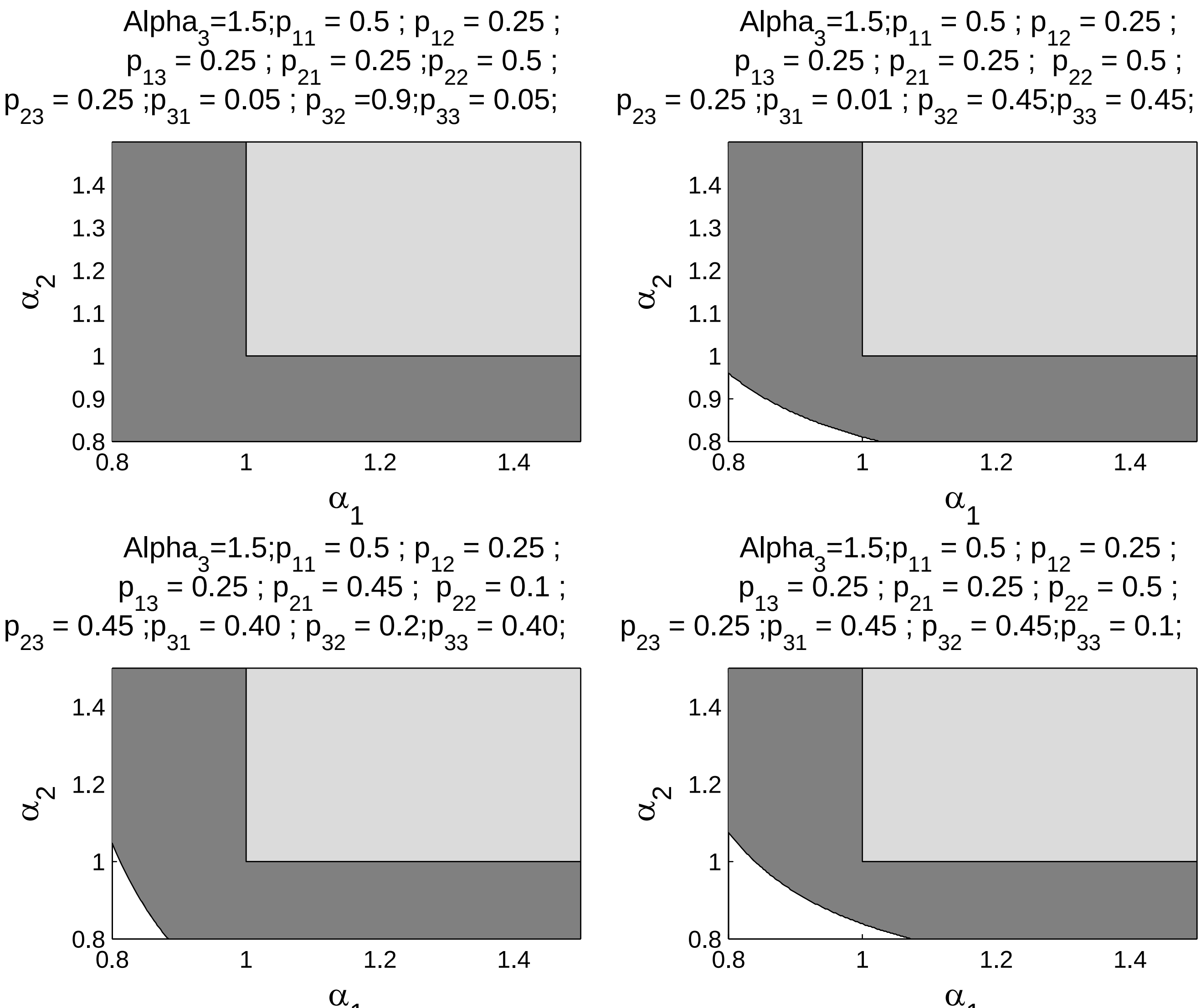
α_2
α_1
Appendix-19

Appendix-20



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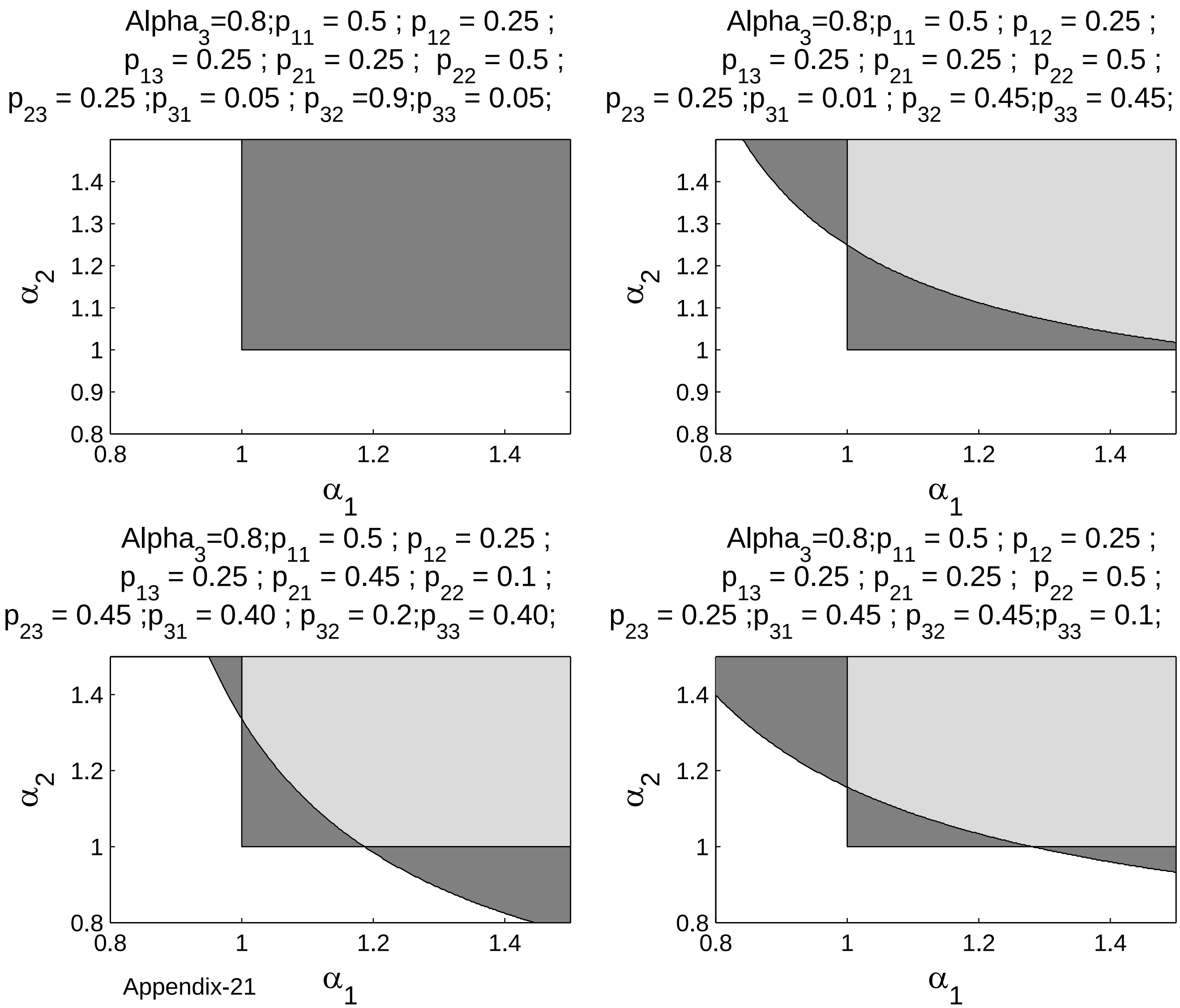
Appendix-21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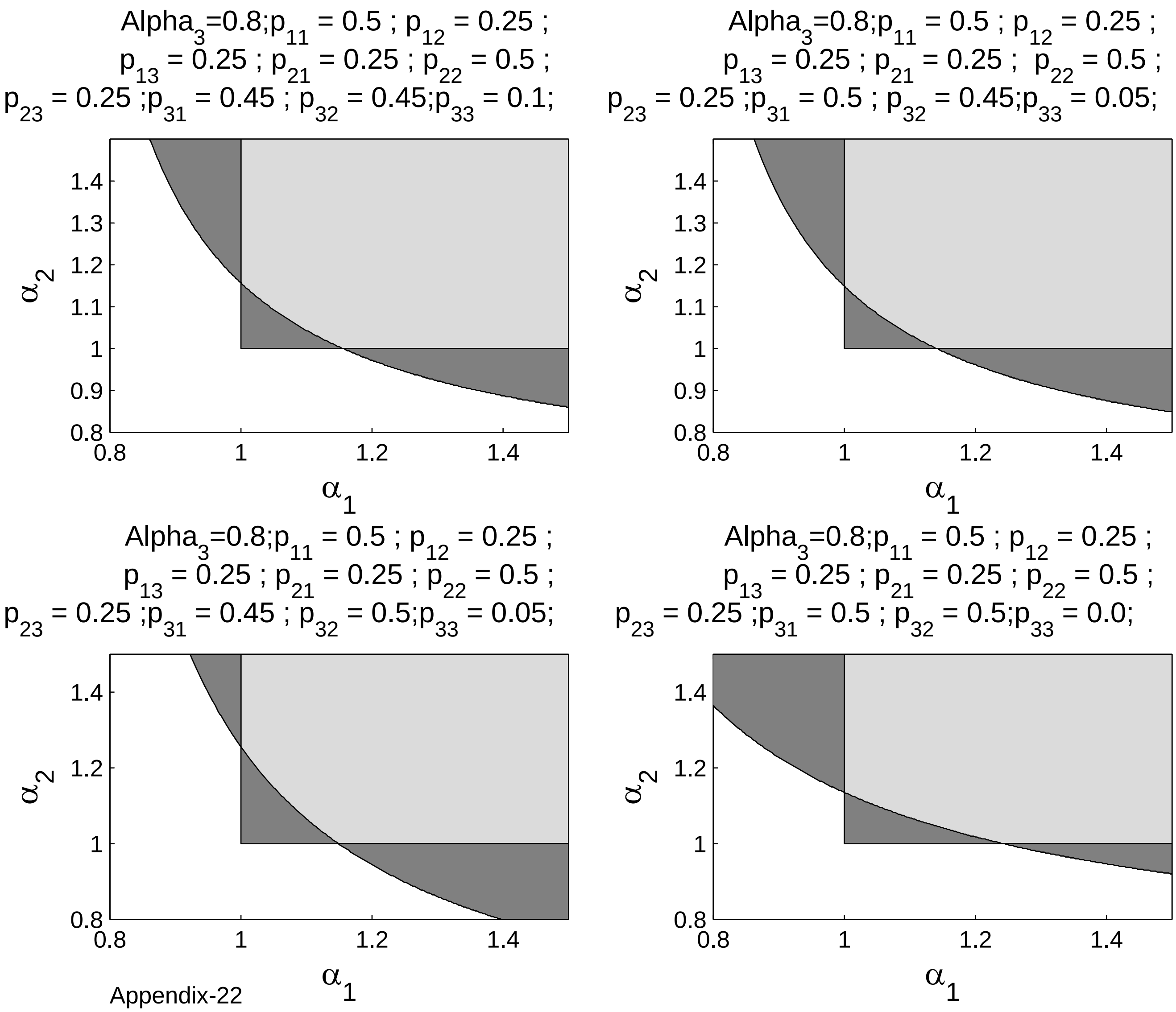
α_1
α_2
0.8
1
1.2
1.4
0.9
1.1
1.3
Appendix-21

Appendix-22



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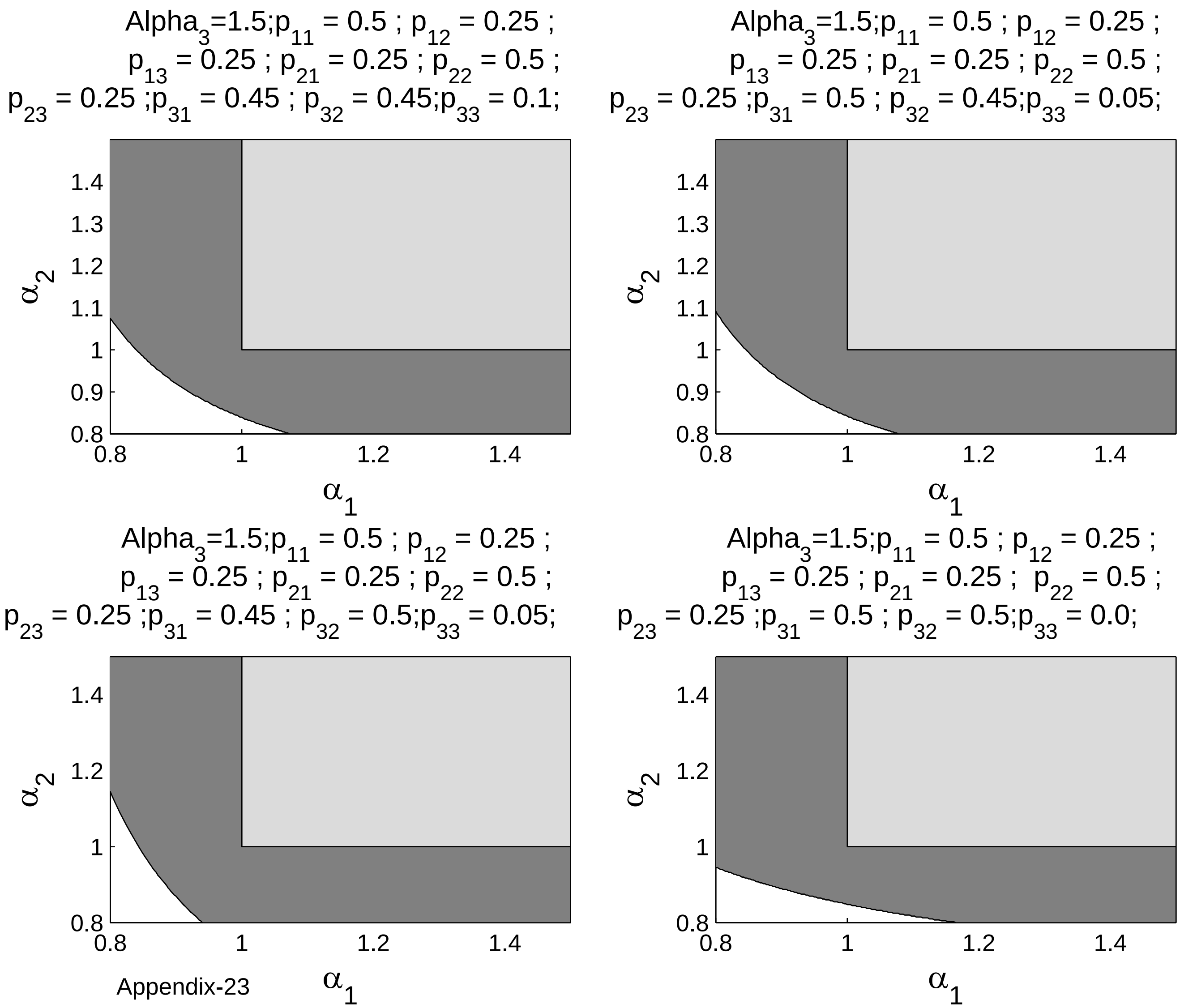
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Alpha$_3$=1.5;p$_{11}$ = 0.5 ; p$_{12}$ = 0.25 ;
p$_{13}$ = 0.25 ; p$_{21}$ = 0.25 ; p$_{22}$ = 0.5 ;
p$_{23}$ = 0.25 ;p$_{31}$ = 0.45 ; p$_{32}$ = 0.5;p$_{33}$ = 0.05;
Alpha$_3$=1.5;p$_{11}$ = 0.5 ; p$_{12}$ = 0.25 ;
p$_{13}$ = 0.25 ; p$_{21}$ = 0.25 ; p$_{22}$ = 0.5 ;
p$_{23}$ = 0.25 ;p$_{31}$ = 0.5 ; p$_{32}$ = 0.5;p$_{33}$ = 0.0;
α_1
α_2
0.8
0.9
1
1.1
1.2
1.3
1.4
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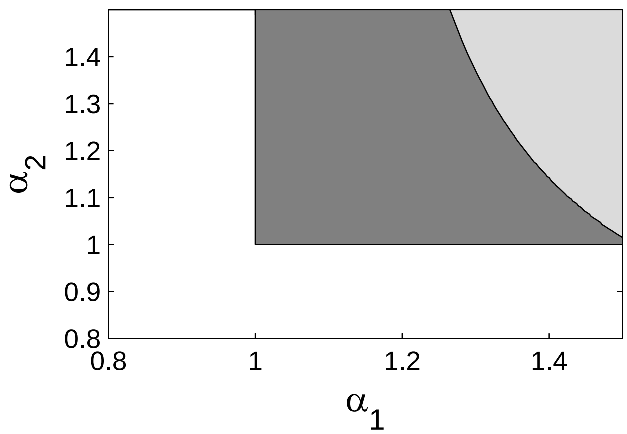
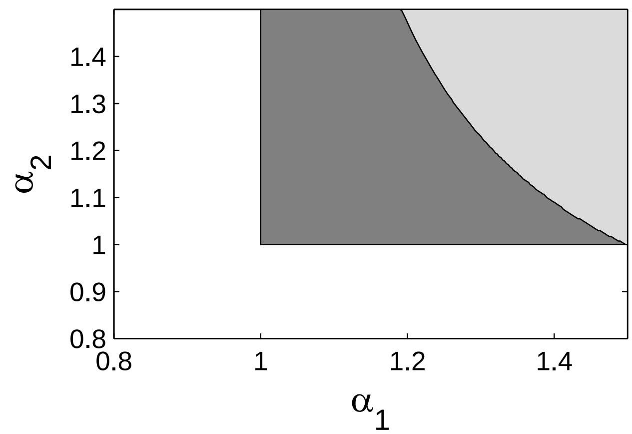
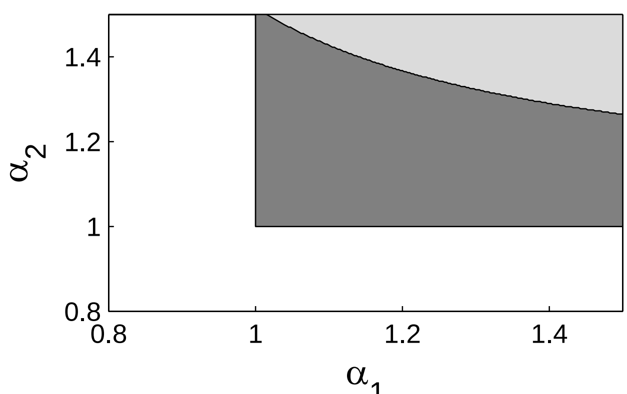
Alpha$_3$=0.8;p_{11} = 0.15 ; p_{12} = 0.15 ;
p_{13} = 0.70 ; p_{21} = 0.25 ;p_{22} = 0.5 ;
p_{23} = 0.25 ;p_{31} = 0.45 ; p_{32} = 0.1;p_{33} = 0.45;



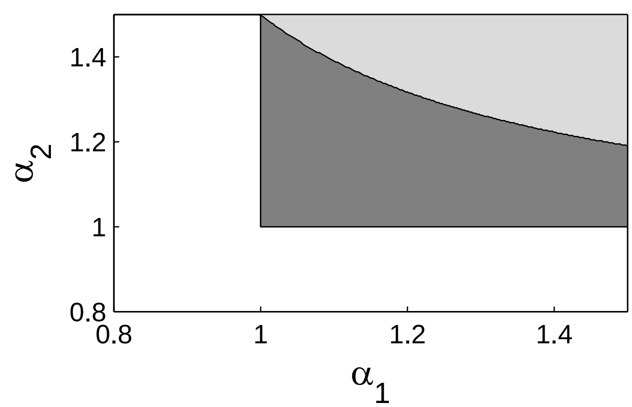
Alpha$_3$=0.8;p_{11} = 0.45 ; p_{12} = 0.1 ;
p_{13} = 0.45 ; p_{21} = 0.25 ; p_{22} = 0.5 ;
p_{23} = 0.25 ;p_{31} = 0.45 ; p_{32} = 0.1;p_{33} = 0.45;



Alpha$_3$=0.8;p_{11} = 0.5 ; p_{12} = 0.25 ;
p_{13} = 0.25 ; p_{21} = 0.15 ;p_{22} = 0.15 ;
p_{23} = 0.70 ;p_{31} = 0.1 ; p_{32} = 0.45;p_{33} = 0.45;



Alpha$_3$=0.8;p_{11} = 0.5 ; p_{12} = 0.25 ;
p_{13} = 0.25 ; p_{21} = 0.30 ; p_{22} = 0.35 ;
p_{23} = 0.45 ;p_{31} = 0.1 ; p_{32} = 0.45;p_{33} = 0.45;



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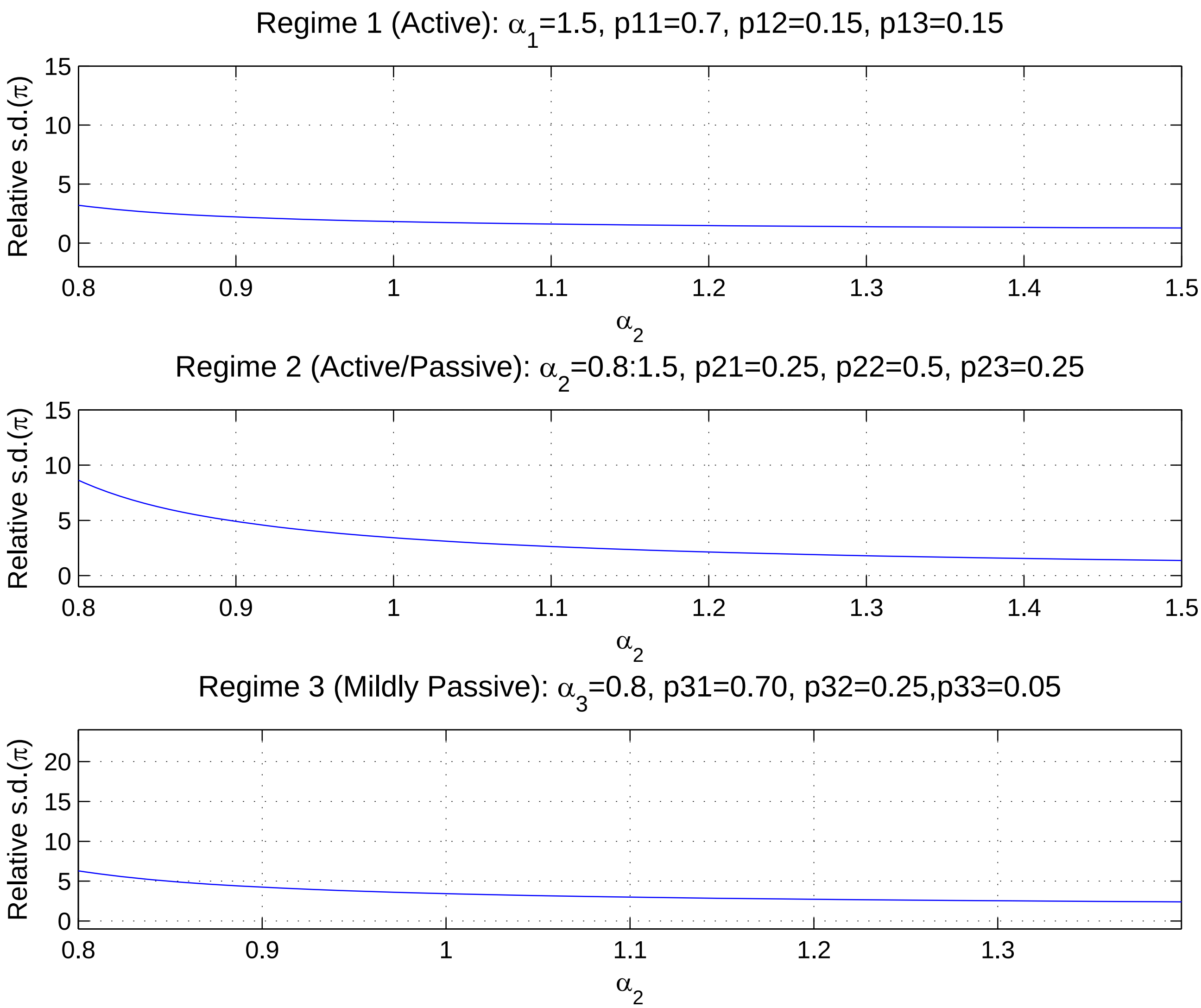
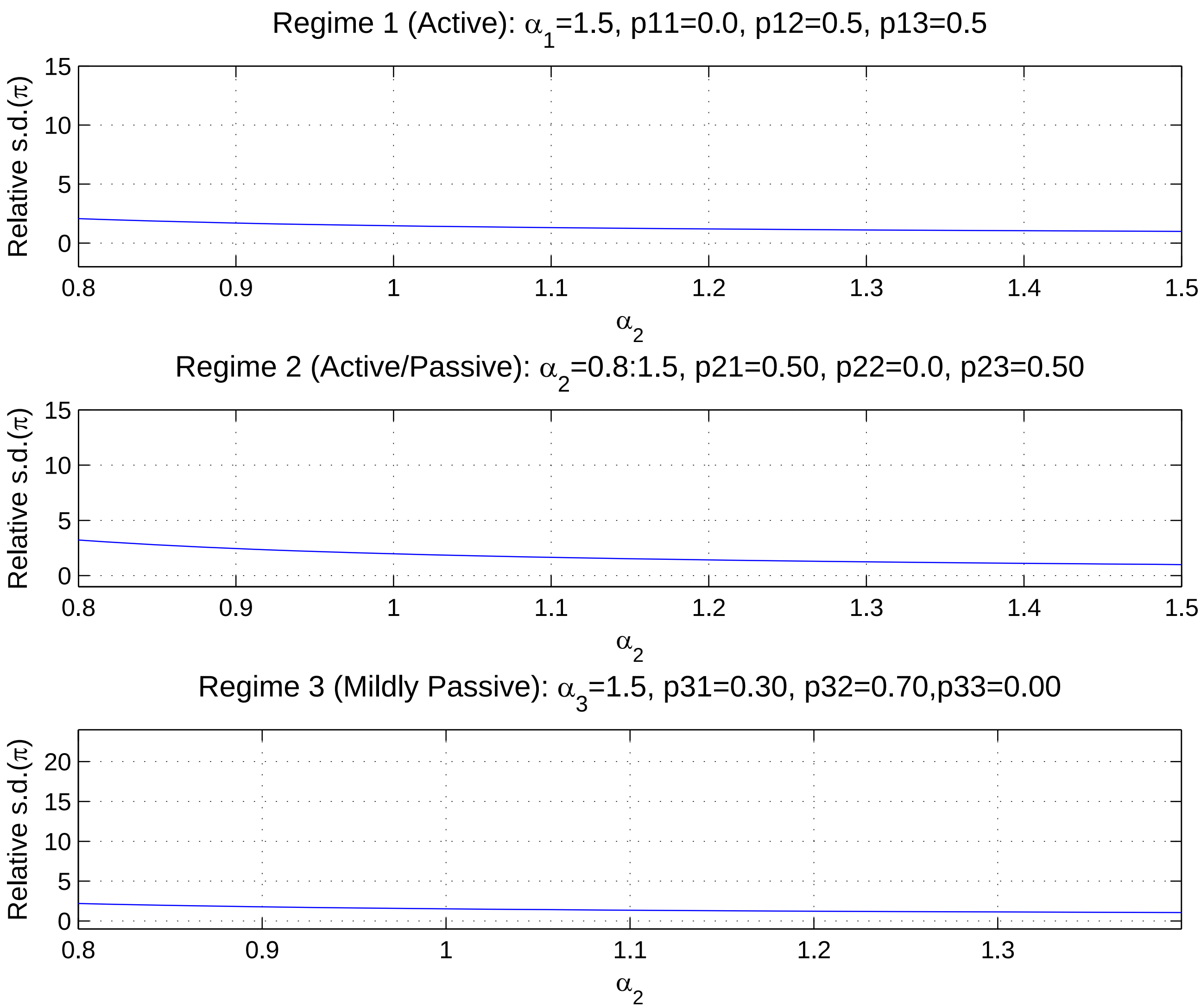


Regime 1 (Active): α1=1.5, p11=0.7, p12=0.15, p13=0.15
Relative s.d.(π)
15
10
5
0
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
α2
Regime 2 (Active/Passive): α2=0.8:1.5, p21=0.25, p22=0.5, p23=0.25
Relative s.d.(π)
15
10
5
0
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
α2
Regime 3 (Mildly Passive): α3=0.8, p31=0.70, p32=0.25,p33=0.05
Relative s.d.(π)
20
15
10
5
0
0.8
0.9
1
1.1
1.2
1.3
α2

Appendix-27



Appendix-27

Appendix-27

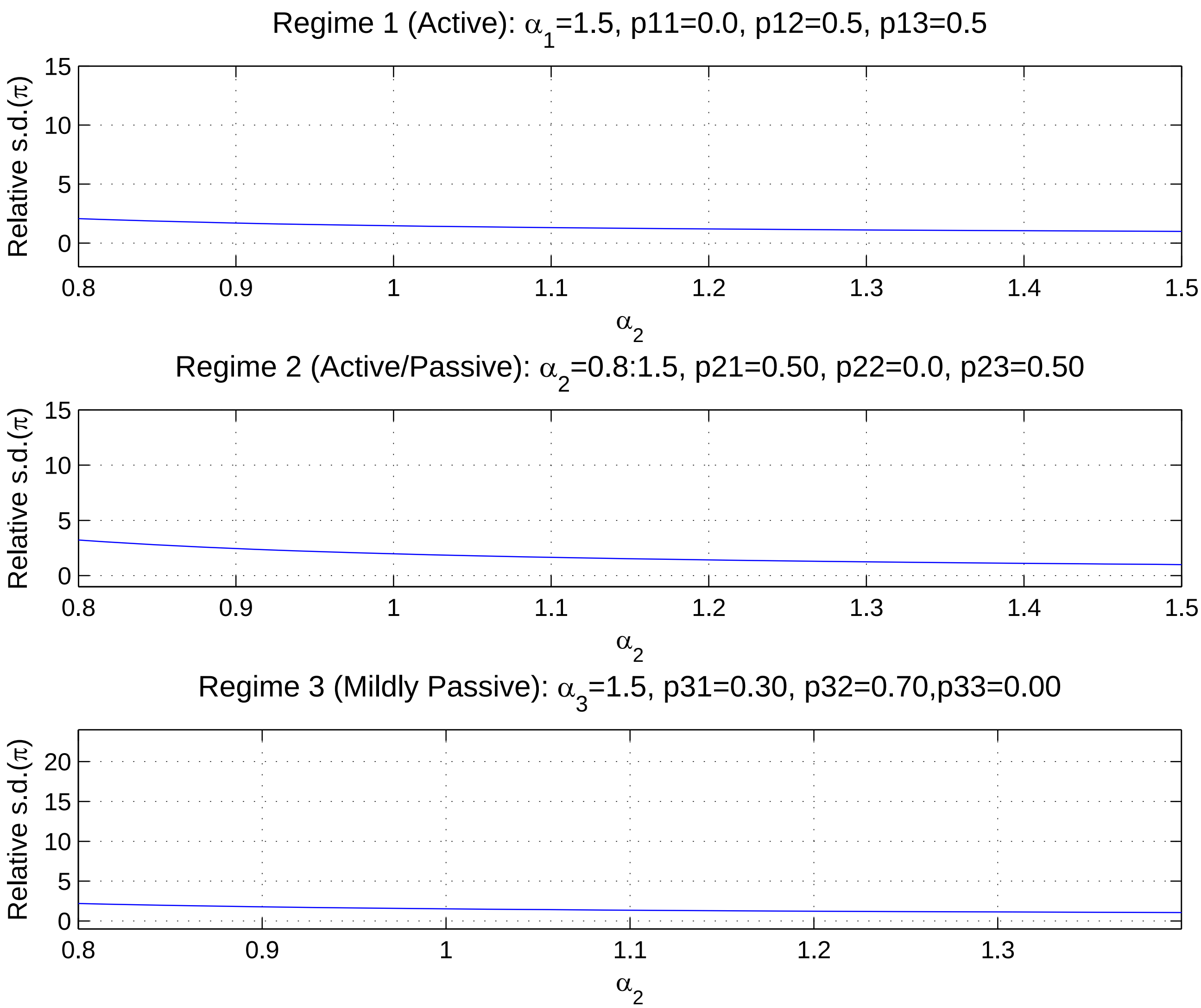


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Table1.1

p_11	Alpha2	Regime1 Active	Regime2 Very Passive	Regime3 Mildly Passive	Alpha3	p_33	p_23
0.95	0.1	5.547(1.25)	58.197(17.43)	86.749(27.2)	0.8	0.5	0
							0
0.975	0.1	1.9551(.80)	24.074(13.1)	36.877(20.9)	0.8	0.5	0
	0.05	6.6224(1.3)	136.83(35.76)	201.67(53.96)	0.8	0.5	0
0.99	0.1	1.2834(0.62)	17.693(11.4)	27.551(18.36)	0.8	0.5	0
	0.05	1.7269(0.74)	43.811(25.15)	65.724(38.45)	0.8	0.5	0
	0.025	3.8237(1.09)	167.3(63.3)	246.21(94.2)	0.8	0.5	0
	0.02	7.4942(1.33)	383.48(90.8)	562.16(134.48)	0.8	0.5	0
							0
0.995	0.1	1.1305(0.57)	16.24(10.9)	25.427(17.65)	0.8	0.5	0
	0.05	1.2966(0.62)	35.635(22.86)	53.774(35.11)	0.8	0.5	0
	0.025	1.7488(0.75)	88.456(50.45)	130.97(75.43)	0.8	0.5	0
	0.02	2.068(0.83)	125.73(66.50)	185.45(98.87)	0.8	0.5	0
							0
0.999	0.1	1.0245(0.533)	15.233(10.56)	23.956(17.13)	0.8	0.5	0
	0.05	1.0517(0.54)	30.982(21.31)	46.974(32.84)	0.8	0.5	0
	0.025	1.1089(0.563)	64.137(43.38)	95.431(65.1)	0.8	0.5	0
	0.02	1.139(0.573)	81.602(54.71)	120.96(81.65)	0.8	0.5	0
Addendum							
0.999							
Alpha1=2.0	0.001	7.2247	7413.4	10837	0.8	0.5	

Note: We have always assumed p_13 = p_31 = p_23 =p_22 = 0

Table1.2

p_11	Alpha2	Regime1 Active	Regime2 Very Passive	Regime3 Mildly Passive	Alpha3	p_33	p_23
0.95	0.1	ND	ND	ND	0.8	0.5	0.01
0.975	0.1	2.2462(0.87)	31.105(16.04)	47.153(25.14)	0.8	0.5	0.01
	0.05	ND	ND	ND	0.8	0.5	0.01
0.99	0.1	1.3438(0.64)	21.25(13.57)	32.75(21.53)	0.8	0.5	0.01
	0.05	2.2393(0.86)	73.989(38.1)	109.83(57.35)	0.8	0.5	0.01
	0.02	ND	ND	ND	0.8	0.5	0.01
0.995	0.1	1.1558(0.58)	19.196(12.9)	29.749(20.55)	0.8	0.5	0.01
	0.05	1.4487(0.67)	53.4(33.14)	79.738(50.13)	0.8	0.5	0.01
0.999	0.1	1.029(0.53)	17.811(12.41)	27.724(19.83)	0.8	0.5	0.01
	0.02	1.5757(0.71)	334.9(200.9)	491.17(295.45)	0.8	0.5	0.01
0.999	0.001	ND	ND	ND	0.8	0.5	0.01

Note: We have always assumed p_13 = p_31 = p_22 = 0

Table1.3

p_11	Alpha2	Regime1 Active	Regime2 Very Passive	Regime3 Mildly Passive	Alpha3	p_33	p_23
0.95	0.1	ND	ND	ND	0.8	0.01	0.01
0.975	0.1	2.1715(0.85)	29.301(15.29)	35.556(18.89)	0.8	0.01	0.01
0.995	0.1	1.1495(0.58)	18.464(12.40)	22.664(15.445)	0.8	0.01	0.01
0.999	0.1	1.0279(0.53)	17.175(11.94)	21.129(14.9)	0.8	0.01	0.01

Note: We have always assumed p_13 = p_31 = p_22 = 0

Table1.4

		Regime1	Regime2	Regime3				
p_11	**Alpha2**	**Active**	**Very Passive**	**Mildly Passive**	**Alpha3**	**p_33**	**p_23**	**p_13**
0.975	0.4	1.3684	9.9008	12.475	0.8	0.01	0.2	0.025
	0.5	1.1994	5.8178	7.6175	0.8	0.01	0.2	
	0.5	1.3886	10.389	13.056	0.8	0.01	0.3	
0.99	0.4	1.1337	8.8752	11.255	0.8	0.01	0.2	0.01
	0.5	1.076	5.4753	7.21	0.8	0.01	0.2	
	0.5	1.1421	9.3698	11.844	0.8	0.01	0.3	
0.995	0.4	1.0649	8.5744	10.897	0.8	0.01	0.2	0.005
	0.5	1.0374	5.3683	7.0827	0.8	0.01	0.2	
	0.5	1.0691	9.068	11.484	0.8	0.01	0.3	
0.999	0.4	1.0127	8.3464	10.626	0.8	0.01	0.2	0.001
	0.5	1.0074	5.285	6.9836	0.8	0.01	0.2	
	0.5	1.0135	8.8384	11.211	0.8	0.01	0.3	

Note: We have assumed p_22=p_31=p_13=0

Table1.5

		Regime1	Regime2	Regime3				
p_11	**Alpha2**	**Active**	**Very Passive**	**Mildly Passive**	**Alpha3**	**p_33**	**p_23**	**p_13**
0.95	0.4	1.3349	5.2123	2.7391	2	0.01	0.2	0.05
	0.5	1.2164	3.7223	2.0351	2	0.01	0.2	
	0.5	1.2362	3.9712	2.1527	2	0.01	0.3	
0.975	0.4	1.1563	4.7747	2.5324	2	0.01	0.2	0.025
	0.5	1.1041	3.5141	1.9367	2	0.01	0.2	
	0.5	1.1138	3.7483	2.0474	2	0.01	0.3	
0.99	0.4	1.0601	4.5392	2.421	2	0.01	0.2	0.01
	0.5	1.0407	3.3967	1.8812	2	0.01	0.2	
	0.5	*1.0445*	*3.6223*	1.9878	2	0.01	0.3	
0.995	*0.4*	*1.0297*	*4.4646*	2.3858	2	0.01	0.2	0.005
	0.5	*1.0202*	*3.3588*	1.8633	2	0.01	0.2	
	0.5	*1.0221*	*3.5815*	1.9685	2	0.01	0.3	
0.999	*0.4*	*1.0059*	*4.4063*	2.3583	2	0.01	0.2	0.001
	0.5	*1.004*	*3.3288*	1.8491	2	0.01	0.2	
	0.5	*1.0044*	*3.5492*	1.9533	2	0.01	0.3	

Note: We have assumed p_22=p_31=p_13=0

Table1_6								
		Regime1	Regime2	Regime3				
p_11	Alpha2	Active	Very Passive	Mildly Passive	Alpha3	p_31	p_23	p_13
0.95	0.4	1.3431	6.4519	5.3158	0.8	0.5	0.2	0.05
	0.5	1.2502	4.576	4.1468	0.8	0.5	0.2	
	0.5	1.2973	5.5267	4.7392	0.8	0.5	0.3	
0.975	0.4	1.1605	5.897	4.8779	0.8	0.5	0.2	0.025
	0.5	1.1198	4.2822	3.895	0.8	0.5	0.2	
	0.5	1.1413	5.1333	4.4131	0.8	0.5	0.3	
0.99	0.4	1.0618	5.597	4.6412	0.8	0.5	0.2	0.01
	0.5	1.0468	4.1175	3.7538	0.8	0.5	0.2	
	0.5	1.0549	4.9155	4.2324	0.8	0.5	0.3	
0.999	0.4	1.006	5.4275	4.5074	0.8	0.5	0.2	0.001
	0.5	1.0046	4.0225	3.6723	0.8	0.5	0.2	
	0.5	1.0054	4.7906	4.1289	0.8	0.5	0.3	
Note: We assume p_12=p_22=p_33=0								

Table1_7								
		Regime1	Regime2	Regime3				
p_11	Alpha2	Active	Very Passive	Mildly Passive	Alpha3	p_32	p_23	p_13
0.95	0.4	1.0385	4.0532	1.4843	2	0.5	0.2	0.05
	0.5	1.0207	3.1307	1.261	2	0.5	0.2	
	0.5	1.0218	3.1853	1.2742	2	0.5	0.3	
0.975	0.4	1.0194	4.0099	1.4695	2	0.5	0.2	0.025
	0.5	1.0105	3.1126	1.2542	2	0.5	0.2	
	0.5	1.0111	3.1671	1.2673	2	0.5	0.3	
0.99	0.4	1.0078	3.9836	1.4605	2	0.5	0.2	0.01
	0.5	1.0042	3.1015	1.2501	2	0.5	0.2	
	0.5	1.0045	3.1559	1.2631	2	0.5	0.3	
0.999	0.4	1.0008	3.9676	1.455	2	0.5	0.2	0.001
	0.5	1.0004	3.0947	1.2476	2	0.5	0.2	
	0.5	1.0004	3.1491	1.2605	2	0.5	0.3	
Note: We assume p_12=p_22=p_33=0								