



Data Science Methods

Grammar Rules for Conversation About Changes in Debt

- We've developed two grammar rules for natural language processing (NLP) to detect conversation events in corporate transcripts about corporate debt, and whether it is expected to increase or decrease.
- Companies identified by our "decrease rule" were 1.59 times (between 1.53 and 1.64 times at the 95% CL) more likely to reduce debt between the last annual reporting date and the next compared with those who weren't. Those identified by our "increase rule" were 1.07 times (between 1.02 and 1.13 times at the 95% CL) more likely to raise debt over the same period.

FIGURE 1

High-level summary of the rules

Debt reduction grammar rule

We look for synonyms of the verb "reduce" whose object contains a synonym of "debt".

We exclude cases where:

1. We identify the wrong concept, e.g. "bad debt" or "debt rate"
2. The conversation is in reference to a different company

Raise debt grammar rule

We look for synonyms of the verb "raise" whose object contains a synonym of "debt".

We exclude cases where:

1. We identify the wrong concept, e.g. "bad debt", "net debt" or "debt fund", or "issue" as a noun, or "debt ratio"
2. The conversation is in reference to a different company

Source: Barclays Research

- Detailed pseudo-code for these rules is included in the text of this note, and the actual Python code in the appendix.
- The reduction rule has an out-of-sample precision of about 79.2%, and out-of-sample recall of about 71.7% over the subset of sentences selected using term search and manually classified.
- The increase rule has an out-of-sample precision of about 73.2% and out-of-sample recall of about 69.5% 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 corporate debt in these transcripts.

The down-side of using logic is that it is brittle. If the rules miss synonyms for debt, or if sophisticated grammar is used to talk about it, we will miss events we would have liked to detect. Language about debt can be unclear and therefore difficult to capture, hurting both precision and recall.

More time and effort generally yield better results. 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 whether companies expect to pay off debt (our "reduce debt" or "decrease debt" rule), and another for whether they expect to take on more debt (our "raise debt" or "increase debt" rule). With natural language signals, it's easy to try a lot of things 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 it for the "raise debt" rule since the detection is more complex than "decrease debt" rule. For the reduction rule, we use the same rule refinement steps as with our "raise debt" rule.

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 debt expectations", we generated the list of terms in Figure 2.

FIGURE 2
List of terms in broad rule matching

Debt Synonyms	Raise Synonyms
"debt", "bond"	"raise", "issue", "fund"

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 expectations for raising debt. The goal at this stage is very high recall (trying to capture all conversation about expectations to raise debt), and 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 expectations to raise debt" or not (Figure 3). As a result of our lemmatized search, these are more likely to be positive examples (i.e. detections of expectations to raise) than a selection of random sentences.

FIGURE 3

Sample sentences from manual classification

Sentences	Classification
So to clarify, as we get to the 9.5% to 10%, we will be issuing debt as necessary to do our buyback.	1
will fund about half of that expansion, and when we talk about the net debt we are excluding that construction fund balance from the net debt calculation.	0
I think the other thing is Pat has been able, the Treasury team, to go out and raise debt this year at very favorable rates.	1
You know, with the dislocations that are going on with the issues that debt markets are having?	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 our sample included many false positives, with a precision of around 32% for our lemmatized search. It is fairly difficult to detect intent to raise debt given such low precision.

FIGURE 4

Confusion matrix of lemmatized matching

	Raise debt mentioned	No raised debt mentioned
Detected	32	68
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 70% precision and 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**Raise debt grammar rule**

We look for synonyms of the verb “raise” whose object contains a synonym of “debt”.

We exclude cases where:

1. We identify the wrong concept, e.g. “bad debt”, “net debt” or “debt fund”, or “issue” as a noun, or “debt ratio”
2. The conversation is in reference to a different company

Source: Barclays Research

FIGURE 6

Pseudocode of the main framework of raise debt topics grammar rules**Raise debt 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 = ['debt','bond','note']
```

```
target_list = ['raise', 'issue', 'fund','increase','grow','offer','offering','take'],
```

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

```
# main function
```

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

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

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

```
    detected = False
```

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

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

```
    if not mention_contains_excluded_terms and not mention_is_negated:
```

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

```
    return detected
```

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

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

```
    # Input:
```

```
    # Output: boolean variable False if no events are not detected, True if detected
```

```
    detected = False
```

```
    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
```

```
    return detected
```

Source: Barclays Research

These rules have significantly improved performance. You can see the confusion matrix in Figure 7. The precision is 71.1% and recall is 84.4%.

FIGURE 7

Confusion matrix of grammar rule matching

	Raise debt mentioned	No raise debt mentioned
NLP detected	27	11
NLP not detected	5	57

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 lemmatized search 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

	Raise debt mentioned	No raise debt mentioned
NLP detected	41	15
NLP not detected	18	26

Source: Refinitiv, Barclays Research

The precision went from 71.1% in our first set of manual classifications to 73.2% in our last set. The recall went from 84.4% to 69.5%. There is a small (likely random) improvement in the precision without recall falling below our threshold (around 70%), so 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 run 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 debt, which we'll do in the last section of this report.

Detecting Conversation About Expectations to Reduce Debt

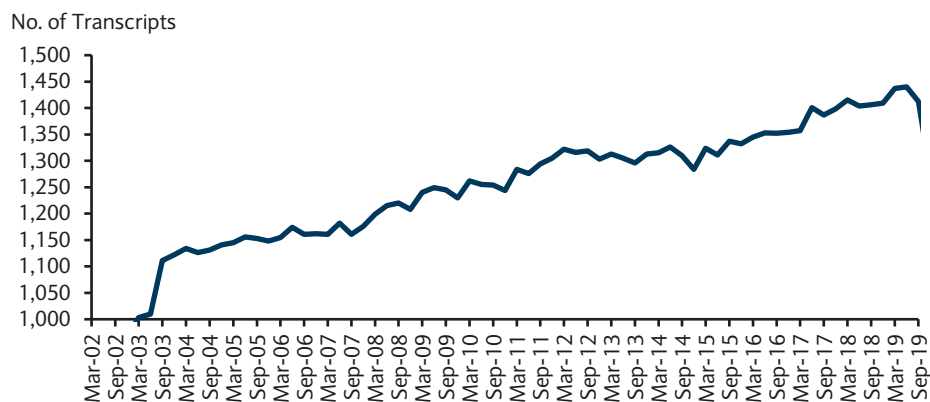
We also wanted to develop a rule to detect conversation about reducing debt. We used the same procedure as our "raise debt" rule. Specifically, we changed the verb list to include synonyms of "reduce", conducted lemmatized matching, and found a precision of 51%. We iterated following steps 3 and 4, adding some logic to detect additional grammatical structures that correspond with expected debt reduction.

We ended up with an in-sample precision of 89.6% and in-sample recall of 84.3%. Testing out-of-sample, the precision is 79.2% and recall is 71.7%. Both numbers do not differ from the in-sample metrics enough for us to justify further refinement.

Predictive Power of Rules

Our testing results are based on the available 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

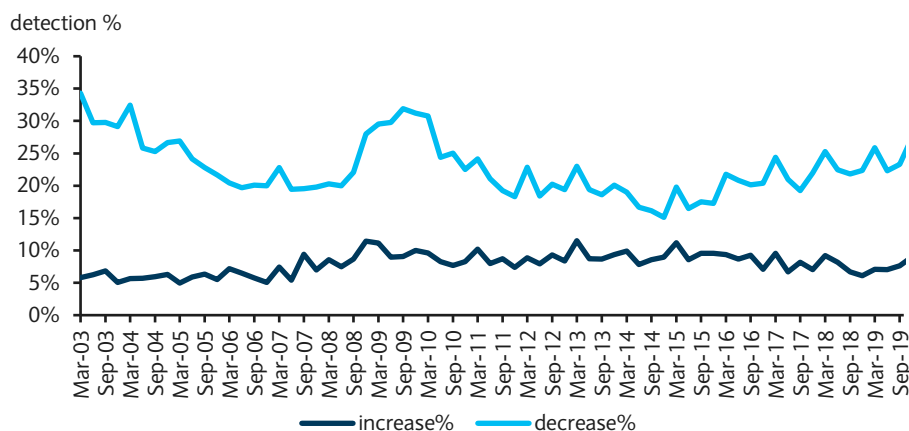
S&P 1500 transcript coverage by quarter from Q1 2002 to Q3 2019

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 entire S&P 1500.

The following Figure 10 shows the percentage of detections (count of detections over the count of total transcripts available) of both increase and decrease of debt over time for the available S&P 1500 companies' earnings call transcripts from Refinitiv. We observed these series are negatively correlated, with correlation around -0.13 from Q1 2003 to Q3 2019 (where there are sufficient transcript data).

FIGURE 10

Number of "Debt Reduction" vs "Raise Debt" 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 reducing/raising debt actually reduced/raised debt between the last annual reporting date and the next compared with ones we classified as not talking about debt.

Figure 11 and Figure 12 shows the confusion matrix of expectations for debt decrease and increase, respectively.

FIGURE 11

The confusion matrix of “debt reduction” on the whole available S&P 1500 transcripts

	Debt Reduction	No Debt Reduction
NLP detected	8964	9232
NLP not detected	19060	42284

Source: Refinitiv, Barclays Research

FIGURE 12

The confusion matrix of “raise debt” on the whole available S&P 1500 transcripts

	Raise Debt	No Debt increase
NLP detected	4399	1976
NLP not detected	46894	25942

Source: Refinitiv, Barclays Research

The odds ratio for debt reduction detection is 1.59 (between 1.53 and 1.64 at the 95% CL). The odds ratio for increase in debt expectations detection is 1.07 (between 1.02 and 1.13 at the 95% CL).

The confidence interval for debt reduction excludes 1, suggesting that this rule is out-performing well enough that it isn't just by chance. However, for the “raise debt” rule, although we achieved fairly high precision and recall with our sentence detection, the detections do not give us a reliable indication of whether companies will indeed raise debt or not.

Appendix: Our Rules

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

The debt reduction key words matching is shown below:

FIGURE 13

Code of debt reduction topics lemmatized matching

```

Debt reduction topics detection key words matching

def detection_debt_reduction_lemmatized_matching(doc):
    """
    Input: document
    Output: sentence contains key words of interests

    """
    events = []
    doc_included = None
    for token in doc:
        if token.lemma_ in ["debt", "loan"]:
```

```

if doc_included == None:
    for token in doc:
        if token.lemma_ in ["reduce", "reduction", "paydown", "pay",
                             "down", "payment", "accelerate"]:
            if doc_included == None:
                doc_included = doc
            events.append(doc.text)

return events

```

Source: Barclays Research

The debt reduction rules we iterated to at the end of the process are:

FIGURE 14

Code of the debt reduction topics grammar rules

Debt reduction topics detection grammar rules code

```

def f_debt_reduction_rule(doc):
    """
    Input: document
    Output: binary variable, 1: debt reduction related topics detected, 0:otherwise

    """
    event = 0
    negation_indicator = 0
    for token in doc:
        if token.lemma_ in ['reduce', 'pay', 'paydown', 'reduction']:
            token_children = [child for child in token.children]
            if len(token_children) > 0:
                for child in token_children:
                    if child.dep_ == 'neg':
                        negation_indicator = 1
                if negation_indicator == 0:
                    for child in token_children:
                        if child.lemma_ in ['debt', 'note'] and doc[child.i-1].lemma_ not in ['bad']:
                            event = 1
                        elif child.lemma_ in ['rate']:
                            event = 0
                    else:
                        if len([c for c in child.children]) > 0:
                            for word in [c for c in child.children]:
                                if (word.lemma_ in ['debt', 'loan']
                                    and doc[word.i-1].lemma_ not in ['bad']):
                                    event = 1
                                if word.dep_ == 'prep' and len([c for c in word.children]) > 0:
                                    for word_child in [c for c in word.children]:
                                        if (word_child.dep_ == 'pobj' and
                                            word_child.lemma_ in ['debt', 'loan']
                                            and doc[word_child.i-1].lemma_ not in ['bad']):
                                                event = 1
                        elif negation_indicator == 0:
                            if token.head.lemma_ in ['debt', 'loan'] and doc[token.head.i-1].lemma_ not in
                                ['bad']:
                                    event = 1

    if negation_indicator == 0:
        for token in doc:

```



```

        if token.lemma_ in ['debt', 'loan'] and doc[token.i-1].lemma_ not in ['bad']:
            if token.head.lemma_ in ['reduce','pay','decrease', 'reduction']:
                event = 1
    return event

```

Source: Barclays Research

The raise debt key words matching is shown below:

FIGURE 15

Code of the raise debt topics lemmatized matching

Raise debt topics detection key words matching

```

def detection_raise_debt_lemmatized_matching(doc):
    """
    Input: document
    Output: sentence contains key words of interests

    """
    events = []
    doc_included = None
    for token in doc:
        if token.lemma_ in ['debt', 'bond']:
            if doc_included == None:
                for token_sub in doc:
                    if token_sub.lemma_ in ['raise','issue','fund']:
                        if doc_included == None:
                            doc_included = doc
                            events.append(doc.text)

    return events

```

Source: Barclays Research

The raise debt rules we iterated to at the end of the process are:

FIGURE 16

Code of the raise debt topics grammar rules

Raise debt 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 and 'NNS' not in target.tag_:
                    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.tag_ in ['CD']:
            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[0] and doc[word.i - 1].lemma_ in ['net', 'no', 'bad']:
                exclusion_indicator = 1

            if doc[word.i] != doc[-1] and doc[word.i + 1].lemma_ in ['pay', 'mature']:
                exclusion_indicator = 1

            while word.head:
                if word.head.lemma_ in ['fund'] and 'NN' in word.head.tag_:
                    exclusion_indicator = 1
                    break
                elif word.head.lemma_ in ['reduce', 'decrease', 'buy', 'repay', 'call', 'pay'] and 'VB' in
word.head.tag_:
                    exclusion_indicator = 1
                    break
                else:
                    if word != word.head:
                        word = word.head
                    else:
                        break

            if 'issue' in word.lemma_ and 'NN' in word.tag_:
                exclusion_indicator = 1

            if word.lemma_ in target_list:
                for child in [child for child in word.children]:
                    if child.dep_ == 'dobj' and child.lemma_ in ['dividend', 'money', 'ratio']:
                        exclusion_indicator = 1

            while word.head:
                if 'VB' in word.head.tag_:
                    if len([t.lemma_ for t in doc[word.head.i].lefts]) > 0:
                        temp = [t.lemma_ for t in doc[word.head.i].lefts][0]
                        if temp in ['be', 'Can', 'can']:
                            if len(set([temp, '-PRON-']).difference(set([t.lemma_ for t in
doc[word.head.i].lefts]))) == 0:

```

```

        exclusion_indicator = 1

        for child in [child for child in word.head.children]:
            if child.lemma_ in ['could', 'generally', 'cost', 'if']:
                exclusion_indicator = 1
        if word == word.head:
            if word.lemma_ == 'be' and doc[word.i] == doc[0]:
                exclusion_indicator = 1
            break
        if exclusion_indicator == 1:
            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':
                    negation = 1

            if word.head.lemma_ in ['plan']:
                for child in [child for child in word.head.children]:
                    if child.lemma_ in ['no']:
                        negation = 1

        while word.head:
            if word.head.tag_ in ['VBC', 'VBD']:
                for child in [child for child in word.head.children]:
                    if child.dep_ == 'neg':
                        negation = 1
                if negation == 1 or word == word.head:
                    break
            else:
                word = word.head
        else:
            if word != word.head:
                word = word.head
            else:
                break

    return negation

def f_raise_debt_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)

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

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