In [1]:
```python
import gamspy as gp
import gamspy.math as gpm
from gamspy import Sum, Card

import sys
import numpy as np
import pandas as pd
```

In [2]:
```python
m = gp.Container(load_from="digits.gdx")

# Sets
p, headr = m.getSymbols(["Dim1", "Dim2"])

# Parameters
[data] = m.getSymbols(["Data"])
display(data.pivot())

train = gp.Set(m,'train',domain=p)
test = gp.Set(m,'test',domain=p)
j = gp.Set(m,'j',domain=headr,description='index of independent variables')
y = gp.Parameter(m,'y',domain=p)

j.setRecords([str(x) for x in range(1, 65)])
# y.setRecords(records=[x for x in range(1, 65)])
# Determine j and y here

y[p].where[data[p, '65'] + data[p, '66'] + data[p, '67'] + data[p, '68'] + c
y[p].where[data[p, '65'] + data[p, '66'] + data[p, '67'] + data[p, '68'] + c

train[p] = gp.Number(1).where[p.val <= 3500]
test[p] = ~train[p]
```

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
|---|---|---|---|---|---|---|---|---|---|
| **1** | -0.0 | -0.33954 | 0.34365 | 0.98892 | 0.98735 | 0.78802 | -0.11683 | -0.12673 | -0. |
| **2** | -0.0 | -0.33954 | -1.16098 | -2.79747 | -0.38360 | 1.32295 | 1.65503 | -0.12673 | -0. |
| **3** | -0.0 | -0.33954 | -0.30119 | -0.90428 | -2.66852 | -0.99509 | -0.41214 | -0.12673 | -0. |
| **4** | -0.0 | -0.33954 | 0.34365 | 0.51562 | 0.53037 | 1.32295 | 0.47379 | -0.12673 | -0. |
| **5** | -0.0 | -0.33954 | -1.16098 | -2.56082 | 0.07339 | -0.63847 | -0.41214 | -0.12673 | -0. |
| **...** | ... | ... | ... | ... | ... | ... | ... | ... | |
| **4492** | -0.0 | -0.33954 | -0.73108 | 0.27897 | 0.98735 | 1.32295 | 0.76910 | -0.12673 | -0. |
| **4493** | -0.0 | -0.33954 | -0.08625 | 0.04232 | -1.29757 | -0.99509 | -0.41214 | -0.12673 | -0. |
| **4494** | -0.0 | -0.33954 | -0.73108 | -0.66763 | 0.98735 | 0.07477 | -0.41214 | -0.12673 | -0. |
| **4495** | -0.0 | 1.95952 | 1.41838 | 0.75227 | 0.98735 | 0.78802 | -0.11683 | -0.12673 | -0. |
| **4496** | -0.0 | 3.10905 | 2.06322 | 0.98892 | -1.06907 | -0.99509 | -0.41214 | -0.12673 | -0. |

4496 rows × 74 columns

In [3]:

```
C = gp.Parameter(m,'C',records=1)

# Write SVM model here
i = m.addSet('i', domain=p)
i[p] = train[p]

delta = m.addVariable('delta','positive',domain=p)
w = m.addVariable('w','free',domain=j)
gamma = m.addVariable('gamma','free')

cons = m.addEquation('cons', domain=p)
cons[i] = y[i]*(Sum(j, data[i,j]*w[j]) + gamma) + delta[i] >= 1

svm = m.addModel('svm',
    equations=m.getEquations(),
    problem=gp.Problem.QCP,
    sense=gp.Sense.MIN,
    objective=C*Sum(i, delta[i]) + 0.5*Sum(j, gpm.sqr(w[j]))
)

err = m.addSet('err',domain=p)
svm.solve(solver='mosek')
```

Out[3]:

| | Solver Status | Model Status | Objective | Num of Equations | Num of Variables | Model Type | Solve |
|---|---|---|---|---|---|---|---|
| **0** | Normal | OptimalGlobal | 689.382602201402 | 3501 | 3566 | QCP | MOSE |

Following cell sets up the folds for cross-validation. The set train is split into k subsets (or folds) that are randomly selected subsets of train.

We then use cross-validation to determine the CV error for each "trial" value of $C$
.

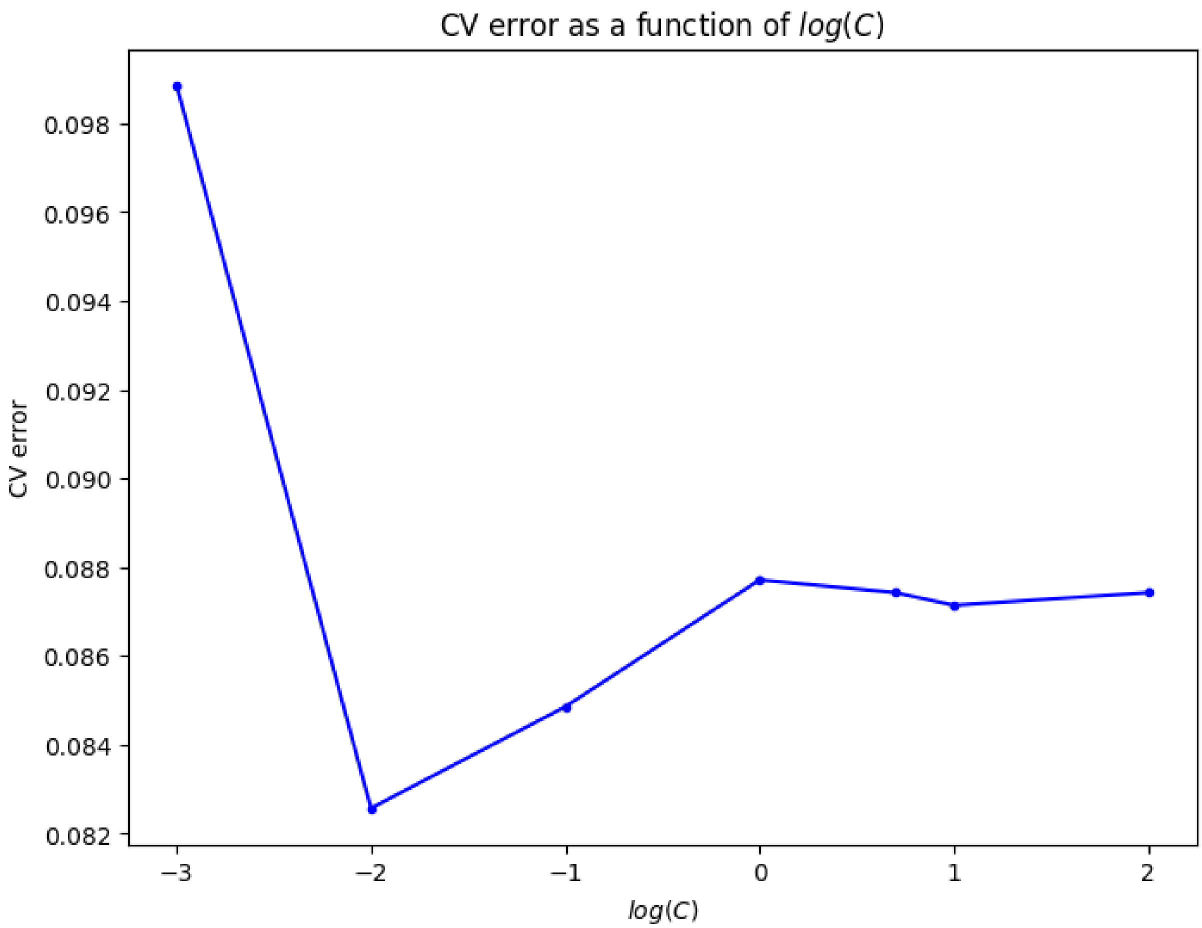
In [ ]:

```
from sklearn.model_selection import KFold

kf = KFold(n_splits=5, shuffle=True, random_state=42)

trialvals = [0.001, 0.01, 0.1, 1, 5, 10, 100]

# do CV here
cv = []
for C_val in trialvals:
    C[:] = C_val
    err[p] = False
    for train_index, tune_index in kf.split(train.records):
        i.setRecords(train.records.loc[train_index])
        svm.solve(solver='mosek',output=None)
        i.setRecords(train.records.loc[tune_index])
        err[i].where[(Sum(j, data[i,j]*w.l[j]) - gamma.l) * y[i] < 0] = True
    cv.append(len(err.records)/len(train.records))

idx = 0
for value in cv:
    print(f"The error rate on trial value {trialvals[idx]} is: {round(value
    idx += 1

print("The best trial value for C is 0.01!")
```

```
The error rate on trial value 0.001 is: 9.89
The error rate on trial value 0.01 is: 8.26
The error rate on trial value 0.1 is: 8.49
The error rate on trial value 1 is: 8.77
The error rate on trial value 5 is: 8.74
The error rate on trial value 10 is: 8.71
The error rate on trial value 100 is: 8.74
```

In [5]:

```
%matplotlib inline
import matplotlib.pyplot as plt

fig, ax = plt.subplots(figsize=(8,6))
ax.set_title("CV error as a function of $log(C)$")
ax.set_xlabel("$log(C)$")
ax.set_ylabel("CV error")
ax.plot(np.log10(trialvals),cv,"b.-");
```




Finally, we set the value of $C$ to the best one (from CV) and rerun the model using all the data, then generate predictions in the test set

In [20]:
```
# Evaluation at best value of C
C.setRecords(0.01)

pred = m.addParameter('pred',domain=p,description='prediction')
errorrate = m.addParameter('errorrate')

i[p] = train[p]
svm.solve()

pred[test] = gpm.sign(Sum(j, data[test,j]*w.l[j]) - gamma.l)

errorrate[:] = Sum(test, (pred[test] * y[test] < 0)) / len(test.records)


print(f"The Error Rate on unseen data is {round(errorrate.toValue() * 100, 2
```

```
The Error Rate on unseen data is 8.03%
```