The Web of Innovation:

Using Website Data to Understand How Firms Innovate

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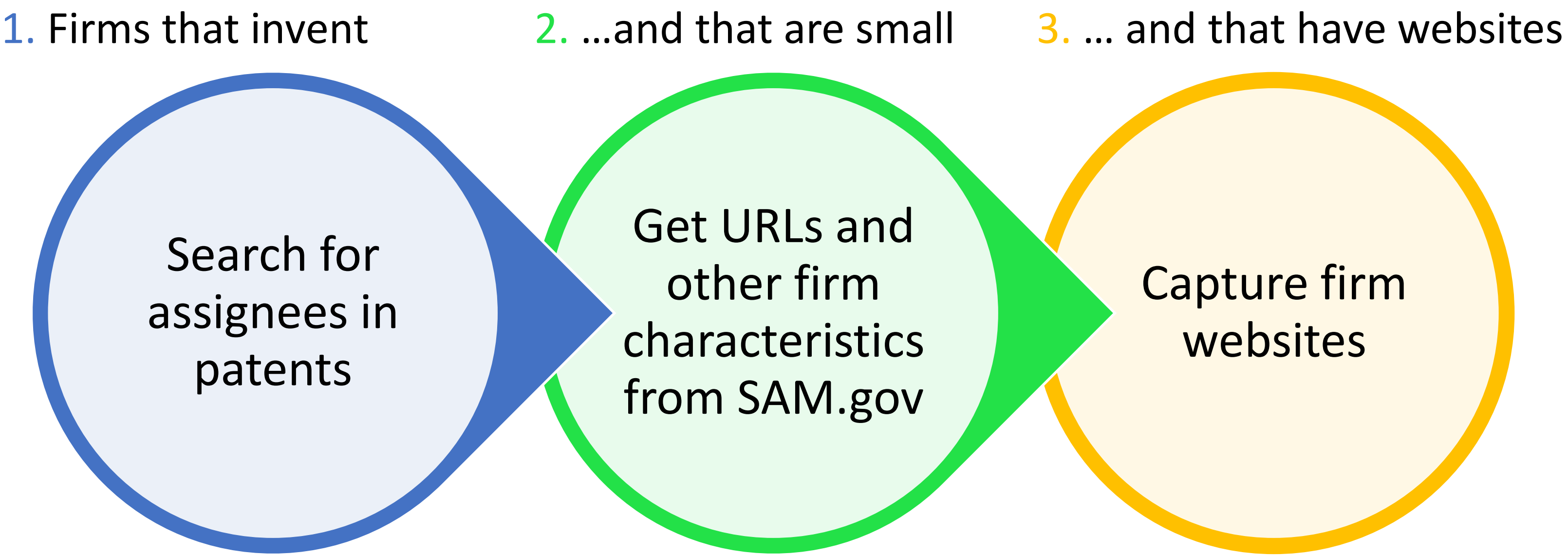
Previous work and motivations

- Website data on firms is freely available; prior research has found that many innovative firms have websites but lack patents (Yin et al., 2016)
- Moreover, survey response rates for firms continue to fall (Baruch, 1999)
- Working with websites presents specific challenges to social scientists who must be increasingly adept at processing unstructured data and operationalizing valid and reliable variables (Arora et al., 2016)
- Previous work has attempted to scrape firm websites *and*:
    - Validate the operationalization of variables to assess internal validity concerns (Gok et al., 2015)
    - Cluster firms by type of firm using simple keyword based approaches (Arora et al., 2013)
    - Measure firm change over time (as a proxy for firm “seizing”) as an endogenous predictor of performance (Arora et al., 2017)

Our contributions

- Our work seeks to improve applications of using website data for studying innovation
- This presentation focuses on our method for building a sample of innovative (inventive) firms whose websites can be mined and analyzed
- In particular, we explore narrative construction and detection on firm websites within a comparative framework setting

Data sources and sample frame definition


1. Firms that invent
2. …and that are small
3. … and that have websites
Search for assignees in patents
Get URLs and other firm characteristics from SAM.gov
Capture firm websites

- Utility patents in three sectors: nanotechnology, synthetic biology, and renewable energy

- Check for firm size using sam.gov and obtain URLs

- Collect visible text from firm websites

Patents querying approach

- Using prior published work search terms are obtained for
  - nanotechnology sector (Arora et. al, 2012)
  - green technology sector (Shapiro, Klochikhin et. al, 2013)
- For synthetic biology sector, terms are obtained from wikipedia by using below steps:
  - A base list of terms is obtained from prior published work (Raimbault et. al, 2016)
  - From the Wikipedia page (if present) of each of the terms, all outgoing links are gathered
  - The above list is reviewed to retain terms that are deemed relevant by the researchers
  - Link extraction and review is repeated on retained terms to obtain researchers' terms list
  - The researchers‘ final terms list is reviewed by a domain expert to correct for false positives and false negatives
- Patents, and consequently assignee firms, are selected by searching for the final list of terms in the patent database (in title and abstract)
- Using data provided United States System for Award Management (SAM), firms are filtered based on their small business status and their corporate URLs are obtained

Who are these firms?

Stat	Values		
Number of organization in SAM list	620,206		
Small businesses in SAM list	347,249		
Total number of patents	6,200,505		
	Green Sector	**Synbio Sector**	**Nano Sector**
Utility patent containing the terms	2,436	1,694	8,584
Patents with US assignee information	1,576	1,277	6,981
Unique number of assignee organization	607	573	1,099
Patent assignees org in SAM small business list	41	196	87
patent assignee org with URL in SAM DB	27	104	66

Assignee Representation in SAM by Patent Category

	Over Represented	Under Represented
Green Technology	Basic electric elements	
Synthetic Biology		Physical or chemical processes or apparatus in general; Climate change
Nanotechnology	Medical or veterinary science; hygiene	

Comparison of Small and Large Businesses in SAM

	More Small Businesses	More Large Businesses

Green Technology	Lighting;
	Organic/Inorganic chemistry;
	Beers, spirits & wine
		Electric elements; Climate change

Synthetic Biology	Medical or veterinary science; hygiene; Organic chemistry; biochemistry	
Nanotechnology	Biochemistry working of plastics Cements; concrete; artificial stone; ceramics; organic compounds and their chemical preparation	

Webcrawling details

- 195 firm websites across three sectors (178 unique)
- Clean urls and extract visible text data using Python/Beautiful Soup
- 162 website homepages successfully parsed
  - 23 in green goods, 84 in synthetic biology and 55 in nanotechnology
  - Some websites couldn’t be parsed
    - For example, Ziptronix Inc. was purchased by Tessera in 2015 [1], and its site no longer exists

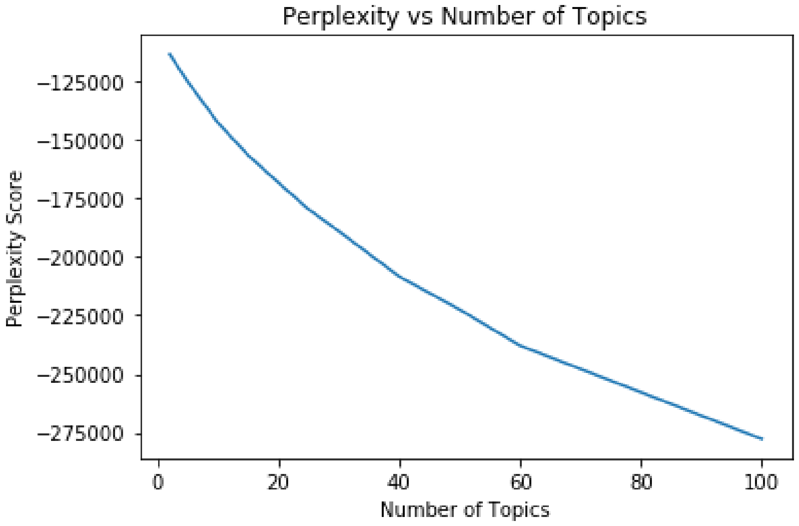
[1] BusinessWire (2015); [2]

Method for Narrative analysis

- Core question: How do the narratives constructed by companies’ differ across sectors?
- Method:
  - Use LDA to Identify topics for each paragraph in each website
  - Map transition probabilities between topics
  - Use these topic and transition mappings to explore the dominant narratives in each sector

Website analysis: modeling narratives

- Understanding narrative through paragraph topics
- One topic model across all sectors together
- Perplexity doesn’t provide much information here
- Number of topics: 28



Top Topics Descriptions

Overall Rank	Topic Concept	Top 3 Associated Words
1	“Research”	product, technology, research
2	“Product”	product, use, package
3	“Cell Biology”	system, cell, cancer
4	“Materials”	material, provide, solution
5	“Biotech”	mass, cytometric, use

- Most Common Topic by sector:
  - **Nanotechnology:** “Product”
  - **Synthetic Biology**: “Research”
  - **Green Technology**: “Cell Biology”

Example Paragraphs for top Topics

- **Research:** “The FACTORIAL™ assays have been extensively validated over the years of research contract work for biopharmaceutical companies, academia, and regulatory agencies.” ***[Synbio, www.attagene.com]***

- **Product:** “ABBOTT, BIGFOOT PARTNER ON DIABETES CARE Abbott and Bigfoot Biomedical have entered into an agreement to develop breakthrough diabetes technologies.” ***[Nanotechnology, www.abbott.com]***

- **Cell Biology**: “TECHNOLOGY FOR MEDICAL DIAGNOSTICS Medical infrared (IR) Imaging, sometimes known as Thermography, offers interesting diagnostics for many diseases, bruises and other surface injuries. It is a technique that can image the temperature distribution, blood flow and other irregularities resulting from various disease related abnormalities…” ***[Green Goods, www.magnoliaoptical.com]***

Topic Transitions

- The ‘most likely’ topic sequences differ across area

Area	First Para	Second Para	Third Para
Green Technology	‘company’ (develop, company, product)	‘product/system’ (system, product, substrate)	‘energy’ (electric, research, energy)
Nano Technology	‘biotech’ (technology, develop, assay)	‘engineering’ (product, learn, engineer)	‘DNA Technology’ (DNA, technology, system)
Synthetic Biology	‘cell technology” (mass, cytometric, use)	‘product/system’ (system, product, substrate)	‘engineering’ (product, learn, engineer)

Topic Transitions cont’d

Area	First Para	Second Para	Third Para
Green Goods	‘research’ (product, technology, research)	‘solution’ (system, product, solution)	‘research’ (product, technology, research)
Nanotechnology	‘DNA Technology’ (DNA, technology, system)	‘technology solution’ (technology, product, system)	‘solution’ (system, product, solution)
Synthetic Biology	‘engineering’ (product, learn, engineer)	‘industrial’ (industry, technology, product)	‘technical innovation’ (technology, new, advance)

Discussion

- The topical order in which a narrative unfolds reveals the firm or entrepreneur’s approach to building storylines
  - Storylines may be packaged into *plots* of expected patterns and conclusions (Downing, 2005)
  - Our results suggest a sectoral “dominant logic” of plots appearing in nanotechnology, synthetic biology and green goods, but further investigation is needed
- Why do these narratives matter?
  - Stories package “factual information about [a firm’s] stock of tangible and intangible capital into a simpler, more coherent and meaningful whole” (Martens et al., 2007)
  - Prior research has shown that subjectively defined “symbolic management” activities facilitate resource acquisition and enhanced performance outcomes (Zott and Huy, 2007)
  - Storylines and plots emerge and congeal to create “niches” where technology developers can co-interpret opportunities and marshal resources in networked settings (Geels and Smit, 2000)

Methodological limitations and next steps

- Potential bias introduced when building sample frame (patents) and filtering assignees to create the final sample (via SAM.gov)
- Full probability distribution from topic model not currently used
- Deeper exploration of narrative structure
- Other areas of exploration:
    - Use of image data to help describe firm websites
    - Improving construct validity, e.g., disentangling mentions of "universities" as a way of signaling reputation, disclosing meaningful partnerships, or revealing relevant academic training and skills of staff (c.f., Arora et al., 2016)

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Thank you

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