



# Data Science Methods

## Grammar Rules for Conversation

### About Changes in Revenue Expectations

- We've developed two grammar rules for natural language processing (NLP) to detect conversation events in corporate transcripts about revenue, and whether it is expected to increase or decrease.
- Companies identified by our "decrease rule" were 1.50 times (between 1.45 and 1.55 times at the 95% CL) more likely to earn less revenue between the last annual reporting date and the next compared with those who weren't. Those identified by our "increase rule" were 1.14 times (between 1.10 and 1.18 times at the 95% CL) more likely to earn more revenue.

FIGURE 1  
High-level summary of the rules

#### Revenue decrease grammar rule

We look for synonyms of the verb "decline" whose object contains a synonym of "revenue".

We exclude cases where:

1. We identify the wrong concept, e.g. "fee" or "revenue mix"
2. The conversation is in reference to a different company

#### Revenue increase grammar rule

We look for synonyms of the verb "increase" whose object contains a synonym of "revenue".

We exclude cases where:

1. We identify the wrong concept, e.g. "fee" or "revenue mix"
2. The conversation is in reference to a different company

Source: Barclays Research

- Detailed pseudocode for these rules is included in the text of this note, and the actual Python code in the appendix.
- The decrease rule has an out-of-sample precision of about 76.5% and an out-of-sample recall of about 83.9% over the subset of sentences selected using term search and manually classified.
- The increase rule has an out-of-sample precision of about 78.7% and out-of-sample recall of about 86.8% over the sentences selected with lemmatized search and manually classified.
- We expect the precision of these rules to generalize well from our training sub-samples to the whole transcript data set, but not the recall.

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## Appropriateness of Our Approach

We detail the use of logic rules for NLP in our report *Data Science Methods: Natural Language Processing: Grammar Rules for Event Detection in Corporate Transcripts*, October 2, 2019. We apply these to detecting mentions of expectations for revenue in these transcripts.

The down-side of using logic is that it is brittle. If the rules miss synonyms for revenue, or if sophisticated grammar is used to talk about it, we will miss events we would have liked to detect.

More time and effort generally yield better results. Positive mentions of revenue expectations might be much easier to detect relative to negative mentions. Including convoluted grammar and euphemisms can increase the number of rules we would need to write to reach a given level of detection performance. We stop short of defining an exhaustive list of specific terms, probably losing some recall as a result.

## Rule Refinement

We've written a rule for detecting lowered revenue expectations, and another for increases in expectations. With natural language signals, it's easy to try many formulations of a rule to p-hack a good result. We've developed our procedure specifically to avoid that problem, as we detail in our report *Data Science Methods: Natural Language Processing: Grammar Rules for Event Detection in Corporate Transcripts*, October 2, 2019. We'll walk through the construction of the "revenue reduction" rule. We wrote the "revenue increase" rule by using the "revenue reduction" rule as a starting place, and repeating steps 3 and 4 below until we were happy with the result.

### Step 1: Lemmatized Search for Surfacing Candidates

We start by defining keywords of interest to surface candidate phrases. For the example of trying to detect "conversation about revenue expectations", we generated the list of terms in Figure 2.

FIGURE 2  
List of terms in broad rule matching

Revenue Synonyms	Decrease Synonyms
"revenue", "top line"	"pressure", "decline", "deterioration", "degradation", "weakness"

Source: Barclays Research

We use these in a lemmatized search of all sentences in our entire collection of transcripts to get a set of candidates for detection which are much more likely to be talking about lowered revenue expectations. The goal at this stage is very high recall (trying to capture all conversation about reduction in revenue expectations), and relatively low precision (also getting lots of irrelevant conversation).

### Step 2: Manual Classification

From these candidates, we select a random sample of 100 sentences to pass along to a domain expert to manually classify as "conversation about reduced revenue expectations" or not (Figure 3). These are more likely to be positive examples (i.e. detections of reduced expectations) than a selection of random sentences.

FIGURE 3

**Sample sentences from manual classification**

Sentences	Classification
and we anticipate declining revenue from China that's built into our outlook.	1
And then finally, on ASC just looking at Q4 revenue the rate of decline dropped dramatically.	0
I guess I'm not surprised by the decline in revenues and transformation of solutions, but I am disappointed that it looks like operating expenses were up 20% in that group ?	1
Are you seeing those rebates as a percentage of revenue decline?	0

Source: Refinitiv, Barclays Research

This is a random sample of results from the lemmatized search (step 1), so the precision we measure in the random set of 100 should be a good measurement of our baseline precision to improve by refining our set of logic rules.

You can see from Figure 4 that at this stage our sample included many false positives, with a precision of 53% (additional work is still needed for more accurate detection) for our lemmatized search.

FIGURE 4

**Confusion matrix of lemmatized matching**

	Revenue decrease mentioned	Revenue decrease not mentioned
Detected	53	47
Not Detected	0	0

Source: Refinitiv, Barclays Research

We'll refine our rules in the next step to filter out bad examples from the set of manually classified sentences.

**Step 3: Iteratively Improving Precision**

The next step is a cycle where we write and test grammar rules in the set of 100 sentences we've selected and manually classified, as follows:

- Add rules to look for specific grammatical structures to our pipeline
- Measure the new precision and recall on the set of manually classified examples
- If we improve precision without losing too much recall (i.e. without excluding positive examples), keep the new rule. Otherwise, revise or remove the rule, and repeat the cycle.

Through this process, we manage precision and recall against our baseline, and can stop when we decide the results are "good enough" on this test set. For us, that was around 80% precision and 80% recall.

The rules we ended up with are summarized in Figure 5 and the pseudocode is in Figure 6

FIGURE 5

**Qualitative Description of our rules****Revenue decrease grammar rule**

We look for synonyms of the verb “decline” whose object contains a synonym of “revenue”.

We exclude cases where:

1. We identify the wrong concept, e.g. “fee” or “revenue mix”
2. The conversation is in reference to a different company

Source: Barclays Research

FIGURE 6

**Pseudocode of the main framework of revenue decrease topics grammar rules****Revenue decrease topics detection grammar rules pseudocode**

```
# get a sentence from transcripts, using spaCy to parse and tag the given sentence, then pass the sentence as the input parameter
```

```
# define two lists of words:
```

```
word_list = ['revenue','top','business']
```

```
target_list = ['deterioration', 'decline', 'degradation',
               'weakness','pressure','fall','deteriorate','degrade','down'],
```

```
then pass them as the input parameters
```

```
# main function
```

```
def detection_revenue_decrease_topics(sentence, word_list, target_list):
```

```
    # Input: sentence, word_list, target_list
```

```
    # Output: boolean variable False if not detected, True if detected
```

```
    detected = False
```

```
    contains_excluded_terms = exclusion_detector(sentence, word_list, target_list)
```

```
    mention_is_negated = negation_detector(sentence, target_list)
```

```
    if not contains_excluded_terms and not mention_is_negated:
```

```
        detected = event_detector(doc, word_list, target_list)
```

```
    return detected
```

```
# tree based event detection function:
```

```
def event_detector (sentence, word_list, target_list):
```

```
    detected = False
```

```
    special_words = ['be','go','line','comment','put','see','come', 'experience','with','poise',
                    'guide','continue','show']
```

```
    For word in sentence:
```

```
        If the lemma of the word is in word_list:
```

```
            For target in sentence:
```

```
                If the lemma of the target is in target_list:
```

```
                    If target is one of the word's ancestors:
```

```
                        detected = True
```

```
                    If the first common ancestor of both word and target is in special_words:
```

```
                        detected = True
```

```
    return detected
```

Source: Barclays Research

These rules have significantly improved performance. You can see the confusion matrix in Figure 7. The precision is 80.3% and recall is 92.5%.

FIGURE 7

**Confusion matrix of grammar rule matching**

	Revenue decrease mentioned	No revenue decrease mentioned
NLP detected	49	12
NLP not detected	4	35

Source: Refinitiv, Barclays Research

**Step 4: Testing**

We wanted to make sure we don't "over-train" by tailoring our rules to a limited number of cases in which our model works well. We re-ran our random selection process to generate 100 new examples, manually classified these, and checked our precision and recall with our rules in this new set. The resulting confusion matrix is in Figure 8.

FIGURE 8

**Confusion matrix of grammar rules on out of sample test set**

	Revenue decrease mentioned	No revenue decrease mentioned
NLP detected	52	16
NLP not detected	10	22

Source: Refinitiv, Barclays Research

The precision went from 80.3% in our first set of manual classifications to 76.5% in our last set. The recall went from 92.5% to 83.9%. Without too much loss in both precision and recall, we were satisfied to apply this to our larger data set after spot-checking some out-of-sample positive cases.

**Step 5: Spot-Check Out-of-sample Recall**

At this point, we have a set of grammar rules that work well on random samples from a larger corpus, therefore we can expect them to work comparably across the whole corpus. We ran the logic rules against all sentences from all transcripts, and so have (Company, Date) pairs with positive detections that we can use as a potential investment signal.

An application of the grammar rules is to check whether the detections actually correlate with changes in revenue, which we'll do in the last section of this report.

**Detecting Conversation About Increasing Revenue Expectations**

We also wanted to develop a rule to detect conversation about increasing revenue expectations. Using the same procedure and structure of the rule-based method developed for detecting revenue decrease rule, we changed the verb list to include synonyms of "increase", conduct the lemmatized matching and found a precision of 55%. The precision of lemmatized matching is measured relative to manual classification, so it's generally much less than 100% by default.

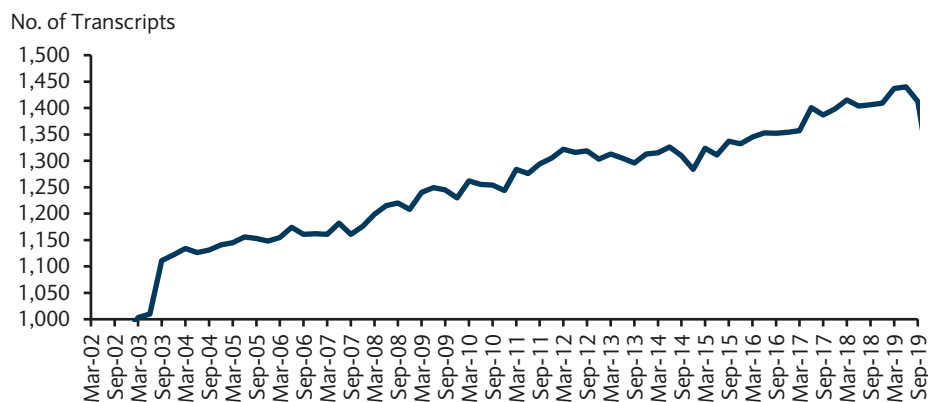
We iteratively repeated steps 3 and 4, adding some logic to detect additional grammatical structures regarding expectations of revenue increasing. We ended up with an in-sample precision of 76.2% and in-sample recall of 87.3%. For the out of sample sentences, the precision is 78.7% and recall is 86.8%. Both numbers do not differ from the in-sample metrics enough for us to justify further refinement.

**Predictive Power of Rules**

Our test results are based on earnings call transcript data from Refinitiv. The coverage of the S&P 1500 varies a little with time, with better coverage after 2011. You can see this selection in Figure 9, where we show the S&P 1500 transcript coverage by quarter.

FIGURE 9

S&amp;P 1500 transcript coverage by quarter from Q1 2002 to Q3 2019



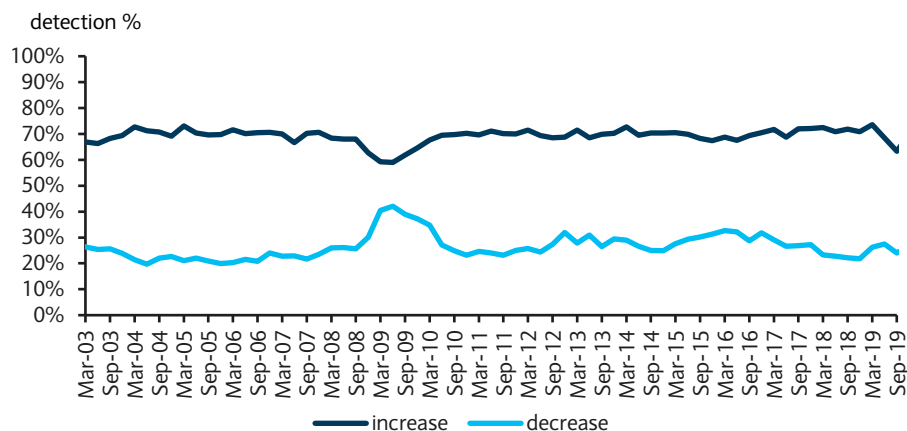
Source: Refinitiv, Barclays Research

We tend to lose some older companies in our transcript data. Specifically, Refinitiv's transcript product tags companies who will be merger targets with the RICs of their future acquirers, attributing those transcripts to the wrong company in the past (resulting in double or more transcripts for some companies), and apparently missing the target's transcript from the past data. Keeping in mind this selection process, we made sure our baseline for improvement was the companies within S&P 1500 for which we had transcripts, rather than the whole S&P 1500.

The following Figure 10 shows the percentage of detection (count of detections over the count of total transcripts available) of both revenue expectations increase and reduction over time for the available SP1500 companies earnings call transcript data from Refinitiv. We observed that they are negatively correlated, with correlation around -0.67 from Q1 2003 to Q3 2019 (where there are sufficient transcripts data).

FIGURE 10

Percentage of "Revenue Decrease" vs "Revenue Increase" detections by quarter from Q1 2003 to Q3 2019



Source: Refinitiv, Barclays Research

We wanted to see how often companies we detected as talking about decreasing/increasing revenue expectations actually had lower/higher revenue between the last annual reporting date and the next compared with ones we classified as not talking about revenue expectations.

Figure 11 and Figure 12 shows the confusion matrix of revenue expectations decrease and increase respectively.

FIGURE 11

The confusion matrix of revenue decrease on the whole available S&P 1500 transcripts

	Revenue decrease	No revenue decrease
NLP detected	7550	13120
NLP not detected	14300	44241

Source: Refinitiv, Barclays Research

FIGURE 12

The confusion matrix of revenue increase on the whole available S&P 1500 transcripts

	Revenue increase	No revenue increase
NLP detected	40717	13313
NLP not detected	16636	8545

Source: Refinitiv, Barclays Research

The odds ratio for decrease in revenue expectations detection is 1.50 (between 1.45 and 1.55 at the 95% CL). The odds ratio for increase in revenue expectations detection is 1.14 (between 1.10 and 1.18 at the 95% CL).

Over all time, the confidence intervals exclude 1, suggesting that this rule is out-performing well enough that it isn't just by chance.

## Appendix: Our Rules

We used the following rules to try to find all sentences that might be talking about revenue expectations. We used the python library spaCy to do our processing, and so doc is a spacy.Doc object in the code below:

The revenue expectations decrease key words matching is shown below:

FIGURE 13

Code of the revenue decrease topics lemmatized matching

Revenue decrease topics detection key words matching
<pre>def detection_revenue_pressure_lemmatized_matching(doc):     """     Input: document     Output: sentence contains key words of interests     """     events = []     doc_included = None     for token in doc:         if token.lemma_ in ["revenue"]:             if doc_included == None:                 for token in doc:                     if token.lemma_ in ["pressure", "decline", "deterioration",  "degradation", "weakness"]:</pre>

```

        if doc_included == None:
            doc_included = doc
            events.append(doc.text)
    elif token.lemma_ in ["top"]:
        if doc[token.i] != doc[-1] and doc[token.i+1].text in ["line"]:
            if doc_included == None:
                for token in doc:
                    if token.lemma_ in ["pressure", "decline", "deterioration",
                                         "degradation", "weakness"]:
                        if doc_included == None:
                            doc_included = doc
                            events.append(doc.text)

    return events

```

Source: Barclays Research

The revenue expectation decrease rules we iterated to at the end of the process are:

FIGURE 14

#### Code of the revenue decrease topics grammar rules

##### Revenue decrease topics detection grammar rules code

```

def tree_base_event_detector(doc, word_list, target_list):
    indicator = 0
    for word in doc:
        if word.lemma_ in word_list:
            for target in doc:
                if target.lemma_ in target_list:
                    cur_word, cur_target = word, target
                    len_word, len_target = 1, 1
                    while cur_word != cur_word.head:
                        len_word += 1
                        cur_word = cur_word.head
                    while cur_target != cur_target.head:
                        len_target += 1
                        cur_target = cur_target.head
                    cur_word, cur_target = word, target
                    for i in range(abs(len_word - len_target)):
                        if len_word >= len_target:
                            cur_word = cur_word.head
                        else:
                            cur_target = cur_target.head
                    while cur_word != cur_target and cur_word.head != cur_word and
cur_target.head != cur_target:
                        cur_word, cur_target = cur_word.head, cur_target.head
                    if cur_word != cur_target:
                        break
                    if cur_word.lemma_ in target_list:
                        indicator = 1
                    if cur_word.lemma_ in ['be', 'go', 'line', 'comment',
                                           'put', 'see', 'come',
                                           'experience', 'with', 'poise',
                                           'guide', 'continue', 'show'] :
                        indicator = 1

    return indicator

```



```

def exclusion_detector(doc, word_list, target_list):
    exclusion_indicator = 0
    for word in doc:
        if word.lemma_ in word_list:
            if doc[word.i] != doc[-1] and doc[word.i + 1].lemma_ in ['mix', 'base', 'offset',
                                                                    'point', 'opportunity',
                                                                    'flat', 'per', 'up']:
                exclusion_indicator = 1
            if doc[word.i] != doc[0] and doc[word.i - 1].lemma_ in ['their', 'surcharge', 'fee', 'high']:
                exclusion_indicator = 1
            while word.head:
                if word.head.lemma_ in ['percentage']:
                    exclusion_indicator = 1
                    break
                else:
                    if word != word.head:
                        word = word.head
                    else:
                        break
            if word.lemma_ in ['inventory', 'region', 'customer', 'if', 'pricing', 'price']:
                while word.head:
                    if word.head.lemma_ in target_list:
                        exclusion_indicator = 1
                        break
                    else:
                        if word != word.head:
                            word = word.head
                        else:
                            break
            if word.lemma_ in target_list:
                if doc[word.i] != doc[-1] and doc[word.i + 1].lemma_ in ['or']:
                    if doc[word.i + 1] != doc[-1] and doc[word.i + 2].lemma_ in ['no', 'not']:
                        exclusion_indicator = 1
                while word.head:
                    if word.head.lemma_ in ['producer', 'exclude']:
                        exclusion_indicator = 1
                        break
                    else:
                        if word != word.head:
                            word = word.head
                        else:
                            break
    return exclusion_indicator

def negation_detector(doc, target_list):
    negation = 0
    for word in doc:
        if word.lemma_ in target_list:
            for child in [child for child in word.children]:
                if child.dep_ == 'neg':
                    negation = 1
            while word.head:
                if word.head.tag_ in ['NN']:
                    for child in [child for child in word.head.children]:
                        if child.lemma_ in ['no']:

```

```

        negation = 1
        if word.head.tag_ in ['VBZ','VBG','VB','VBN']:
            for child in [child for child in word.head.children]:
                if child.lemma_ in ['even', 'despite', 'although']:
                    negation = 1
        if word != word.head:
            word = word.head
        else:
            break
    return negation

def f_revenue_pressure_rule(doc, word_list, target_list):
    """
    Input: sentences. Output: binary variables 0, 1.
    0: nothing detected. 1: potential revenue decline detected
    """
    event = 0
    exclusion_indicator = exclusion_detector(doc, word_list, target_list)
    negation_indicator = negation_detector(doc, target_list)
    if exclusion_indicator == 0 and negation_indicator == 0:
        event = tree_base_event_detector(doc, word_list, target_list)
    if exclusion_indicator == 0 and negation_indicator == 0 and event == 0:
        event = tree_base_event_detector(doc, target_list, word_list)
    return event

```

Source: Barclays Research

The revenue expectations increase key words matching is shown below:

FIGURE 15

#### Code of the revenue increase topics lemmatized matching

##### Revenue increase topics detection key words matching

```

def detection_revenue_increase_lemmatized_matching(doc):
    """
    Input: document
    Output: sentence contains key words of interests
    """
    events = []
    doc_included = None
    for token in doc:
        if token.lemma_ in ["revenue"]:
            if doc_included == None:
                for token in doc:
                    if token.lemma_ in ["improvement", "improve", "strength",
                                         "growth", "increase", "grow"]:
                        if doc_included == None:
                            doc_included = doc
                            events.append(doc.text)
    return events

```

Source: Barclays Research

The revenue expectations increase rules we iterated to at the end of the process are:

FIGURE 16

**Code of the revenue increase topics grammar rules****Revenue increase topics detection grammar rule code**

```

def tree_base_event_detector(doc, word_list, target_list):
    indicator = 0
    for word in doc:
        if word.lemma_ in word_list:
            for target in doc:
                if target.lemma_ in target_list:
                    cur_word, cur_target = word, target
                    len_word, len_target = 1, 1
                    while cur_word != cur_word.head:
                        len_word += 1
                        cur_word = cur_word.head
                    while cur_target != cur_target.head:
                        len_target += 1
                        cur_target = cur_target.head
                    cur_word, cur_target = word, target
                    for i in range(abs(len_word - len_target)):
                        if len_word >= len_target:
                            cur_word = cur_word.head
                        else:
                            cur_target = cur_target.head
                    while cur_word != cur_target and cur_word.head != cur_word and
cur_target.head != cur_target:
                        cur_word, cur_target = cur_word.head, cur_target.head
                    if cur_word != cur_target:
                        break
                    if cur_word.lemma_ in target_list:
                        indicator = 1
                    if cur_word.lemma_ in ['be', 'have', 'see', 'continue', 'indicate'] :
                        indicator = 1

                    for child in [child for child in cur_word.children]:
                        if child.dep_ in ['dobj', 'nsubj'] and child.lemma_ in word_list:
                            indicator = 1
            if word.lemma_ in word_list:
                for child in [child for child in word.children]:
                    if child.lemma_ in target_list:
                        indicator = 1
    return indicator

def exclusion_detector(doc, word_list, target_list):
    exclusion_indicator = 0
    for word in doc:
        if word.lemma_ in word_list:
            if doc[word.i] != doc[word.i - 1] and doc[word.i + 1].lemma_ in ['per', 'relationship', 'cycle']:
                exclusion_indicator = 1

            if doc[word.i] != doc[0] and doc[word.i - 1].lemma_ in ['average', 'low', 'mainframe', 'defer']:
                exclusion_indicator = 1

            while word.head:
                if word.head.lemma_ in ['percentage']:
                    exclusion_indicator = 1

```

```

        break
    else:
        if word != word.head:
            word = word.head
        else:
            break
    if word.lemma_ in target_list:
        for child in [child for child in word.children]:
            if child.lemma_ in ['price']:
                exclusion_indicator = 1
    while word.head:
        if word.head.lemma_ in ['from','less','question','compare']:
            exclusion_indicator = 1
            break
        elif word.head.lemma_ in ['kind']:
            if doc[word.head.i] != doc[0] and doc[word.head.i - 1].lemma_ in ['what']:
                exclusion_indicator = 1
            break
        elif word.head.lemma_ in ['be']:
            for child in [child for child in word.head.children]:
                if child.lemma_ in ['assumption']:
                    exclusion_indicator = 1
            if exclusion_indicator == 1 or word == word.head:
                break
        else:
            word = word.head

    elif word.head.tag_ in ['VBC','VBP']:
        for child in [child for child in word.head.children]:
            if child.lemma_ in ['if','what']:
                exclusion_indicator = 1
            if exclusion_indicator == 1 or word == word.head:
                break
        else:
            word = word.head

    else:
        if word != word.head:
            word = word.head
        else:
            break

    return exclusion_indicator

def negation_detector(doc, word_list, target_list):
    negation = 0
    for word in doc:
        if word.lemma_ in target_list:
            for child in [child for child in word.children]:
                if child.dep_ == 'neg' or child.lemma_ in ['little', 'no', 'modest','relative']:
                    negation = 1

        while word.head:
            if word.head.tag_ in ['VBC','VBD','VB']:
                for child in [child for child in word.head.children]:
                    if child.dep_ == 'neg' or child.lemma_ in ['low','lose','slow']:

```

```

        negation = 1
        if negation == 1 or word == word.head:
            break
        else:
            word = word.head
    else:
        if word != word.head:
            word = word.head
        else:
            break
    if word.tag_ in ['VBN']:
        for child in [child for child in word.children]:
            if child.dep_ == 'dobj' and child.lemma_ in word_list:
                for child_sub in [child for child in word.children]:
                    if child_sub.dep_ == 'neg':
                        negation = 1

    return negation

def head_detector(doc):
    count_head = 0
    for token in doc:
        if token.head == token:
            count_head += 1
    return count_head

def f_revenue_increase_rule(doc, word_list, target_list):
    """
    Input: sentences. Output: binary variables 0, 1.
    0: nothing detected. 1: potential revenue increase detected
    """
    event = 0
    exclusion_indicator = exclusion_detector(doc, word_list, target_list)
    negation_indicator = negation_detector(doc, word_list, target_list)
    count_head = head_detector(doc)
    if exclusion_indicator == 0 and negation_indicator == 0:
        event = tree_base_event_detector(doc, word_list, target_list)
    return event

```

Source: Barclays Research

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