# Silent Suffering: Using Machine Learning to Measure CEO Depression

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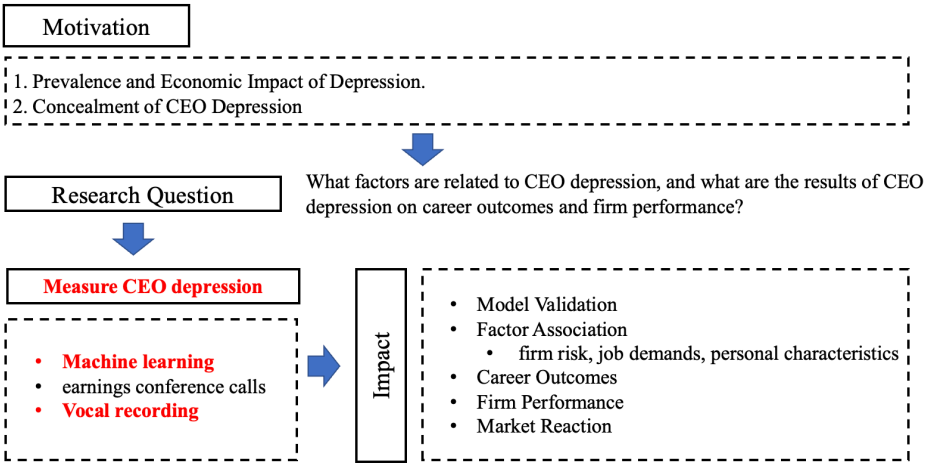
# Desgin


Motivation
1. Prevalence and Economic Impact of Depression.
2. Concealment of CEO Depression
Research Question
What factors are related to CEO depression, and what are the results of CEO depression on career outcomes and firm performance?
Measure CEO depression
Machine learning
earnings conference calls
Vocal recording
Impact
Model Validation
Factor Association
firm risk, job demands, personal characteristics
Career Outcomes
Firm Performance
Market Reaction

# Comparison

**Commonalities:**

- **Non-traditional Data Sources:**
  - Analyzing and predicting economic behavior or decision-making
  - (1)Digital footprints, (2)facial expressions, (3)vocal acoustic features
- **Paper2, 3**
  - Emotion analysis
- **Paper1, 2**
  - Predicting consumer default

**Differences:**

- **Research Objects**
  - Digital Footprints: historical data,
  - Real-time information: facial expressions
  - CEO Depression: Earnings calls
- **Indicator Construction Methods:**
  - Paper 2,3: Machine learning
  - Paper 1: simple, easily accessible variables

# Motivation: CEO depression is high prevalence

- Depression is a pervasive condition
  - Depression and anxiety result in an estimated *12 billion lost workdays annually*, costing the global economy around *1 trillion* per year(WHO2023)
  - How to detect depression: PHQ, QIDS-SR...
- CEO Depression is high prevalence
  - *Pivotal role as decision-makers*, CEOs'emotional states significantly impact their careers, firms, and the broader economy.
  - The uncertainty and ambiguity inherent in CEOs'roles can exacerbate anxiety and depression
  - So, ***What factors are related to CEO depression, and what are the results of CEO depression on career outcomes and firm performance?***

# Motivation: CEO depression remains hidden

- CEO depression remains hidden
  - Due to stigma and concerns about professional reputation, Depression often underrecognized and undertreated.
  - Unlike more visible traits such as overconfidence, narcissism and extraversion
- Introduce a measure that captures CEO depression using CEOs'vocal acoustic features.
  - Understand the prevalence and severity of depression among CEOs.
  - Examine how CEO depression relates to career outcomes
  - Building the CEO depression measure and analyses

# Contribution: CEO depression effect

- Literature on how CEO characteristics explain variation in CEO turnover and firm investment...
  - Prior: static traits(military background, MBA degree, overconfidence, narcissism...)
  - Extend: dynamic psychological state: depression
- Understanding of managerial labor markets
  - Prior: the nonlinear effect of CEO optimism on turnover
  - Extend: quantify the association between CEO depression and career outcomes
- Examining the effect of general mood changes on economic agents'activity and decisions
  - Prior: use weather or hospital admissions as proxies for low mood
  - Extend: directly measure CEO depression from vocal acoustic features

# Contribution: introduce a measure captures CEO depression

- The impact of vocal cues in financial markets
  - Prior: how voices are perceived by investors, analysts, and auditors
  - Extend: analyze vocal acoustic features imperceptible to the human ear
- Literature on machine learning techniques in accounting and finance
  - Prior: predicting lending decisions, fundamental analysis
  - Extend: the first to use CEOs'vocal acoustic features to predict CEO depression

# Hypotheses

- Risk factors(CEO performance, firm risk, CEO linguistic patterns during conference calls, job demands, and personal characteristics and seasonal effects) is associated with CEO depression
- CEO depression is associated with career outcomes, including turnover, career prospects, TPS, compensation, and PPS
- CEO depression explains firm performance in the short or long term
- CEO depression explains abnormal returns around conference calls

# Training the depression detection model

**1. DAIC data**

1. American English proficiency
2. Gender balance
3. Neutral and depression-specific questions

**2. Three subsamples**

1. Training (107 observations, 57%)
2. Development (35 observations, 18%)
3. Testing (47 observations, 25%)

**3. Feature extraction**

1. Acoustic features: Extracted 6,373 ComParE and 89 GeMAPS features
2. YAMNet Model
3. PCA: Reduced feature dimensions.

| No | Machine Learning Model | Input | Output | RMSE | MAE | RMSE Baseline | MAE Baseline |
|---|---|---|---|---|---|---|---|
| 1 | Linear regression | ComParE and GeMAPS Features | Depression Score based on the PHQ-8 Scale | 6.69 | 5.42 | 7.78 | 5.72 |
| 2 | Linear regression | YAMNet Embeddings | Depression Score based on the PHQ-8 Scale | 5.83 | 4.87 | 7.78 | 5.72 |
| 3 | Support vector regression (SVR) | ComParE and GeMAPS Features | Depression Score based on the PHQ-8 Scale | 6.16 | 4.95 | 7.78 | 5.72 |
| 4 | Support vector regression (SVR) | YAMNet Embeddings | Depression Score based on the PHQ-8 Scale | 5.71 | 4.67 | 7.78 | 5.72 |
| 5 | Convolutional neural network (CNN) | Spectrogram images of audio signals | Depression Score based on the PHQ-8 Scale | 6.51 | 5.64 | 7.78 | 5.72 |

# Method for measuring CEO depression

1. **Data Collection & Screening**
   - Data Source: earnings conference calls (2010-2021), focusing on the CEO presentation at the beginning for longer speech duration.
   - Final Sample: 14,608 firm-quarter observations from 421 firms and 826 CEOs
2. **Model Application**
   - Predict Depression Score: Input features into trained depression detection model (YAMNet-based SVR)
   - Indicator : Score $>$ 10 indicates depression (1), otherwise not depressed (0)
3. **Validation**
   - Event Validation: Compare depression scores from 500 calls with other events within 14 days, average difference 4.66 (close to MAE 4.67)
   - Factor Analysis: Test associations with CEO depression factors
   - Known Cases: Verify model predictions for CEOs with known depression

# Results 1: factors associated with CEO depression

- Female and older CEOs have a lower probability of depression
- Factors related to firm risk are positively associated with CEO depression
- Factors related to CEO job demands are negatively associated with CEO depression.

Panel G: All variables using principal components analysis

| Dependent Variable = | *CEO Depression Indicator* (1) | *CEO Depression Score* (2) |
|---|---|---|
| *CEO Performance Factor* | −0.0008 | 0.0447 |
| | (−0.1539) | (0.7249) |
| *Firm Risk* | 0.0083 | 0.2228** |
| | (0.9116) | (2.3782) |
| *CEO Speech Properties Factor* | 0.0029 | 0.0219 |
| | (0.4017) | (0.3917) |
| *CEO Job Demands Factor* | −0.0049 | −0.1763*** |
| | (−0.5475) | (−2.7155) |
| *Female* | −0.1553*** | −1.8800*** |
| | (−4.8398) | (−7.9623) |
| *CEO Age* | −0.0032*** | −0.0293*** |
| | (−2.6725) | (−2.8286) |
| *Season* | −0.0041 | −0.2269 |
| | (−0.3234) | (−1.4282) |

# Results 2: CEO depression and CEO career outcomes

- No evidence that CEO depression is associated with CEO turnover
- Limited evidence that CEO depression is associated with higher TPS, higher compensation, and higher pay-performance sensitivity

| Dependent Variable = | *CEO Turnover* | | *CEO Departure to Larger Firm* | | *CEO Departure to Smaller Firm* | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *CEO Depression Indicator Mode* | 0.0051 | | −0.0003 | | −0.0006 | |
| | (0.4449) | | (−0.1344) | | (−0.2849) | |
| *Mean CEO Depression Score* | | 0.0002 | | −0.0001 | | −0.0004 |
| | | (0.1752) | | (−0.2837) | | (−1.2131) |
| *Sales Growth* | 0.0069 | 0.0073 | −0.0014 | −0.0014 | −0.0102 | −0.0102 |
| | (0.1788) | (0.1877) | (−0.4367) | (−0.4332) | (−0.7914) | (−0.7949) |

# Results 3: CEO depression and firm performance

- No evidence that CEO depression is associated with firm performance in the short term or long term

| Dependent Variable = | $Return_q$ | | $Return_{q+1,q+4}$ | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *CEO Depression Indicator* | −0.0008 | | −0.0040 | |
| | (−0.1447) | | (−0.7426) | |
| *CEO Depression Score* | | −0.0007 | | −0.0004 |
| | | (−1.5421) | | (−1.0368) |
| *MB* | 0.0051*** | 0.0051*** | 0.0013* | 0.0013* |
| | (5.2640) | (5.2586) | (1.8532) | (1.8462) |
| *Return Volatility* | 0.2214 | 0.2258 | 1.1941*** | 1.1948*** |
| | (1.1687) | (1.1903) | (6.9158) | (6.9152) |

# Results 4: CEO depression and stock market reactions

- No association between CEO depression and abnormal returns around conference calls
- Investors do not detect CEO depression during these calls

| Dependent Variable = | *CAR[0,+1]* | |
|---|---|---|
| | (1) | (2) |
| *CEO Depression Indicator* | 0.0004 | |
| | (0.4358) | |
| *CEO Depression Score* | | −0.0000 |
| | | (−0.5672) |
| *CEO Tone* | 0.0420*** | 0.0420*** |
| | (9.0547) | (9.0467) |
| *MB* | 0.0000 | 0.0000 |
| | (0.0256) | (0.0070) |

# Ideas

- 相对于消极情绪，抑郁特点在于其是长期的心理疾病，因此可跟踪同一个 CEO 更加长期的发言状态数据去衡量抑郁状态
- 加入控制变量：CEO 积极、消极情绪
- 综合语调、文本、表情、动作衡量 CEO 抑郁状态，考察 CEO 抑郁状态对决策和公司未来表现影响
- 抑郁症导致 CEO 对负面结果敏感性增加，风险承担能力降低，因此可以研究 CEO 抑郁对企业创新产出的影响，极端事件发生时对企业的决策影响