Cloud-Native Data Architecture and Bankruptcy Prediction for MSBA Financial Group

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[1]:
```
import pyarrow.parquet as pq
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import boto3
from io import StringIO
import warnings
warnings.filterwarnings('ignore')

%matplotlib inline
sns.set_style('whitegrid')

print('Libraries Imported')
```

```
/home/ec2-user/anaconda3/envs/python3/lib/python3.10/site-
packages/pandas/core/computation/expressions.py:21: UserWarning: Pandas requires
version '2.8.4' or newer of 'numexpr' (version '2.7.3' currently installed).
  from pandas.core.computation.check import NUMEXPR_INSTALLED
```

```
Libraries Imported
```

[2]:
```
s3_client = boto3.client('s3', region_name='us-east-1')
bucket_name = 'msba-financial-data-ritvik'
```

[3]:
```
files = s3_client.list_objects_v2(
    Bucket=bucket_name,
    Prefix = 'processed-data/combined_financial_data/train/'
)
```

[4]:
```
import io

dfs = []
for obj in files.get('Contents', []):
    if obj['Key'].endswith('.parquet'):
        print(f"   Reading: {obj['Key']}")
        file_obj = s3_client.get_object(Bucket=bucket_name, Key=obj['Key'])
```

```
        df_temp = pd.read_parquet(io.BytesIO(file_obj['Body'].read()))
        dfs.append(df_temp)

df = pd.concat(dfs, ignore_index=True)
print('Training Data Loaded')
```

```
   Reading: processed-data/combined_financial_data/train/part-00000-31f68e42-
3f3a-4d6c-84f3-0e8dbd0acc64-c000.snappy.parquet
   Reading: processed-data/combined_financial_data/train/part-00001-31f68e42-
3f3a-4d6c-84f3-0e8dbd0acc64-c000.snappy.parquet
   Reading: processed-data/combined_financial_data/train/part-00002-31f68e42-
3f3a-4d6c-84f3-0e8dbd0acc64-c000.snappy.parquet
   Reading: processed-data/combined_financial_data/train/part-00003-31f68e42-
3f3a-4d6c-84f3-0e8dbd0acc64-c000.snappy.parquet
Training Data Loaded
```

[5]:
```
files_test = s3_client.list_objects_v2(
    Bucket=bucket_name,
    Prefix='processed-data/combined_financial_data/test/'
)
```

[6]:
```
dfs_test = []
for obj in files_test.get('Contents', []):
    if obj['Key'].endswith('.parquet'):
        print(f"   Reading: {obj['Key']}")
        file_obj = s3_client.get_object(Bucket=bucket_name, Key=obj['Key'])
        df_temp = pd.read_parquet(io.BytesIO(file_obj['Body'].read()))
        dfs_test .append(df_temp)
df_test = pd.concat(dfs_test, ignore_index=True)
print('Test Data Loaded')
```

```
   Reading: processed-data/combined_financial_data/test/part-00000-a3aa98fc-
bf1e-4abe-8ba6-edfe698e4691-c000.snappy.parquet
   Reading: processed-data/combined_financial_data/test/part-00001-a3aa98fc-
bf1e-4abe-8ba6-edfe698e4691-c000.snappy.parquet
   Reading: processed-data/combined_financial_data/test/part-00002-a3aa98fc-
bf1e-4abe-8ba6-edfe698e4691-c000.snappy.parquet
   Reading: processed-data/combined_financial_data/test/part-00003-a3aa98fc-
bf1e-4abe-8ba6-edfe698e4691-c000.snappy.parquet
Test Data Loaded
```

[7]:
```
print(f'Shape: {df.shape}')
print(f'Shape: {df_test.shape}')
```

```
Shape: (5522, 24)
Shape: (1297, 24)
```

[8]:
```
bankruptcy_col = 'bankrupt'
bankruptcy_col
```

[8]: 'bankrupt'

[9]:
```
df.dtypes
```

[9]:
```
bankrupt                                  int32
company_id                               object
net_worth_to_assets                     float64
retained_earnings_to_total_assets       float64
working_capital_to_total_assets         float64
working_capital_to_equity               float64
equity_to_longterm_liability            float64
current_liabilities_to_equity           float64
liability_to_equity                     float64
current_liability_to_current_assets     float64
borrowing_dependency                    float64
debt_ratio_percentage                   float64
persistent_eps                          float64
per_share_net_profit_pre_tax            float64
operating_profit_per_share              float64
tax_rate                                float64
operating_gross_margin                  float64
net_income_to_total_assets              float64
roa_before_interest_percent_after_tax   float64
net_profit_before_tax_to_paid_in_capital float64
net_income_to_stockholders_equity       float64
operating_profit_paid_in_capital        float64
total_asset_turnover                    float64
total_expense_to_assets                 float64
dtype: object
```

[10]:
```
miss = df.isnull().sum()
if miss.sum() > 0:
    print(miss[miss>0])
else:
    print('No missing values')
print()
```

```
No missing values
```

[11]:
```
df.describe()
```

[11]:
```
          bankrupt  net_worth_to_assets  retained_earnings_to_total_assets  \
count  5522.000000          5522.000000                        5522.000000
mean      0.032235             0.886930                           0.934734
std       0.176639             0.054449                           0.026537
min       0.000000             0.000000                           0.000000
25%       0.000000             0.850772                           0.931285
```

```
50%      0.000000            0.888729                                  0.937731
75%      0.000000            0.927888                                  0.944905
max      1.000000            1.000000                                  1.000000

       working_capital_to_total_assets  working_capital_to_equity  \
count                      5522.000000                5522.000000
mean                          0.814207                   0.735789
std                           0.059537                   0.012808
min                           0.000000                   0.000000
25%                           0.774267                   0.733604
50%                           0.810320                   0.736003
75%                           0.850366                   0.738586
max                           1.000000                   1.000000

       equity_to_longterm_liability  current_liabilities_to_equity  \
count                   5522.000000                    5522.000000
mean                       0.115828                       0.331506
std                        0.021421                       0.014028
min                        0.025851                       0.153811
25%                        0.110933                       0.328084
50%                        0.112375                       0.329661
75%                        0.117123                       0.332314
max                        1.000000                       1.000000

       liability_to_equity  current_liability_to_current_assets  \
count          5522.000000                          5522.000000
mean              0.280490                             0.031678
std               0.015398                             0.032900
min               0.133503                             0.000122
25%               0.276913                             0.017990
50%               0.278774                             0.027595
75%               0.281490                             0.038421
max               1.000000                             1.000000

       borrowing_dependency  ...  operating_profit_per_share     tax_rate  \
count           5522.000000  ...                 5522.000000  5522.000000
mean               0.374813  ...                    0.109298     0.115100
std                0.017118  ...                    0.028906     0.139957
min                0.187124  ...                    0.000000     0.000000
25%                0.370167  ...                    0.096246     0.000000
50%                0.372585  ...                    0.104307     0.071971
75%                0.376224  ...                    0.116196     0.206296
max                1.000000  ...                    1.000000     1.000000

       operating_gross_margin  net_income_to_total_assets  \
count             5522.000000                 5522.000000
mean                 0.608096                    0.807902
```

```
std                0.015697                0.040579
min                0.156308                0.000000
25%                0.600457                0.796871
50%                0.606062                0.810916
75%                0.614017                0.826375
max                1.000000                0.982879

       roa_before_interest_percent_after_tax  \
count                            5522.000000
mean                                0.558970
std                                 0.065884
min                                 0.000000
25%                                 0.535979
50%                                 0.560428
75%                                 0.588857
max                                 1.000000

       net_profit_before_tax_to_paid_in_capital  \
count                               5522.000000
mean                                   0.182976
std                                    0.031848
min                                    0.000000
25%                                    0.169444
50%                                    0.178580
75%                                    0.191777
max                                    1.000000

       net_income_to_stockholders_equity  operating_profit_paid_in_capital  \
count                        5522.000000                       5522.000000
mean                            0.840298                          0.109170
std                             0.015906                          0.028728
min                             0.000000                          0.000000
25%                             0.840125                          0.096221
50%                             0.841196                          0.104166
75%                             0.842362                          0.116023
max                             1.000000                          1.000000

       total_asset_turnover  total_expense_to_assets
count           5522.000000              5522.000000
mean               0.141240                 0.029226
std                0.101618                 0.027929
min                0.000000                 0.000000
25%                0.076462                 0.014526
50%                0.118441                 0.022676
75%                0.176912                 0.035854
max                1.000000                 1.000000
```

```
[8 rows x 23 columns]
```

[12]:
```
print(f"Total companies: {len(df):}")
```

```
Total companies: 5522
```

[13]:
```
df[bankruptcy_col].value_counts()
```

[13]:
```
bankrupt
0    5344
1     178
Name: count, dtype: int64
```

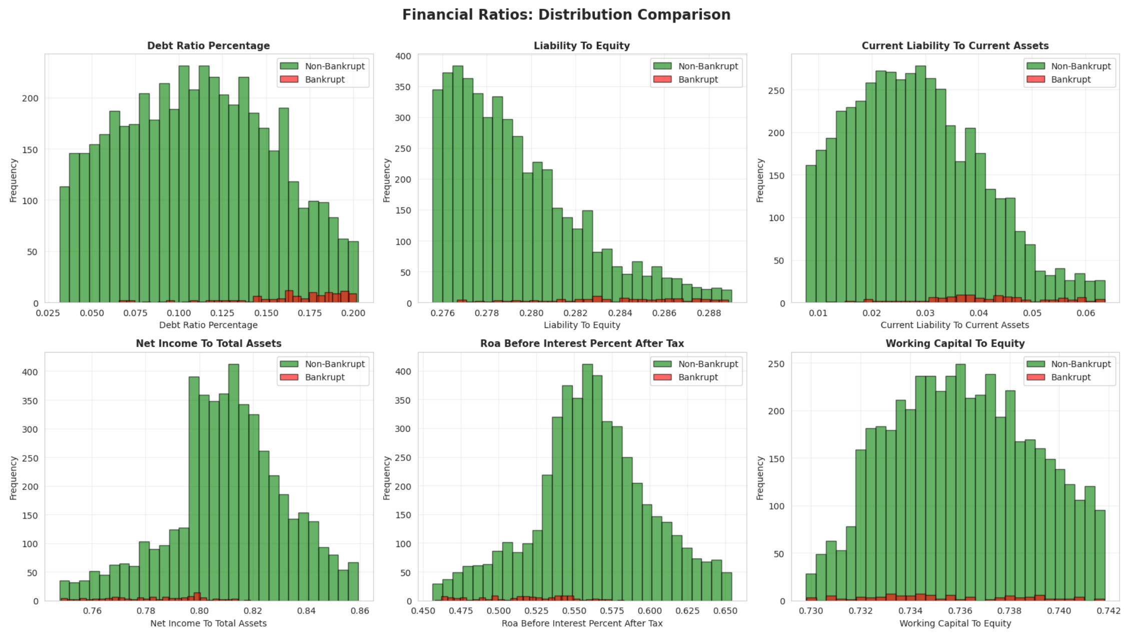
[14]:
```
print(f'Bankruptcy Rate: {df[bankruptcy_col].mean() * 100:.2f}%')
```

```
Bankruptcy Rate: 3.22%
```

[15]:
```
# 220 Bankrupt companies
# 6599 non-Bankrupt companies
```

[16]:
```
key_ratios = [
    'debt_ratio_percentage',
    'liability_to_equity',
    'current_liability_to_current_assets',
    'net_income_to_total_assets',
    'roa_before_interest_percent_after_tax',
    'working_capital_to_equity'
]

fig, axes = plt.subplots(2, 3, figsize=(18,10))
axes = axes.flatten()

for idx, ratio in enumerate(key_ratios):
    q1 = df[ratio].quantile(.05)
    q3 = df[ratio].quantile(.95)
    df_filtered = df[(df[ratio] >= q1) & (df[ratio] <= q3)]

    axes[idx].hist(df_filtered[df_filtered[bankruptcy_col]==0][ratio].dropna(),
                   bins=30, alpha=0.6, label='Non-Bankrupt', color='green',␣
↪edgecolor='black')
    axes[idx].hist(df_filtered[df_filtered[bankruptcy_col]==1][ratio].dropna(),
                   bins=30, alpha=0.6, label='Bankrupt', color='red',␣
↪edgecolor='black')

    axes[idx].set_xlabel(ratio.replace('_', ' ').title(), fontsize=10)
    axes[idx].set_ylabel('Frequency', fontsize=10)
    axes[idx].set_title(f'{ratio.replace("_", " ").title()}', fontsize=11,␣
↪fontweight='bold')
```

```
    axes[idx].legend()
    axes[idx].grid(alpha=0.3)

plt.suptitle('Financial Ratios: Distribution Comparison', fontsize=16,␣
 ↪fontweight='bold', y=1.00)
plt.tight_layout()
plt.show()
```

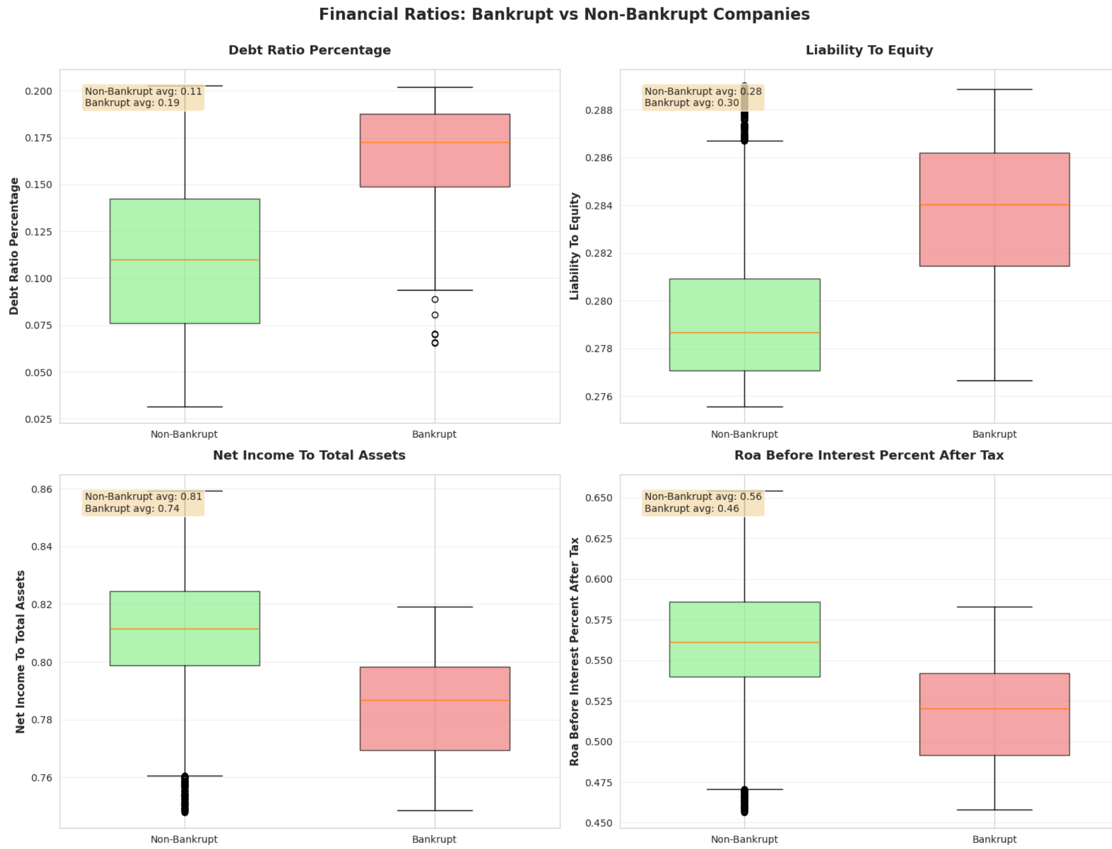


[17]:
```
comparison = df.groupby(bankruptcy_col)[key_ratios].mean().round(3)
comparison.index = ['non-Bankrupt', 'Bankrupt']
print("Mean Value Comparisons:")
print(comparison.T)
```

```
Mean Value Comparisons:
                                     non-Bankrupt  Bankrupt
debt_ratio_percentage                       0.111     0.188
liability_to_equity                         0.280     0.297
current_liability_to_current_assets         0.031     0.062
net_income_to_total_assets                  0.810     0.741
roa_before_interest_percent_after_tax       0.562     0.461
working_capital_to_equity                   0.736     0.724
```

[18]:
```
important_ratios = [
    'debt_ratio_percentage',
    'liability_to_equity',
    'net_income_to_total_assets',
    'roa_before_interest_percent_after_tax'
```

```
]

fig, axes = plt.subplots(2, 2, figsize=(16,12))
axes = axes.flatten()

for idx, ratio in enumerate(important_ratios):
    q1 = df[ratio].quantile(0.05)
    q3 = df[ratio].quantile(0.95)
    df_filtered = df[(df[ratio] >= q1) & (df[ratio] <= q3)]

    box_data = [df_filtered[df_filtered[bankruptcy_col]==0][ratio].dropna(),
                df_filtered[df_filtered[bankruptcy_col]==1][ratio].dropna()]

    bp = axes[idx].boxplot(box_data, labels=['Non-Bankrupt', 'Bankrupt'],
                           patch_artist=True, widths=0.6)

    colors = ['lightgreen', 'lightcoral']
    for patch, color in zip(bp['boxes'], colors):
        patch.set_facecolor(color)
        patch.set_alpha(0.7)
    axes[idx].set_ylabel(ratio.replace('_', ' ').title(), fontsize=11,␣
 ↪fontweight='bold')
    axes[idx].set_title(f'{ratio.replace("_", " ").title()}',
                        fontsize=13, fontweight='bold', pad=15)
    axes[idx].grid(axis='y', alpha=0.3)

    mean_no_bank = df[df[bankruptcy_col]==0][ratio].mean()
    mean_bank = df[df[bankruptcy_col]==1][ratio].mean()

    textstr = f'Non-Bankrupt avg: {mean_no_bank:.2f}\nBankrupt avg: {mean_bank:.
 ↪2f}'
    axes[idx].text(0.05, 0.95, textstr, transform=axes[idx].transAxes,
                   fontsize=10, verticalalignment='top',
                   bbox=dict(boxstyle='round', facecolor='wheat', alpha=0.8))

plt.suptitle('Financial Ratios: Bankrupt vs Non-Bankrupt Companies',
             fontsize=16, fontweight='bold', y=1.00)
plt.tight_layout()
plt.show()
```



[19]:

```python
print("Key Differences between Bankrupt vs. Non-Bankrupt:")
for ratio in important_ratios:
    mean_normal = df[df[bankruptcy_col]==0][ratio].mean()
    mean_bankrupt = df[df[bankruptcy_col]==1][ratio].mean()
    if mean_normal != 0:
        diff_pct = ((mean_bankrupt - mean_normal) / mean_normal * 100)
    else:
        0
    print(f'\n{ratio}: {diff_pct:+.1f}% difference')
```

```
Key Differences between Bankrupt vs. Non-Bankrupt:

debt_ratio_percentage: +70.2% difference

liability_to_equity: +6.2% difference

net_income_to_total_assets: -8.5% difference

roa_before_interest_percent_after_tax: -18.0% difference
```

[20]:
```
numeric_cols = df.select_dtypes(include=[np.number]).columns.tolist()
print(f'{len(numeric_cols)} numeric features')
```

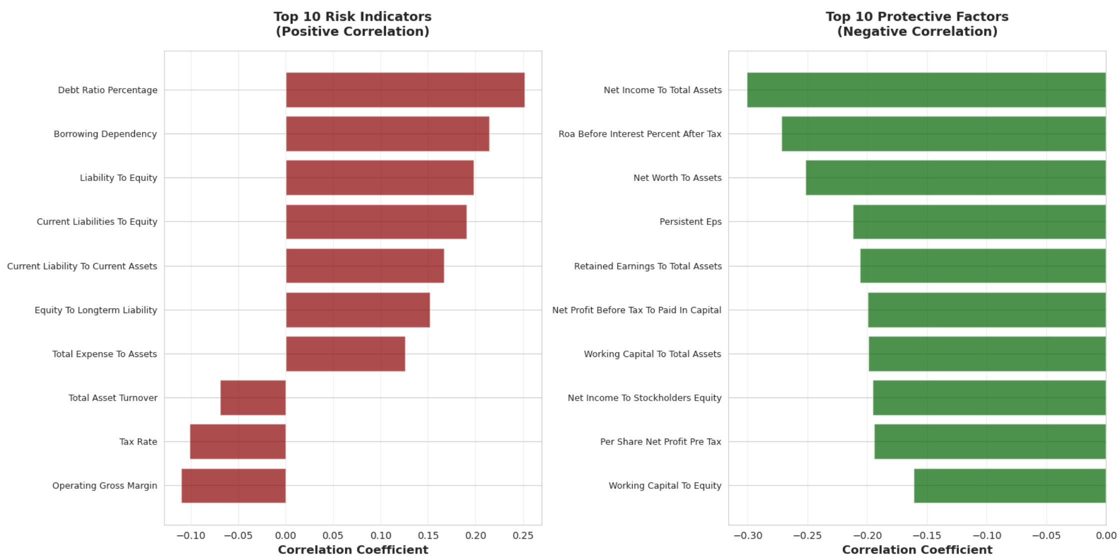
```
23 numeric features
```

[21]:
```
correlations = df[numeric_cols].corr()[bankruptcy_col].
↪sort_values(ascending=False)
correlations = correlations.drop(bankruptcy_col)

print(correlations.head(10).to_string())
print("")
print(correlations.tail(10).to_string())
```

```
debt_ratio_percentage                   0.251741
borrowing_dependency                    0.214362
liability_to_equity                     0.198140
current_liabilities_to_equity           0.191041
current_liability_to_current_assets     0.166677
equity_to_longterm_liability            0.151755
total_expense_to_assets                 0.125832
total_asset_turnover                   -0.068848
tax_rate                               -0.101525
operating_gross_margin                 -0.109776

working_capital_to_equity                   -0.161235
per_share_net_profit_pre_tax                -0.194256
net_income_to_stockholders_equity           -0.195667
working_capital_to_total_assets             -0.199284
net_profit_before_tax_to_paid_in_capital    -0.199889
retained_earnings_to_total_assets           -0.206084
persistent_eps                              -0.211888
net_worth_to_assets                         -0.251741
roa_before_interest_percent_after_tax       -0.271845
net_income_to_total_assets                  -0.300868
```

[22]:
```
fig, axes = plt.subplots(1, 2, figsize=(16,8))

top_10_pos = correlations.head(10)
axes[0].barh(range(len(top_10_pos)), top_10_pos.values, color='darkred', alpha=0.
↪7)
axes[0].set_yticks(range(len(top_10_pos)))
axes[0].set_yticklabels([col.replace('_', ' ').title() for col in top_10_pos.
↪index], fontsize=9)
axes[0].set_xlabel('Correlation Coefficient', fontsize=12, fontweight='bold')
axes[0].set_title('Top 10 Risk Indicators\n(Positive Correlation)',
                  fontsize=13, fontweight='bold', pad=15)
axes[0].invert_yaxis()
axes[0].grid(axis='x', alpha=0.3)
```

```
# Top negative correlations (protective factors)
top_10_neg = correlations.tail(10).sort_values()
axes[1].barh(range(len(top_10_neg)), top_10_neg.values, color='darkgreen',␣
↪alpha=0.7)
axes[1].set_yticks(range(len(top_10_neg)))
axes[1].set_yticklabels([col.replace('_', ' ').title() for col in top_10_neg.
↪index], fontsize=9)
axes[1].set_xlabel('Correlation Coefficient', fontsize=12, fontweight='bold')
axes[1].set_title('Top 10 Protective Factors\n(Negative Correlation)',
                  fontsize=13, fontweight='bold', pad=15)
axes[1].invert_yaxis()
axes[1].grid(axis='x', alpha=0.3)

plt.tight_layout()
plt.show()
```



[23]:
```
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler

feature_cols = [col for col in df.columns if col not in ['company_id',␣
↪bankruptcy_col]]
print(f'{len(feature_cols)} features for prediction')

X = df[feature_cols].copy()
y = df[bankruptcy_col].copy()
print(f'Target distribution: {y.value_counts().to_dict()}')
```

```
X = X.replace([np.inf, -np.inf], np.nan)
X = X.fillna(X.median())

X_train, X_test, y_train, y_test = train_test_split(
    X, y,
    test_size=0.2,
    random_state=42,
    stratify=y
)
print(f"Training set: {X_train.shape[0]} samples ({y_train.mean()*100:.1f}%␣
↪bankruptcy)")
print(f"Test set: {X_test.shape[0]} samples ({y_test.mean()*100:.1f}%␣
↪bankruptcy)")

scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
```

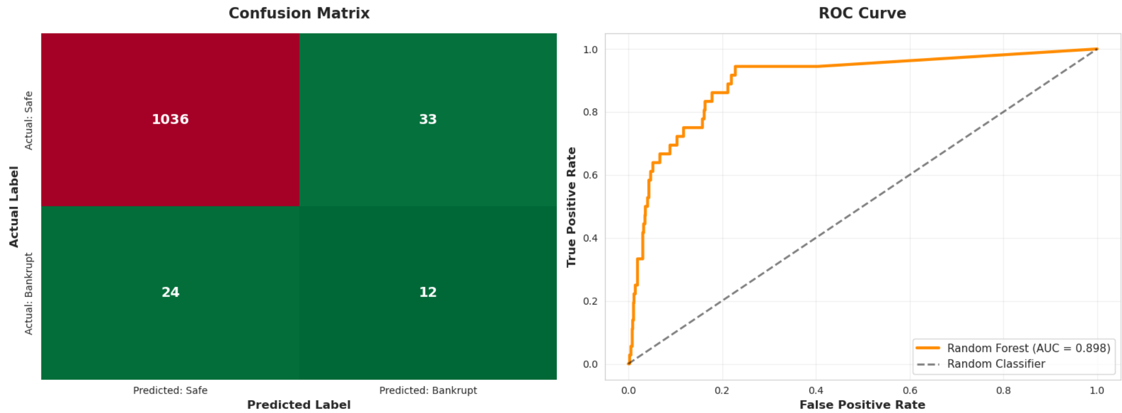
```
22 features for prediction
Target distribution: {0: 5344, 1: 178}
Training set: 4417 samples (3.2% bankruptcy)
Test set: 1105 samples (3.3% bankruptcy)
```

[24]:

```
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import (classification_report, confusion_matrix,
                             roc_auc_score, roc_curve, accuracy_score,
                             precision_score, recall_score, f1_score)

# Decided to use RF for this
rf_model = RandomForestClassifier(
    n_estimators = 100,
    max_depth = 10,
    min_samples_split = 5,
    random_state = 42,
    class_weight = 'balanced',
    n_jobs = -1
)

rf_model.fit(X_train_scaled, y_train)

y_pred = rf_model.predict(X_test_scaled)
y_pred_proba = rf_model.predict_proba(X_test_scaled)[:,1]

# metrics
accuracy = accuracy_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
```

```python
f1 = f1_score(y_test, y_pred)
roc_auc = roc_auc_score(y_test, y_pred_proba)

print(classification_report(y_test, y_pred, target_names=['non-Bankrupt',␣
↪'Bankrupt']))


fig, axes = plt.subplots(1, 2, figsize=(16,6))
cm = confusion_matrix(y_test, y_pred)
sns.heatmap(cm, annot=True, fmt='d', cmap='RdYlGn_r', cbar=False, ax=axes[0],
            xticklabels = ['Predicted: Safe', 'Predicted: Bankrupt'],
            yticklabels = ['Actual: Safe', 'Actual: Bankrupt'],
            annot_kws = {"fontsize": 14, 'fontweight': 'bold'})
axes[0].set_title('Confusion Matrix', fontsize=15, fontweight='bold', pad=15)
axes[0].set_ylabel('Actual Label', fontsize=12, fontweight='bold')
axes[0].set_xlabel('Predicted Label', fontsize=12, fontweight='bold')

fpr, tpr, thresholds = roc_curve(y_test, y_pred_proba)
axes[1].plot(fpr, tpr, linewidth=3, label=f'Random Forest (AUC = {roc_auc:.
↪3f})', color='darkorange')
axes[1].plot([0, 1], [0, 1], 'k--', linewidth=2, label='Random Classifier',␣
↪alpha=0.5)
axes[1].set_xlabel('False Positive Rate', fontsize=12, fontweight='bold')
axes[1].set_ylabel('True Positive Rate', fontsize=12, fontweight='bold')
axes[1].set_title('ROC Curve', fontsize=15, fontweight='bold', pad=15)
axes[1].legend(fontsize=11, loc='lower right')
axes[1].grid(alpha=0.3)

plt.tight_layout()
plt.show()
```

```
              precision    recall  f1-score   support

non-Bankrupt       0.98      0.97      0.97      1069
    Bankrupt       0.27      0.33      0.30        36

    accuracy                           0.95      1105
   macro avg       0.62      0.65      0.63      1105
weighted avg       0.95      0.95      0.95      1105
```

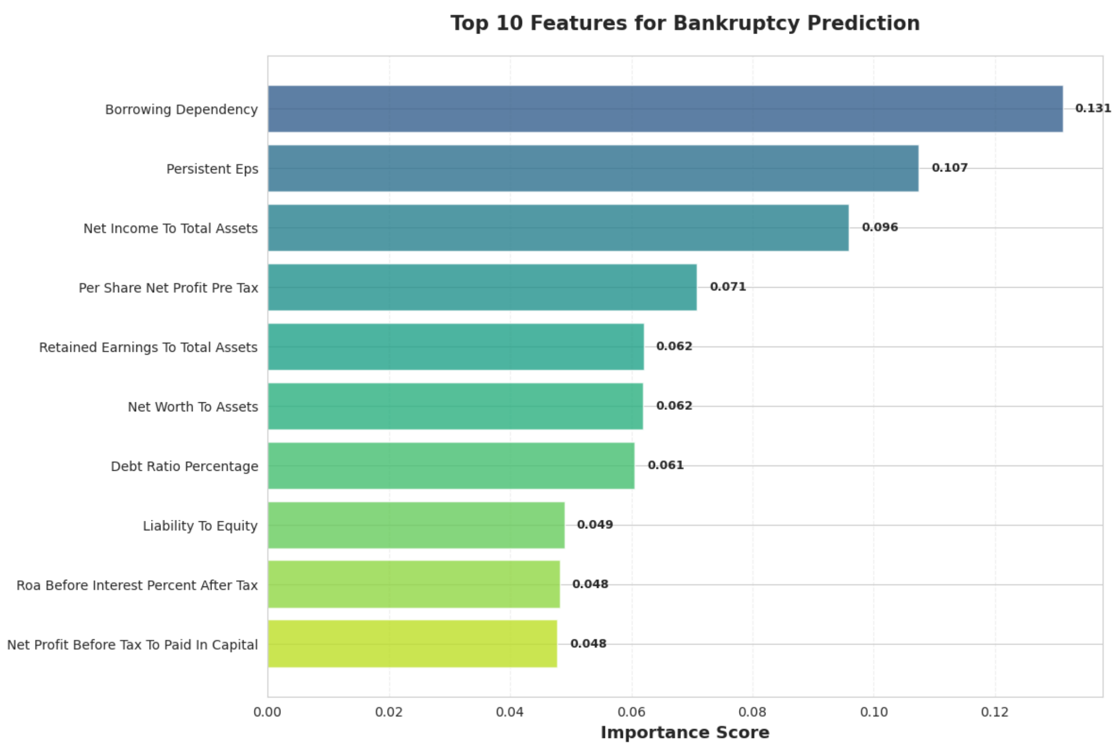


[25]:
```
feature_importance = pd.DataFrame({
    'feature': feature_cols,
    'importance': rf_model.feature_importances_
}).sort_values('importance', ascending=False)

print("Top 10 most important features:")
print(feature_importance.head(10).to_string(index=False))
```

```
Top 10 most important features:
                              feature  importance
                 borrowing_dependency    0.131195
                       persistent_eps    0.107448
             net_income_to_total_assets    0.095930
            per_share_net_profit_pre_tax    0.070879
      retained_earnings_to_total_assets    0.062052
                  net_worth_to_assets    0.061965
                debt_ratio_percentage    0.060598
                  liability_to_equity    0.048988
    roa_before_interest_percent_after_tax    0.048194
net_profit_before_tax_to_paid_in_capital    0.047844
```

[26]:
```
plt.figure(figsize=(12, 8))
top_features = feature_importance.head(10)

colors = plt.cm.viridis(np.linspace(0.3, 0.9, len(top_features)))
bars = plt.barh(range(len(top_features)), top_features['importance'],␣
↪color=colors, alpha=0.8)

plt.yticks(range(len(top_features)), [f.replace('_', ' ').title() for f in␣
↪top_features['feature']], fontsize=10)
plt.xlabel('Importance Score', fontsize=13, fontweight='bold')
plt.title('Top 10 Features for Bankruptcy Prediction', fontsize=15,␣
↪fontweight='bold', pad=20)
```

```
plt.gca().invert_yaxis()
plt.grid(axis='x', alpha=0.3, linestyle='--')

# Add value labels
for i, (idx, row) in enumerate(top_features.iterrows()):
    plt.text(row['importance'] + 0.002, i, f"{row['importance']:.3f}",
            va='center', fontsize=9, fontweight='bold')

plt.tight_layout()
plt.show()
```



[27]:
```
obj_predict = s3_client.get_object(
    Bucket=bucket_name,
    Key = 'machine-learning-data/company_profiles_to_predict_unlabeled.csv'
)

df_predict = pd.read_csv(obj_predict['Body'])
df_predict.head()
```

[27]:
```
   borrowing_dependency           company company_id  \
0              0.458819       western corp    id_6988
1              0.379304  design solutions    id_7413
2              0.384999          innocore    id_8801
```

```
3            0.374219       pharmasolve    id_9614
4            0.370253          ninetech    id_9131

   current_liabilities_to_equity  current_liability_to_current_assets  \
0                       0.372218                             0.060766
1                       0.333345                             0.041220
2                       0.337392                             0.060765
3                       0.329804                             0.030201
4                       0.328093                             0.021710

   debt_ratio_percentage  equity_to_longterm_liability  liability_to_equity  \
0               0.269039                      0.216878             0.337315
1               0.161865                      0.120812             0.282763
2               0.216102                      0.120561             0.292504
3               0.108202                      0.114508             0.278607
4               0.058591                      0.110933             0.276423

   net_income_to_stockholders_equity  net_income_to_total_assets  ...  \
0                           0.765967                    0.641804  ...
1                           0.840533                    0.800780  ...
2                           0.829980                    0.736619  ...
3                           0.841459                    0.815350  ...
4                           0.840487                    0.803647  ...

   operating_profit_per_share  per_share_net_profit_pre_tax  persistent_eps  \
0                    0.050566                      0.106274        0.154297
1                    0.107727                      0.175868        0.217737
2                    0.099910                      0.128945        0.161482
3                    0.104796                      0.180462        0.225206
4                    0.095188                      0.173157        0.218398

   retained_earnings_to_total_assets  roa_before_interest_percent_after_tax  \
0                           0.879445                               0.344636
1                           0.933467                               0.544320
2                           0.911441                               0.445704
3                           0.935449                               0.570922
4                           0.935200                               0.545137

   tax_rate  total_asset_turnover  total_expense_to_assets  \
0  0.000000              0.068966                 0.079232
1  0.564328              0.107946                 0.038927
2  0.000000              0.100450                 0.092802
3  0.157607              0.218891                 0.025482
4  0.005871              0.154423                 0.029884

   working_capital_to_equity  working_capital_to_total_assets
0                   0.718867                         0.720006
```

```
1                    0.733645                         0.769527
2                    0.728731                         0.729416
3                    0.734946                         0.797005
4                    0.735182                         0.813738

[5 rows x 24 columns]
```

[28]:

```
if 'company_name' in df_predict.columns:
    company_names = df_predict['company_name'].copy()
elif 'company' in df_predict.columns:
    company_names = df_predict['company'].copy()
else:
    company_names = [f"Company_{i+1}" for i in range(len(df_predict))]

if 'company_id' in df_predict.columns:
    company_ids = df_predict['company_id'].copy()
else:
    company_ids = [f"ID_{i+1}" for i in range(len(df_predict))]
```

[29]:

```
X_predict = df_predict[feature_cols].copy()

X_predict = X_predict.replace([np.inf, -np.inf], np.nan)
X_predict = X_predict.fillna(X_predict.median())

X_predict_scaled = scaler.transform(X_predict)

predictions = rf_model.predict(X_predict_scaled)
prediction_probabilities = rf_model.predict_proba(X_predict_scaled)[:,1]

results = pd.DataFrame({
    'company_id': company_ids,
    'company_name': company_names,
    'bankruptcy_prediction': predictions,
    'bankruptcy_probability': prediction_probabilities,
    'bankruptcy_risk_pct': prediction_probabilities * 100
})

def categorize_risk(prob):
    if prob < .2:
        return 'LOW RISK'
    elif prob < .5:
        return 'MEDIUM RISK'
    else:
        return 'HIGH RISK'

results['risk_category'] = results['bankruptcy_probability'].
 ↪apply(categorize_risk)
```

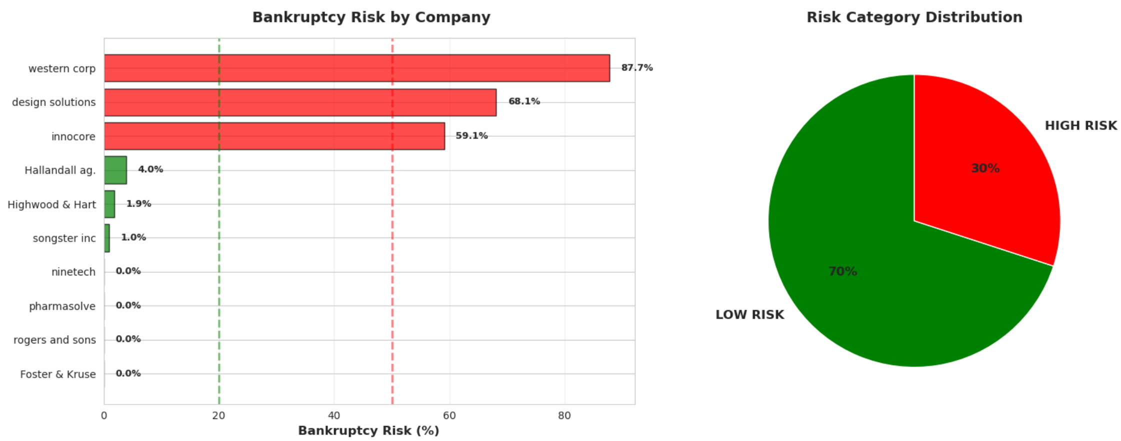
```
results = results.sort_values('bankruptcy_probability', ascending=False)

print("Bankruptcy Predictions")
print(results[['company_name', 'bankruptcy_risk_pct', 'risk_category']].
↪to_string(index=False))
```

```
Bankruptcy Predictions
    company_name  bankruptcy_risk_pct risk_category
    western corp            87.746471     HIGH RISK
design solutions            68.107294     HIGH RISK
        innocore            59.094088     HIGH RISK
  Hallandall ag.             3.967326      LOW RISK
 Highwood & Hart             1.922494      LOW RISK
    songster inc             1.000000      LOW RISK
        ninetech             0.000000      LOW RISK
     pharmasolve             0.000000      LOW RISK
 rogers and sons             0.000000      LOW RISK
  Foster & Kruse             0.000000      LOW RISK
```

[30]:

```
fig, axes = plt.subplots(1, 2, figsize=(16,6))

colors = ['red' if p > .5 else 'orange' if p > .2 else 'green' for p in␣
↪results['bankruptcy_probability']]
axes[0].barh(range(len(results)), results['bankruptcy_risk_pct'], color=colors,␣
↪alpha=0.7, edgecolor='black')
axes[0].set_yticks(range(len(results)))
axes[0].set_yticklabels(results['company_name'], fontsize=10)
axes[0].set_xlabel('Bankruptcy Risk (%)', fontsize=12, fontweight='bold')
axes[0].set_title(' Bankruptcy Risk by Company', fontsize=14, fontweight='bold',␣
↪pad=15)
axes[0].axvline(x=20, color='green', linestyle='--', linewidth=2, alpha=0.5)
axes[0].axvline(x=50, color='red', linestyle='--', linewidth=2, alpha=0.5)
axes[0].grid(axis='x', alpha=0.3)
axes[0].invert_yaxis()

for i, (idx, row) in enumerate(results.iterrows()):
    axes[0].text(row['bankruptcy_risk_pct'] + 2, i,␣
↪f"{row['bankruptcy_risk_pct']:.1f}%",
                va='center', fontsize=9, fontweight='bold')

risk_counts = results['risk_category'].value_counts()
colors_pie = ['green', 'red', 'orange']
axes[1].pie(risk_counts.values, labels=risk_counts.index, autopct='%1.0f%%',
            colors=colors_pie, startangle=90, textprops={'fontsize': 12,␣
↪'fontweight': 'bold'})
axes[1].set_title('Risk Category Distribution', fontsize=14, fontweight='bold',␣
↪pad=15)
```

```
plt.tight_layout()
plt.show()
```



[31]:
```
low_risk = results[results['risk_category'] == 'LOW RISK']
medium_risk = results[results['risk_category'] == 'MEDIUM RISK']
high_risk = results[results['risk_category'] == 'HIGH RISK']

print("These companies show LOW bankruptcy risk:")
for idx, row in low_risk.iterrows():
    print(f"{row['company_name']}:")
    print(f" Bankruptcy Risk: {row['bankruptcy_risk_pct']:.1f}%")
```

```
These companies show LOW bankruptcy risk:
Hallandall ag.:
 Bankruptcy Risk: 4.0%
Highwood & Hart:
 Bankruptcy Risk: 1.9%
songster inc:
 Bankruptcy Risk: 1.0%
ninetech:
 Bankruptcy Risk: 0.0%
pharmasolve:
 Bankruptcy Risk: 0.0%
rogers and sons:
 Bankruptcy Risk: 0.0%
Foster & Kruse:
 Bankruptcy Risk: 0.0%
```

[32]:
```
print("These companies show MEDIUM bankruptcy risk:")
if len(medium_risk) > 0:
    for idx, row in medium_risk.iterrows():
```

```
        print(f"{row['company_name']}")
        print(f" Bankruptcy Risk: {row['bankruptcy_risk_pct']:.1f}%")
else:
    print("No companies available")
```

```
These companies show MEDIUM bankruptcy risk:
No companies available
```

[33]:
```
print("These companies show HIGH bankruptcy risk:")
if len(high_risk) > 0:
    for idx, row in high_risk.iterrows():
        print(f"{row['company_name']}")
        print(f" Bankruptcy Risk: {row['bankruptcy_risk_pct']:.1f}%")
```

```
These companies show HIGH bankruptcy risk:
western corp
 Bankruptcy Risk: 87.7%
design solutions
 Bankruptcy Risk: 68.1%
innocore
 Bankruptcy Risk: 59.1%
```

[34]:
```
print(f"Total companies evaluated: {len(results)}")
print(f"Recommended for investment: {len(low_risk)}")
print(f"Not recommended: {len(high_risk)}")
```

```
Total companies evaluated: 10
Recommended for investment: 7
Not recommended: 3
```

[35]:
```
summary_table = results[['company_name', 'bankruptcy_risk_pct',␣
↪'risk_category']].copy()
summary_table['recommendation'] = summary_table['risk_category'].map({
    'LOW RISK' : 'INVEST',
    'MEDIUM RISK' : 'DO RESEARCH',
    'HIGH RISK' : 'AVOID'
})
print(summary_table.to_string(index=False))
```

```
    company_name  bankruptcy_risk_pct risk_category recommendation
    western corp            87.746471     HIGH RISK          AVOID
design solutions            68.107294     HIGH RISK          AVOID
        innocore            59.094088     HIGH RISK          AVOID
  Hallandall ag.             3.967326      LOW RISK         INVEST
 Highwood & Hart             1.922494      LOW RISK         INVEST
    songster inc             1.000000      LOW RISK         INVEST
        ninetech             0.000000      LOW RISK         INVEST
     pharmasolve             0.000000      LOW RISK         INVEST
 rogers and sons             0.000000      LOW RISK         INVEST
```

```
  Foster & Kruse               0.000000      LOW RISK         INVEST
```

[36]:
```python
csv_buffer = StringIO()
results.to_csv(csv_buffer, index=False)

s3_client.put_object(
    Bucket = bucket_name,
    Key = 'predictions/bankruptcy_predictions.csv',
    Body = csv_buffer.getvalue()
)

print('predictions saved to s3')
```

```
predictions saved to s3
```

[37]:
```python
# Summary metrics for presentation (potential)
print(f"Model Accuracy: {accuracy*100:.1f}%")
print(f"ROC-AUC Score: {roc_auc:.3f}")
print(f"Companies to invest in: {len(low_risk)}")
print(f"Companies to avoid: {len(high_risk)}")
print(f"Top 3 risk indicators: {', '.join(feature_importance.head(3)['feature'].
 ↪tolist())}")
```

```
Model Accuracy: 94.8%
ROC-AUC Score: 0.898
Companies to invest in: 7
Companies to avoid: 3
Top 3 risk indicators: borrowing_dependency, persistent_eps,
net_income_to_total_assets
```