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In[1]:= (* C3.AI COVID CHALLENGE *)

In[1]:= Clear["Global`*"]

In[4]:= type = "Deaths_per_Million";
policy = "C6_Policy";

In[6]:= pD0 = 0.9122;
pD1 = 0.0748;
pD2 = 0;
pD3 = 0.0086;
pD4 = 0.0044;
pD0 + pD1 + pD2 + pD3

Out[11]= 0.9956

In[12]:= (* COnditional Prob *)

In[12]:= pD0C6l0 = 0.2874189425162114;
pD1C6l0 = 0.002604169114582501;
pD2C6l0 = 0.022727302272730225;
pD3C6l0 = 0.041666695833330415;
pD4C6l0 = 1 - pD0C6l0 - pD1C6l0 - pD2C6l0 - pD3C6l0;

In[17]:= pD0C6l1 = 0.149878970024206;
pD1C6l1 = 0.002604169114582501;
pD2C6l1 = 0.022727302272730225;
pD3C6l1 = 0.041666695833330415;
pD4C6l1 = 1 - pD0C6l1 - pD1C6l1 - pD2C6l1 - pD3C6l1;

In[22]:= pD0C6l2 = 0;
pD1C6l2 = 0;
pD2C6l2 = 0;
pD3C6l2 = 0;
pD4C6l2 = 0;

In[27]:= pD0C6l3 = 0.4977749004450199;
pD1C6l3 = 0.15885394598965838;
pD2C6l3 = 0.022727302272730225;
pD3C6l3 = 0.8749999125000087;
pD4C6l3 = 1 - pD0C6l3 - pD1C6l3 - pD2C6l3 - pD3C6l3;

In[32]:= pD0C6l4 = 0.0649271870145626;
pD1C6l4 = 0.8359377157811767;
pD2C6l4 = 0.9318180931818093;
pD3C6l4 = 0.041666695833330415;
pD4C6l4 = 1 - pD0C6l4 - pD1C6l4 - pD2C6l4 - pD3C6l4;

In[37]:= (* C6 - 1 *)

In[37]:= prC6l0 = pD0 pD0C6l0 + pD1 pD1C6l0 + pD2 pD2C6l0 + pD3 pD3C6l0 + pD4 pD4C6l0

Out[37]= 0.265577

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In[38]:= prC6l1 = pD0 pD0C6l1 + pD1 pD1C6l1 + pD2 pD2C6l1 + pD3 pD3C6l1 + pD4 pD4C6l1
Out[38]= 0.140718

In[39]:= prC6l2 = pD0 pD0C6l2 + pD1 pD1C6l2 + pD2 pD2C6l2 + pD3 pD3C6l2 + pD4 pD4C6l2
Out[39]= 0.

In[40]:= prC6l3 = pD0 pD0C6l3 + pD1 pD1C6l3 + pD2 pD2C6l3 + pD3 pD3C6l3 + pD4 pD4C6l3
Out[40]= 0.471038

In[41]:= prC6l4 = pD0 pD0C6l4 + pD1 pD1C6l4 + pD2 pD2C6l4 + pD3 pD3C6l4 + pD4 pD4C6l4
Out[41]= 0.118266

In[42]:= prC6l0 + prC6l1 + prC6l2 + prC6l3 + prC6l4
Out[42]= 0.9956

In[43]:= (* Quantum Prob *)
interfC6l0 = Sqrt[pD0 pD0C6l0 pD1 pD1C6l0] Cos[\theta00 - \theta10] +
Sqrt[pD0 pD0C6l0 pD2 pD2C6l0] Cos[\theta00 - \theta20] + Sqrt[pD0 pD0C6l0 pD3 pD3C6l0] +
Cos[\theta00 - \theta30] + Sqrt[pD0 pD0C6l0 pD4 pD4C6l0] Cos[\theta00 - \theta40] +
Sqrt[pD1 pD1C6l0 pD2 pD2C6l0] Cos[\theta10 - \theta20] + Sqrt[pD1 pD1C6l0 pD3 pD3C6l0] +
Cos[\theta10 - \theta30] + Sqrt[pD1 pD1C6l0 pD4 pD4C6l0] Cos[\theta10 - \theta40] +
Sqrt[pD2 pD2C6l0 pD3 pD3C6l0] Cos[\theta20 - \theta30] + Sqrt[pD2 pD2C6l0 pD4 pD4C6l0] +
Cos[\theta20 - \theta40] + Sqrt[pD3 pD3C6l0 pD4 pD4C6l0] Cos[\theta30 - \theta40];

In[44]:= interfC6l1 = Sqrt[pD0 pD0C6l1 pD1 pD1C6l1] Cos[\theta01 - \theta11] +
Sqrt[pD0 pD0C6l1 pD2 pD2C6l1] Cos[\theta01 - \theta21] + Sqrt[pD0 pD0C6l1 pD3 pD3C6l1] +
Cos[\theta01 - \theta31] + Sqrt[pD0 pD0C6l1 pD4 pD4C6l1] Cos[\theta01 - \theta41] +
Sqrt[pD1 pD1C6l1 pD2 pD2C6l1] Cos[\theta11 - \theta21] + Sqrt[pD1 pD1C6l1 pD3 pD3C6l1] +
Cos[\theta11 - \theta31] + Sqrt[pD1 pD1C6l1 pD4 pD4C6l1] Cos[\theta11 - \theta41] +
Sqrt[pD2 pD2C6l1 pD3 pD3C6l1] Cos[\theta21 - \theta31] + Sqrt[pD2 pD2C6l1 pD4 pD4C6l1] +
Cos[\theta21 - \theta41] + Sqrt[pD3 pD3C6l1 pD4 pD4C6l1] Cos[\theta31 - \theta41];

In[45]:= interfC6l2 = Sqrt[pD0 pD0C6l2 pD1 pD1C6l2] Cos[\theta02 - \theta12] +
Sqrt[pD0 pD0C6l2 pD2 pD2C6l2] Cos[\theta02 - \theta22] + Sqrt[pD0 pD0C6l2 pD3 pD3C6l2] +
Cos[\theta30 - \theta32] + Sqrt[pD0 pD0C6l2 pD4 pD4C6l2] Cos[\theta02 - \theta42] +
Sqrt[pD1 pD1C6l2 pD2 pD2C6l2] Cos[\theta12 - \theta22] + Sqrt[pD1 pD1C6l2 pD3 pD3C6l2] +
Cos[\theta12 - \theta32] + Sqrt[pD1 pD1C6l2 pD4 pD4C6l2] Cos[\theta12 - \theta42] +
Sqrt[pD2 pD2C6l2 pD3 pD3C6l2] Cos[\theta22 - \theta32] + Sqrt[pD2 pD2C6l2 pD4 pD4C6l2] +
Cos[\theta22 - \theta42] + Sqrt[pD3 pD3C6l2 pD4 pD4C6l2] Cos[\theta32 - \theta42];

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In[46]:= interfC6l3 = Sqrt[pD0 pD0C6l3 pD1 pD1C6l3] Cos[θ03 - θ13] +
          Sqrt[pD0 pD0C6l3 pD2 pD2C6l3] Cos[θ03 - θ23] + Sqrt[pD0 pD0C6l3 pD3 pD3C6l3]
          Cos[θ03 - θ33] + Sqrt[pD0 pD0C6l3 pD4 pD4C6l3] Cos[θ03 - θ43] +
          Sqrt[pD1 pD1C6l3 pD2 pD2C6l3] Cos[θ13 - θ23] + Sqrt[pD1 pD1C6l3 pD3 pD3C6l3]
          Cos[θ13 - θ33] + Sqrt[pD1 pD1C6l3 pD4 pD4C6l3] Cos[θ13 - θ43] +
          Sqrt[pD2 pD2C6l3 pD3 pD3C6l3] Cos[θ23 - θ33] + Sqrt[pD2 pD2C6l3 pD4 pD4C6l3]
          Cos[θ23 - θ43] + Sqrt[pD3 pD3C6l3 pD4 pD4C6l3] Cos[θ33 - θ43];

In[47]:= interfC6l4 = Sqrt[pD0 pD0C6l4 pD1 pD1C6l4] Cos[θ04 - θ14] +
          Sqrt[pD0 pD0C6l4 pD2 pD2C6l4] Cos[θ04 - θ24] + Sqrt[pD0 pD0C6l4 pD3 pD3C6l4]
          Cos[θ04 - θ34] + Sqrt[pD0 pD0C6l4 pD4 pD4C6l4] Cos[θ04 - θ44] +
          Sqrt[pD1 pD1C6l4 pD2 pD2C6l4] Cos[θ14 - θ24] + Sqrt[pD1 pD1C6l4 pD3 pD3C6l4]
          Cos[θ14 - θ34] + Sqrt[pD1 pD1C6l4 pD4 pD4C6l4] Cos[θ14 - θ44] +
          Sqrt[pD2 pD2C6l4 pD3 pD3C6l4] Cos[θ24 - θ34] + Sqrt[pD2 pD2C6l4 pD4 pD4C6l4]
          Cos[θ24 - θ44] + Sqrt[pD3 pD3C6l4 pD4 pD4C6l4] Cos[θ34 - θ44];

In[48]:= qprC6l0 = prC6l0 + 2 interfC6l0;

In[49]:= qprC6l1 = prC6l1 + 2 interfC6l1;

In[50]:= qprC6l2 = prC6l2 + 2 interfC6l2;

In[51]:= qprC6l3 = prC6l3 + 2 interfC6l3;

In[52]:= qprC6l4 = prC6l4 + 2 interfC6l4;

In[53]:= qprC6l0Norm = FullSimplify[ $\frac{qprC6l0}{qprC6l0 + qprC6l1 + qprC6l2 + qprC6l3 + qprC6l4}$ ];

In[54]:= qprC6l1Norm = FullSimplify[ $\frac{qprC6l1}{qprC6l0 + qprC6l1 + qprC6l2 + qprC6l3 + qprC6l4}$ ];

In[55]:= qprC6l2Norm = FullSimplify[ $\frac{qprC6l2}{qprC6l0 + qprC6l1 + qprC6l2 + qprC6l3 + qprC6l4}$ ];

In[56]:= qprC6l3Norm = FullSimplify[ $\frac{qprC6l3}{qprC6l0 + qprC6l1 + qprC6l2 + qprC6l3 + qprC6l4}$ ];

In[57]:= qprC6l4Norm = 1 - qprC6l3Norm - qprC6l2Norm - qprC6l1Norm - qprC6l0Norm;

In[79]:= Clear[θ00, θ10, θ20, θ30, θ40,
           θ01, θ11, θ21, θ31, θ41,
           θ02, θ12, θ22, θ32, θ42,
           θ03, θ13, θ23, θ33, θ43,
           θ04, θ14, θ24, θ34, θ44];

In[79]:= θ20 = π;
          θ31 = 0.1;
          θ22 = π/2;
          θ43 = π/2;
          θ23 = π;
          θ30 = π;
          θ21 = π;
          θ42 = π;

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In[80]:= res = FindInstance[
  {qprC6l0Norm + qprC6l1Norm + qprC6l2Norm + qprC6l3Norm + qprC6l4Norm == 1},
  {θ00, θ10, θ20, θ30, θ40, θ01, θ11, θ21, θ31, θ41, θ02, θ12, θ22,
   θ32, θ42, θ03, θ13, θ23, θ33, θ43, θ04, θ14, θ24, θ34, θ44}, Reals]
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Out[80]= {θ00 → -12/5, θ10 → -1/2, θ20 → -9/5, θ30 → 3/5, θ40 → -24/5, θ01 → -21/5, θ11 → 11/5,
          θ21 → -3/5, θ31 → -6/5, θ41 → -14/5, θ02 → -19/5, θ12 → -14/5, θ22 → -41/10,
          θ32 → -3/10, θ42 → -17/10, θ03 → 18/5, θ13 → -37/10, θ23 → 13/5, θ33 → -39/10,
          θ43 → -21/10, θ04 → -22/5, θ14 → 1/10, θ24 → 1, θ34 → -9/2, θ44 → -33/10}
```

In[81]:= (\* Params \*)

```
θ10 = res[[1]][[2]][[2]];
θ20 = res[[1]][[3]][[2]];
θ30 = res[[1]][[4]][[2]];
θ40 = res[[1]][[5]][[2]];
θ11 = res[[1]][[7]][[2]];
θ21 = res[[1]][[8]][[2]];
θ31 = res[[1]][[9]][[2]];
θ41 = res[[1]][[10]][[2]];
θ02 = res[[1]][[11]][[2]];
θ12 = res[[1]][[12]][[2]];
θ22 = res[[1]][[13]][[2]];
θ32 = res[[1]][[14]][[2]];
θ42 = res[[1]][[15]][[2]];
θ03 = res[[1]][[16]][[2]];
θ13 = res[[1]][[17]][[2]];
θ23 = res[[1]][[18]][[2]];
θ33 = res[[1]][[19]][[2]];
θ43 = res[[1]][[20]][[2]];
θ04 = res[[1]][[16]][[2]];
θ14 = res[[1]][[17]][[2]];
θ24 = res[[1]][[18]][[2]];
θ34 = res[[1]][[19]][[2]];
θ44 = res[[1]][[20]][[2]];
```

In[82]:= (\* Updated probabilities \*)

```
qprC6l0Norm = Re[FullSimplify[qprC6l0 / (qprC6l0 + qprC6l1 + qprC6l2 + qprC6l3 + qprC6l4)]]
Out[104]= Re[(13.7475 + 1.71873 Cos[θ00] + 3.01589 Sin[θ00]) /
             ((62.3796 + 3.97501 I) + 1.71873 Cos[θ00] -
              2.16157 Cos[θ01] + 3.01589 Sin[θ00] - 0.992725 Sin[θ01])]
```

```

In[105]:= qprC6l1Norm = Re[FullSimplify[ $\frac{qprC6l1}{qprC6l0 + qprC6l1 + qprC6l2 + qprC6l3 + qprC6l4}]$ ]
Out[105]= Re[(13.6232 - 4.0599 Cos[\theta01] - 1.86455 Sin[\theta01]) / ((117.162 + 7.46594 i) +
3.22814 Cos[\theta00] - 4.0599 Cos[\theta01] + 5.66449 Sin[\theta00] - 1.86455 Sin[\theta01])]

In[106]:= qprC6l2Norm = Re[FullSimplify[ $\frac{qprC6l2}{qprC6l0 + qprC6l1 + qprC6l2 + qprC6l3 + qprC6l4}]$ ]
Out[106]= 0.

In[107]:= qprC6l3Norm = Re[FullSimplify[ $\frac{qprC6l3}{qprC6l0 + qprC6l1 + qprC6l2 + qprC6l3 + qprC6l4}]$ ]
Out[107]= Re[(18.2296 + 1.59963 i) / ((36.294 + 2.31276 i) +
1. Cos[\theta00] - 1.25766 Cos[\theta01] + 1.75472 Sin[\theta00] - 0.577593 Sin[\theta01])]

In[108]:= qprC6l4Norm = Re[1 - qprC6l3Norm - qprC6l2Norm - qprC6l1Norm - qprC6l0Norm]
Out[108]= 1. - Re[(13.6232 - 4.0599 Cos[\theta01] - 1.86455 Sin[\theta01]) / ((117.162 + 7.46594 i) +
3.22814 Cos[\theta00] - 4.0599 Cos[\theta01] + 5.66449 Sin[\theta00] - 1.86455 Sin[\theta01])] -
Re[(13.7475 + 1.71873 Cos[\theta00] + 3.01589 Sin[\theta00]) / ((62.3796 + 3.97501 i) +
1.71873 Cos[\theta00] - 2.16157 Cos[\theta01] + 3.01589 Sin[\theta00] - 0.992725 Sin[\theta01])] -
Re[(18.2296 + 1.59963 i) / ((36.294 + 2.31276 i) + 1. Cos[\theta00] -
1.25766 Cos[\theta01] + 1.75472 Sin[\theta00] - 0.577593 Sin[\theta01])]

{qprC6l0Norm, qprC6l1Norm, qprC6l2Norm, qprC6l3Norm, qprC6l4Norm}

In[111]:= p0 = Plot3D[qprC6l0Norm, {\theta00, 0, 2 \pi},
{\theta01, 0, 2 \pi}, ColorFunction → (ColorData["DarkRainbow"] [#3] &),
AxesLabel → {Style[type, 16], Style[policy, 16], Style["Prob", 16]},
BoundaryStyle → Thick, Boxed → False,
Ticks → {{0, Pi/2, Pi, 3 Pi/2, 2 Pi}, {0, Pi/2, Pi, 3 Pi/2, 2 Pi}, Automatic},
TicksStyle → Directive[Black, 12]];

In[112]:= p1 = Plot3D[qprC6l1Norm, {\theta00, 0, 2 \pi},
{\theta01, 0, 2 \pi}, ColorFunction → (ColorData["DarkRainbow"] [#3] &),
AxesLabel → {Style[type, 16], Style[policy, 16], Style["Prob", 16]},
BoundaryStyle → Thick, Boxed → False,
Ticks → {{0, Pi/2, Pi, 3 Pi/2, 2 Pi}, {0, Pi/2, Pi, 3 Pi/2, 2 Pi}, Automatic},
TicksStyle → Directive[Black, 12]];

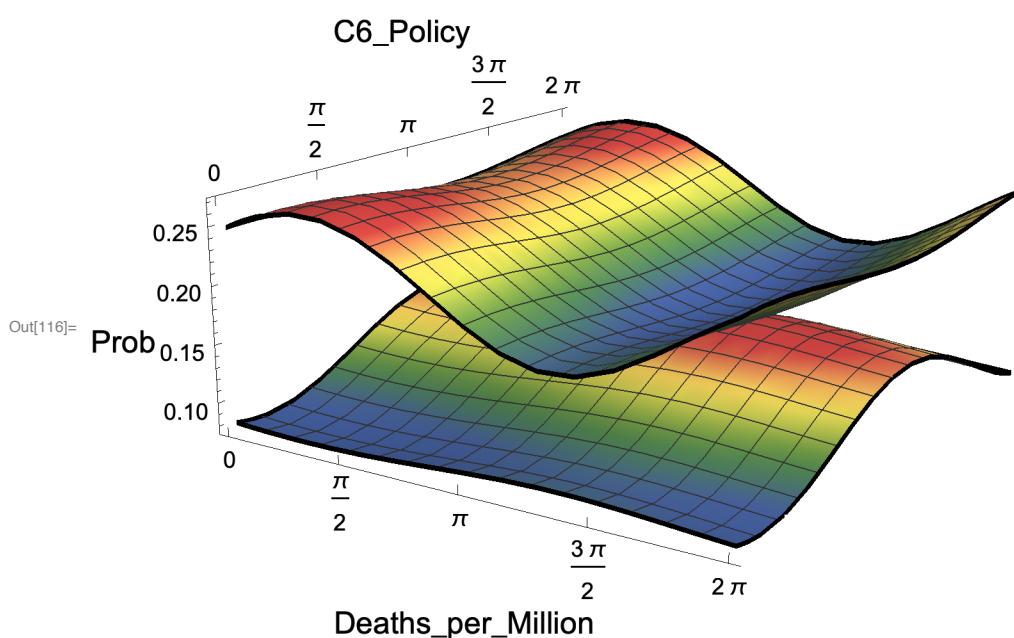
In[113]:= p2 = Plot3D[qprC6l2Norm, {\theta00, 0, 2 \pi},
{\theta01, 0, 2 \pi}, ColorFunction → (ColorData["DarkRainbow"] [#3] &),
AxesLabel → {Style[type, 16], Style[policy, 16], Style["Prob", 16]},
BoundaryStyle → Thick, Boxed → False,
Ticks → {{0, Pi/2, Pi, 3 Pi/2, 2 Pi}, {0, Pi/2, Pi, 3 Pi/2, 2 Pi}, Automatic},
TicksStyle → Directive[Black, 12]];

```

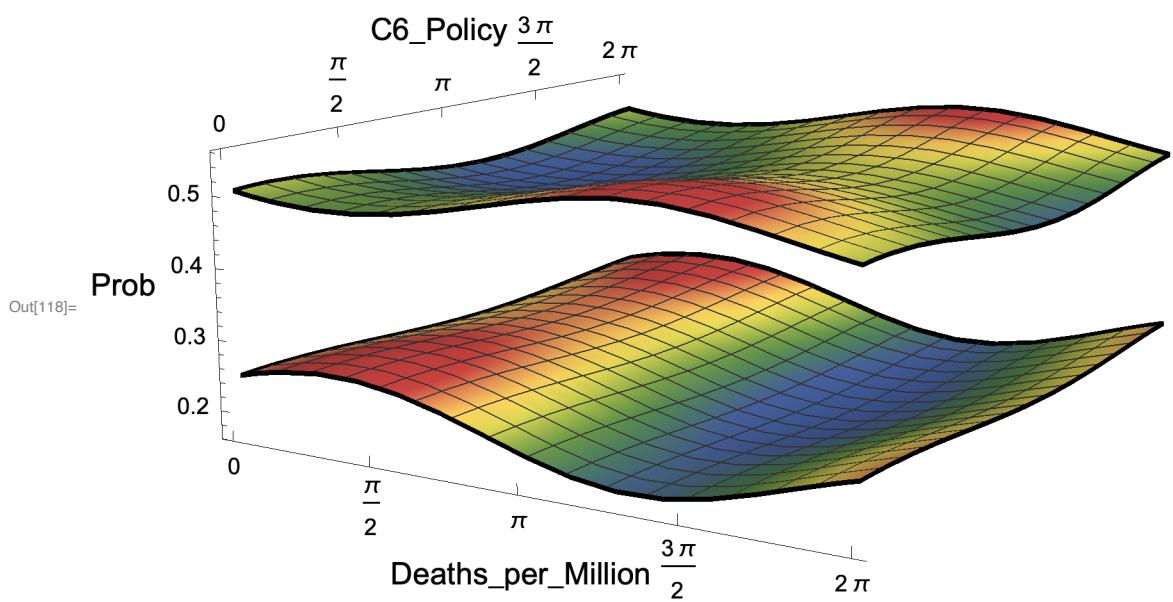
```
In[114]:= p3 = Plot3D[qprC6l3Norm, {θ00, 0, 2 π},
  {θ01, 0, 2 π}, ColorFunction → (ColorData["DarkRainbow"] [#3] &),
  AxesLabel → {Style[type, 16], Style[policy, 16], Style["Prob", 16]},
  BoundaryStyle → Thick, Boxed → False,
  Ticks → {{0, Pi/2, Pi, 3 Pi/2, 2 Pi}, {0, Pi/2, Pi, 3 Pi/2, 2 Pi}, Automatic},
  TicksStyle → Directive[Black, 12]];

In[115]:= p4 = Plot3D[qprC6l4Norm, {θ00, 0, 2 π},
  {θ01, 0, 2 π}, ColorFunction → (ColorData["DarkRainbow"] [#3] &),
  AxesLabel → {Style[type, 16], Style[policy, 16], Style["Prob", 16]},
  BoundaryStyle → Thick, Boxed → False,
  Ticks → {{0, Pi/2, Pi, 3 Pi/2, 2 Pi}, {0, Pi/2, Pi, 3 Pi/2, 2 Pi}, Automatic},
  TicksStyle → Directive[Black, 12]];

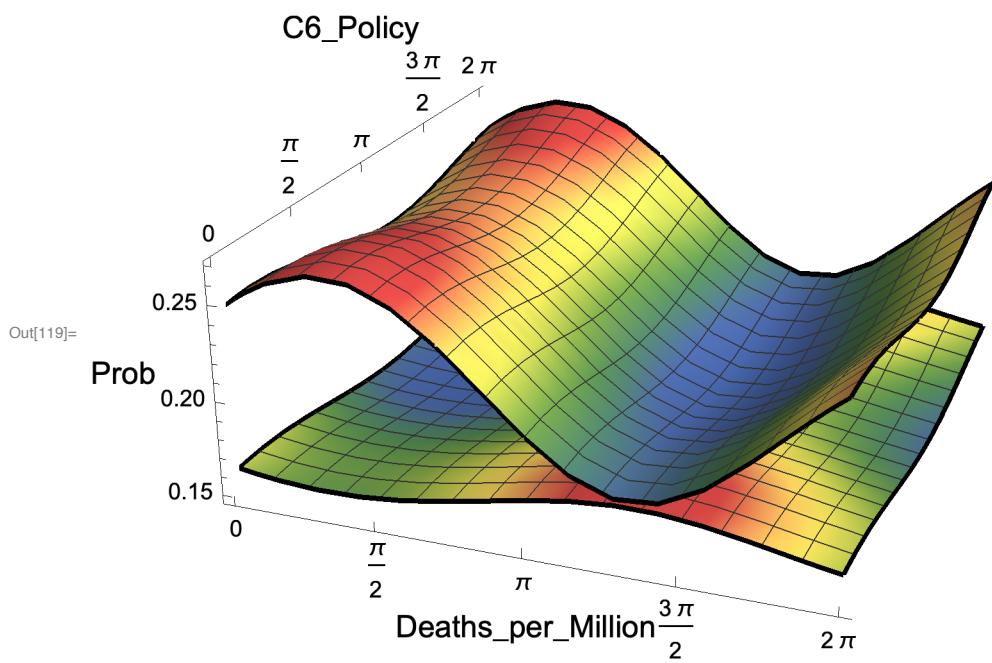
In[116]:= Show[p0, p1]
```



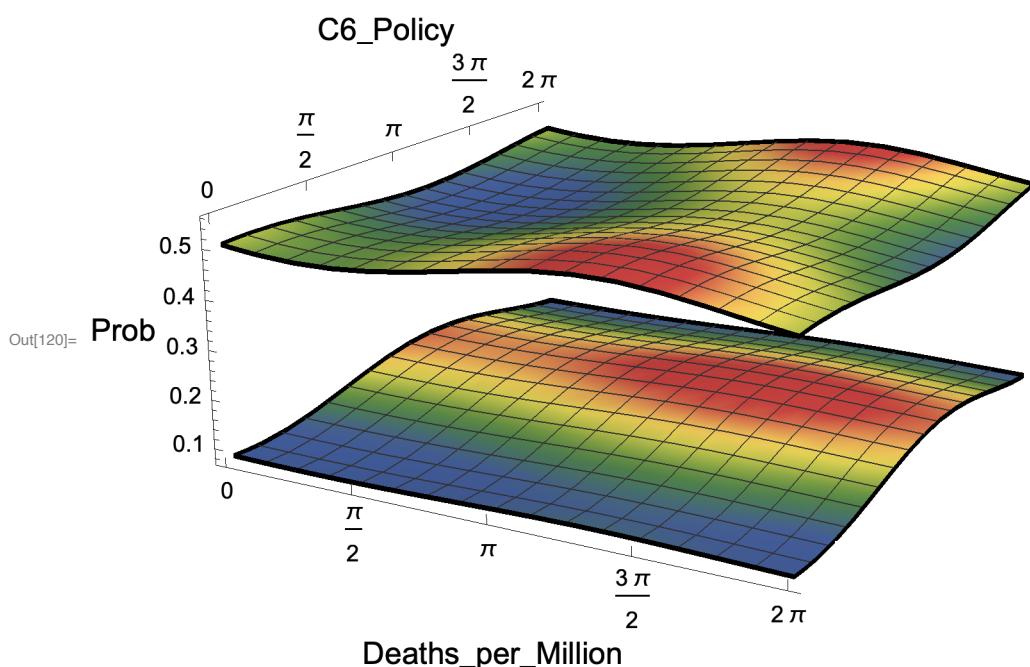
In[118]:= Show[p0, p3]



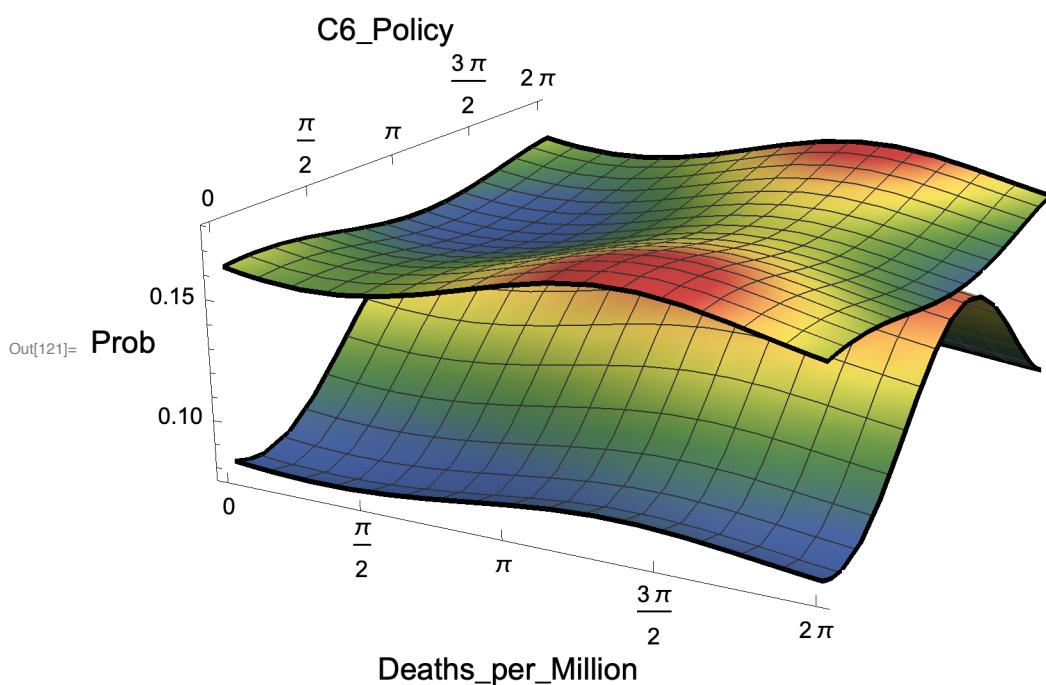
In[119]:= Show[p0, p4]



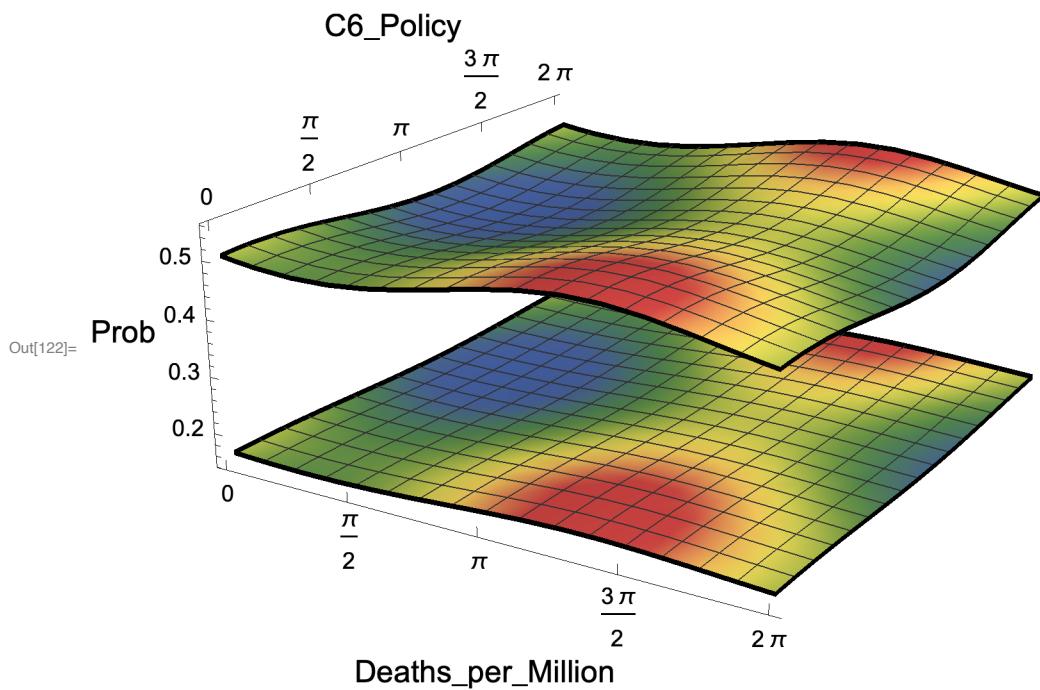
In[120]:= Show[p1, p3]



In[121]:= Show[p1, p4]

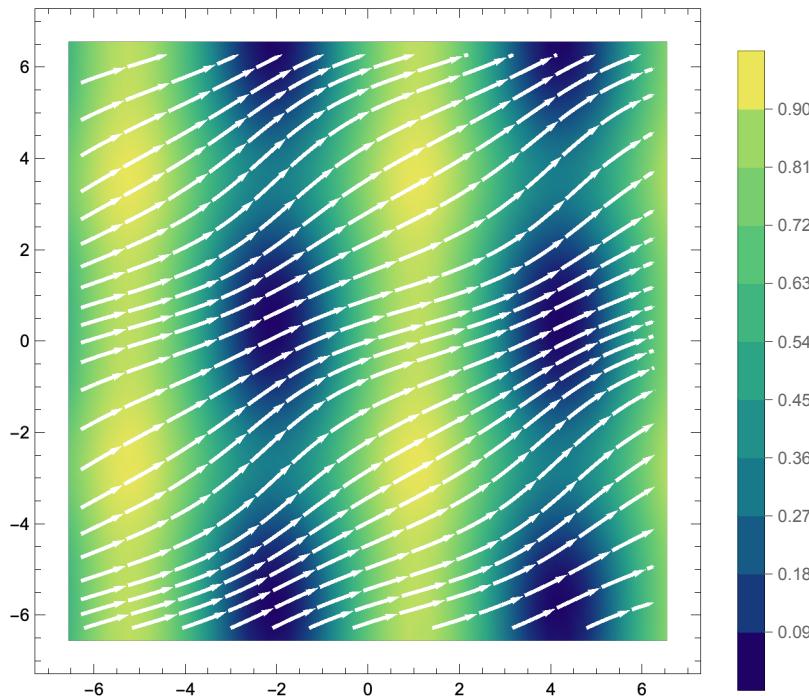


In[122]:= Show[p3, p4]

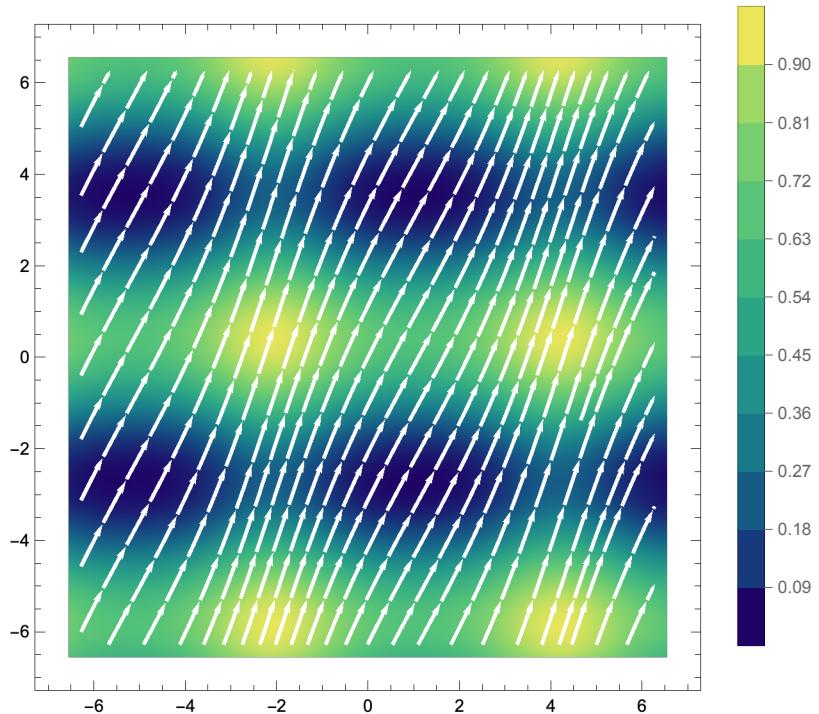


In[124]:=

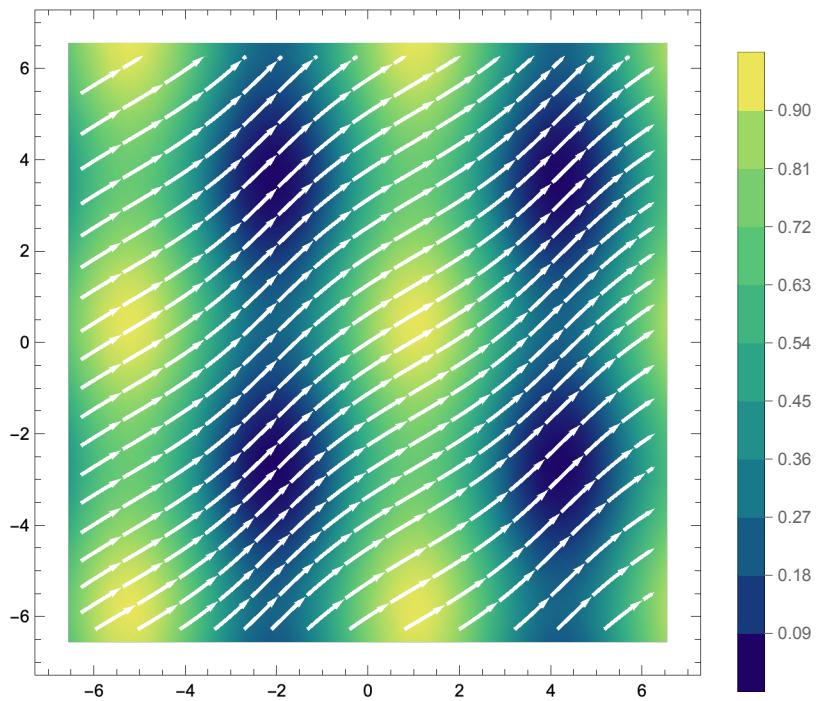
```
fig = StreamDensityPlot[{qprC6l0Norm, qprC6l1Norm},
{θ00, -2 π, 2 π}, {θ01, -2 π, 2 π}, ColorFunction → "BlueGreenYellow",
PlotLegends → BarLegend[{"BlueGreenYellow", {0, 1}}, 10],
AxesLabel → Automatic, StreamStyle → {White, Thick}]
```



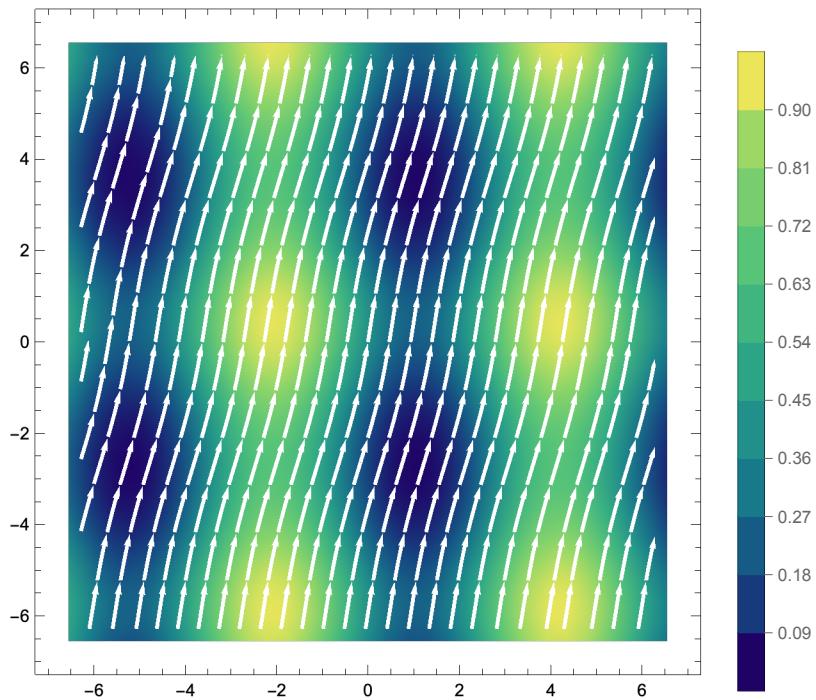
```
In[126]:= fig = StreamDensityPlot[{qprC6l0Norm, qprC6l3Norm},
  {θ00, -2 π, 2 π}, {θ01, -2 π, 2 π}, ColorFunction → "BlueGreenYellow",
  PlotLegends → BarLegend[{"BlueGreenYellow", {0, 1}}, 10],
  AxesLabel → Automatic, StreamStyle → {White, Thick}]
```



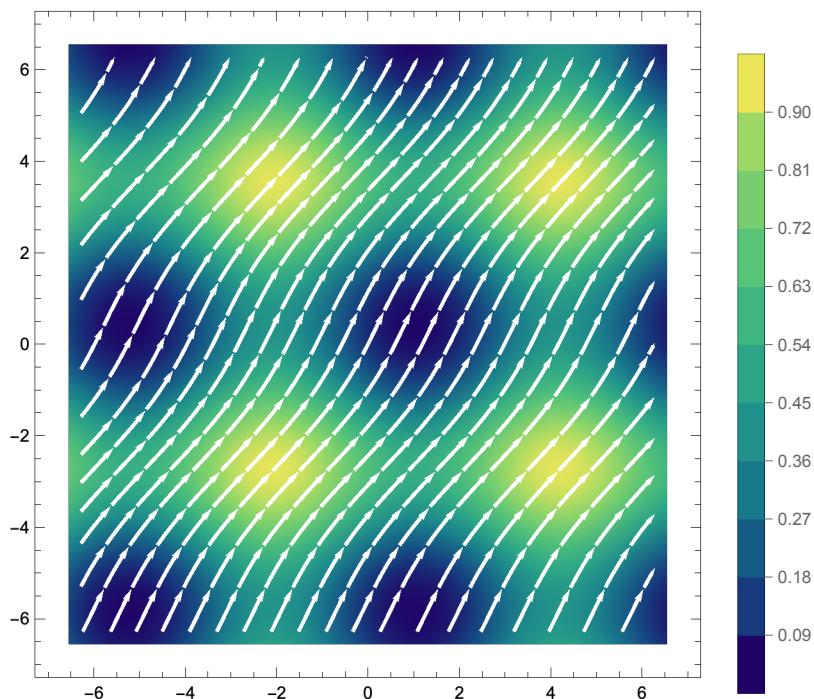
```
In[127]:= fig = StreamDensityPlot[{qprC6l0Norm, qprC6l4Norm},
  {θ00, -2 π, 2 π}, {θ01, -2 π, 2 π}, ColorFunction → "BlueGreenYellow",
  PlotLegends → BarLegend[{"BlueGreenYellow", {0, 1}}, 10],
  AxesLabel → Automatic, StreamStyle → {White, Thick}]
```



```
In[128]:= fig = StreamDensityPlot[{qprC6l1Norm, qprC6l3Norm},  
{θ00, -2 π, 2 π}, {θ01, -2 π, 2 π}, ColorFunction → "BlueGreenYellow",  
PlotLegends → BarLegend[{"BlueGreenYellow", {0, 1}}, 10],  
AxesLabel → Automatic, StreamStyle → {White, Thick}]
```



```
In[129]:= fig = StreamDensityPlot[{qprC6l1Norm, qprC6l4Norm},
  {θ00, -2 π, 2 π}, {θ01, -2 π, 2 π}, ColorFunction → "BlueGreenYellow",
  PlotLegends → BarLegend[{"BlueGreenYellow", {0, 1}}, 10],
  AxesLabel → Automatic, StreamStyle → {White, Thick}]
```



```
In[130]:= fig = StreamDensityPlot[{qprC6l3Norm, qprC6l4Norm},
  {θ00, -2 π, 2 π}, {θ01, -2 π, 2 π}, ColorFunction → "BlueGreenYellow",
  PlotLegends → BarLegend[{"BlueGreenYellow", {0, 1}}, 10],
  AxesLabel → Automatic, StreamStyle → {White, Thick}]
```

