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Three Essays on Audit Innovation: Using Social Media Information and Disruptive Technologies to Enhance Audit Quality

Dissertation Defense

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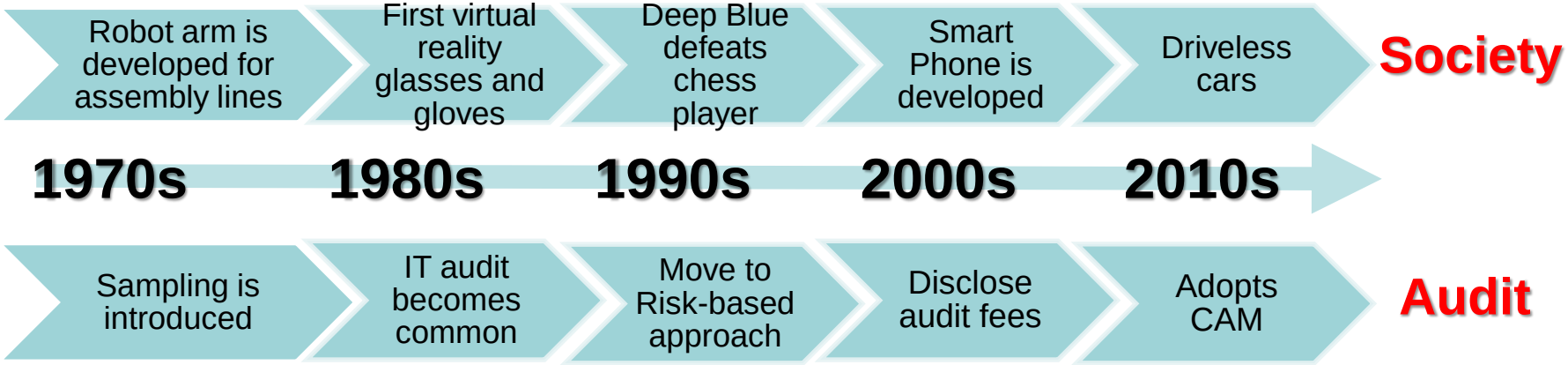
Introduction (1)

The Story

- The world is rapidly changing, technology enables a 365/24/7 economy

- How has the audit profession evolved?

Some major transformations…



Issue?

Auditing is at risk of losing its relevance

Introduction (2)

Motivation

- Technological advances are challenging the relevance of the current audit framework

- Audit community has proposed initiatives that are aimed at understanding the use and impact of technology in auditing

- Technology has the potential to enhance audit quality and transparency in the capital markets but its impact on auditing remains underexplored

Introduction (3)

Contribution:

Fill the gap in the audit analytics literature by informing the audit community on the use of technological innovations to advance auditing and audit quality

Essay One

Enhancing Substantive Analytical Procedures with Third-Party Generated Information from Social Media

"Investors, and others, are accessing and analyzing massive amounts of information from sources, like social media, unimaginable just a few years ago. This new data may be empowering investors to make smarter investment decisions"

Kara Stein – SEC Commissioner 2015

Objectives

- **Do Twitter proxies of consumer interest and consumer satisfaction enhance substantive analytical procedures for the revenue account?**

- **RQ 1A & RQ 1B:** Do **traditional** and **continuous** substantive analytical models with Twitter experience improved **prediction performance**?

- **RQ 2A & RQ1B:** Do **traditional** and **continuous** substantive analytical models with Twitter experience improved **error detection performance**?

Motivation

- Social media postings contain incremental information about firms' stock market prices, and sales performance (e.g. Bollen, Mao, Zheng 2011; Tang 2017)

- Inspection findings indicate that accounting firms fail to develop precise expectations (PCAOB 2007; PCAOB 2016a)

- Social media consumer postings about firms' products and brands could be used as a source of audit evidence

Prior Literature

The Role of Nonfinancial Information in Analytical Models

- Macroeconomic information, customer satisfaction, and employee headcount improves the predictive ability of analytical models (Lev 1980; Ittner and Larcker 1998; Brazel et al. 2009)

- Yoon (2016) demonstrates that weather information is correlated with sales and that it enhances analytical models

- Advance research in analytical procedures by examining a different type of unorthodox audit evidence

Research Design (1)

Sample – 24 B2C industries

- Likefolio, https://home.likefolio.com/, BEA, https://www.bea.gov/, and Compustat

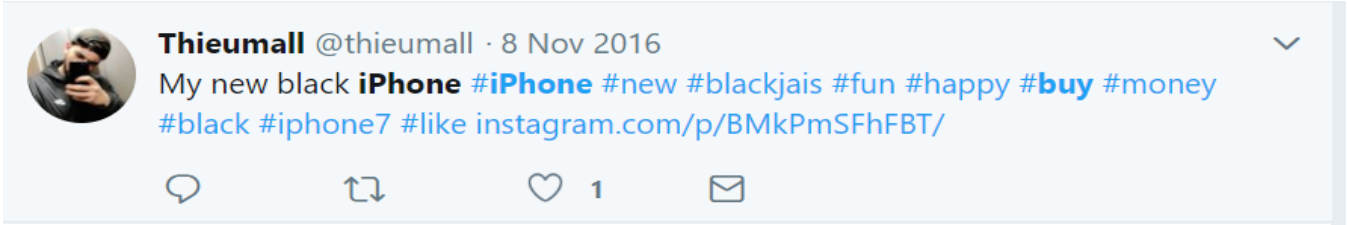
Sample Selection - Firm-Quarter Observations 2012-2017	Firms	Firm-Quarter Observations
Firms that are publicly listed and have third-party generated Twitter information	194	4,656
Less: Firms with missing financial information or zero values	(9)	(216)
Less: Firms with missing information from Twitter for either Consumer Interest or Sentiment	(15)	(360)
Less: Firms without four quarters of data	(73)	(1,752)
Less: Firms in the Financial Services Industry	(9)	(216)
Total	88	2,112

- Quarterly economic and financial information is interpolated into monthly observations and matched with Twitter data

Research Design (2)

Twitter Measures

- Likefolio, https://home.likefolio.com/, provided customer interest and satisfaction for products and brands
  - Mapping of products and brands to the company
  - Customer Interest to Buy



TCI: total count of tweets related to the firm's product or brand past/future interest to buy

  - Customer Sentiment

TCS: ratio of positive tweets to total (positive and negative) tweets

Research Design (3)

Analytical Models with and without Twitter information

$$Sales_{it} = \beta_0 + \beta_1 Sales_{it-1} + \beta_2 TCS_{it}$$

$$Sales_{it} = \beta_0 + \beta_1 Sales_{it-1} + \beta_2 GDP_{t-1} + \beta_3 TCS_{it}$$

$$Sales_{it} = \beta_0 + \beta_1 Sales_{it-1} + \beta_2 AR_{it} + \beta_3 TCS_{it}$$

$$Sales_{it} = \beta_0 + \beta_1 Sales_{it-1} + \beta_2 AR_{it} + \beta_3 GDP_{t-1} + \beta_4 TCS_{it}$$

Results (1)

RQ 1A & RQ 1B: Prediction Performance – 24 industries

Model	Lagged Sales + Lagged GDP + **Twitter Consumer Interest**	Lagged Sales + AR + Lagged GDP + **Twitter Consumer Interest**	Lagged Sales + Lagged GDP + **Twitter Consumer Satisfaction**	Lagged Sales + AR + Lagged GDP + **Twitter Consumer Satisfaction**
Traditional - SAP	16 of 24 industries	14 of 24 industries	14 of 24 industries	15 of 24 industries
Continuous - SAP	21 of 24 industries	22 of 24 industries	20 of 24 industries	22 of 24 industries

Results (2)

RQ 2A & RQ 2B: Error Detection Performance Cost Ratio – 24 industries

Model	Lagged Sales + Lagged GDP + **Twitter Consumer Interest**		Lagged Sales + Lagged GDP + **Twitter Consumer Satisfaction**	
Cost Ratio	1 : 1	1 : 2	1 : 1	1 : 2
Traditional - SAP	12 of 24 industries	12 of 24 industries	12 of 24 industries	12 of 24 industries
Continuous - SAP	13 of 24 industries	13 of 24 industries	13 of 24 industries	13 of 24 industries

Results (3)

The More Effective model:

Continuous - SAP	Lagged Sales + Lagged GDP + **Twitter Consumer Interest**	Lagged Sales + Lagged GDP + **Twitter Consumer Satisfaction**
Prediction Performance	21 of 24 industries	20 of 24 industries
Error Detection Performance	13 of 24 industries	13 of 24 industries

Interesting finding:

- More effective model outperforms model with **Advertising Expense**

Contributions

- Investigates the incremental contribution of social media information that is generated by third-parties to auditing
  - Prediction performance
  - Error detection performance

Limitations and Future Research

- Monthly observations are estimated from quarterly information

- Only one source of Internet information is examined

Essay Two

Redesigning the Audit Process: Towards Robotic Audit Process Automation

"We are going through the process where software will automate software, automation will automate automation"

Mark Cuban

Objectives

- **How can auditors redesign the audit process with RPA to achieve a systematic audit approach that could lead to enhanced audit quality?**

- Propose a framework for redesigning the audit process using RPA
  - RPA for Audit
  - Process Redesign

- Validate feasibility of the framework by applying it to the loan testing audit sub-process of a public accounting firm

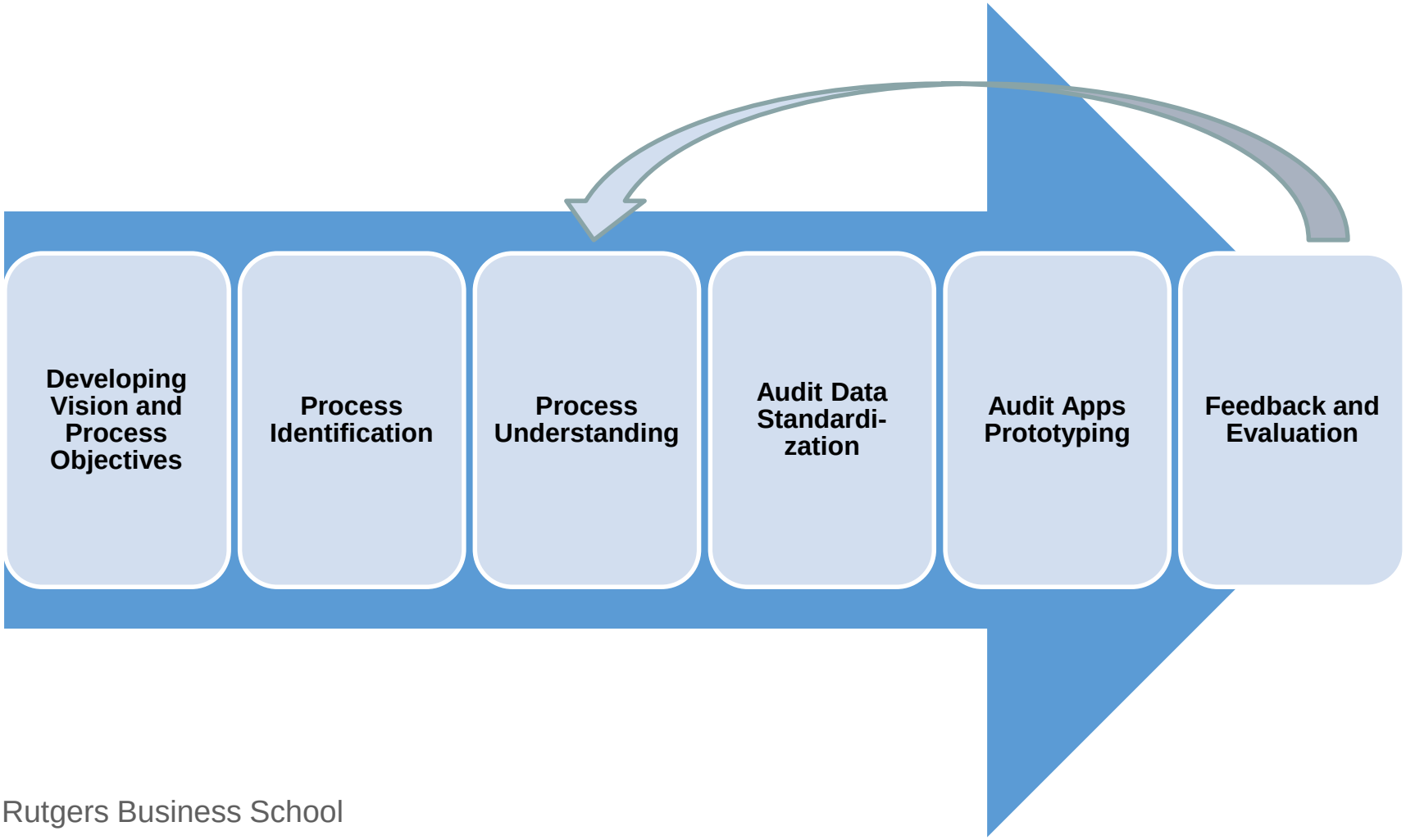
Motivation

- Technology-based audit techniques reflect the direct automation of manual audit tasks (e.g. Vasarhelyi and Halper 1991; Alles et al. 2006; Issa and Kogan 2014)

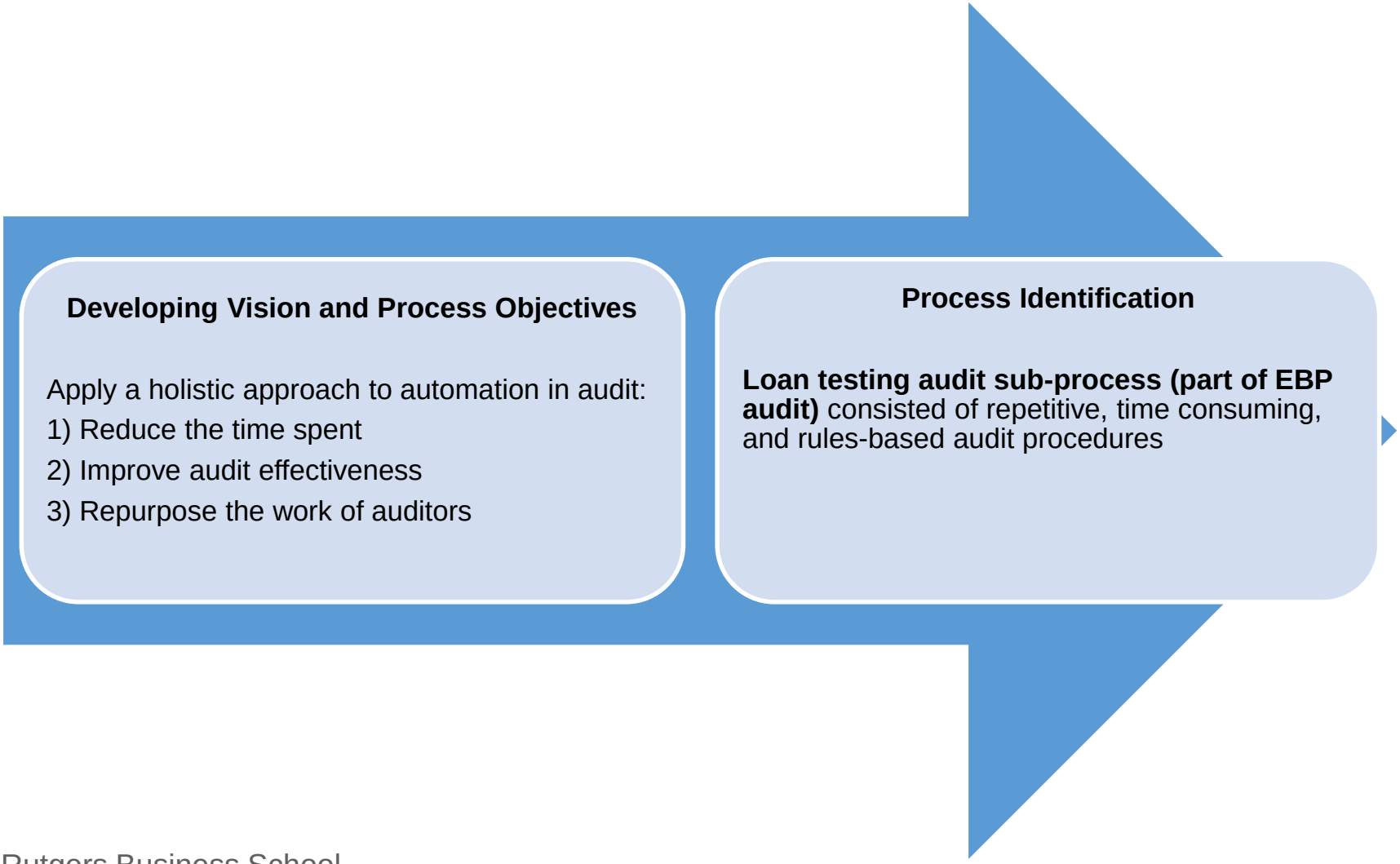
- Audit automation is not a new concept (e.g. Vasarhelyi 1984; Groomer and Murthy 1989), but the rethinking of the audit process to formalize it remains underexplored

- Public accounting firms are starting explore RPA (e.g. Cooper et al. 2018; Moffit et al. 2018; Huang 2018)

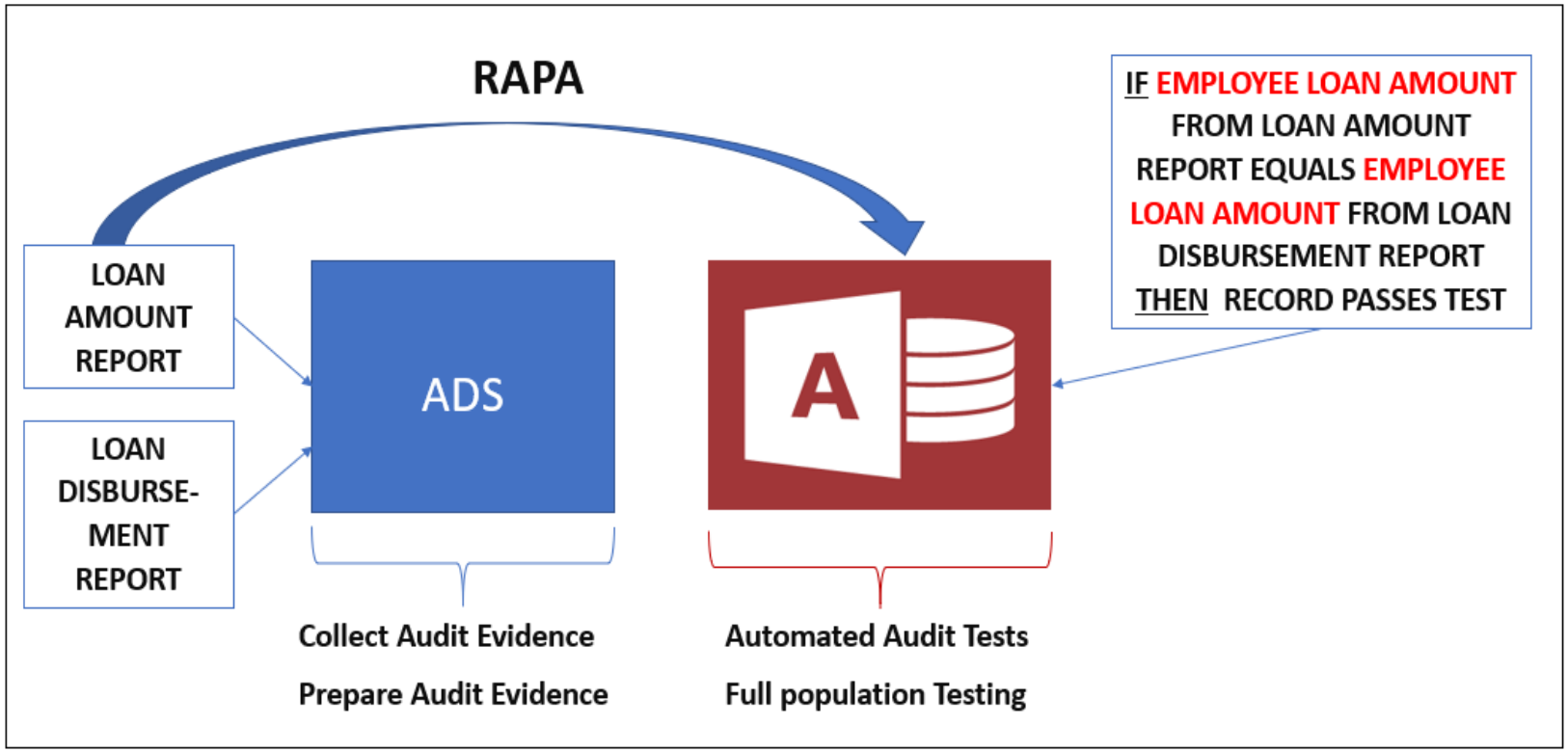
RAPA (Robotic Audit Process Automation) Framework



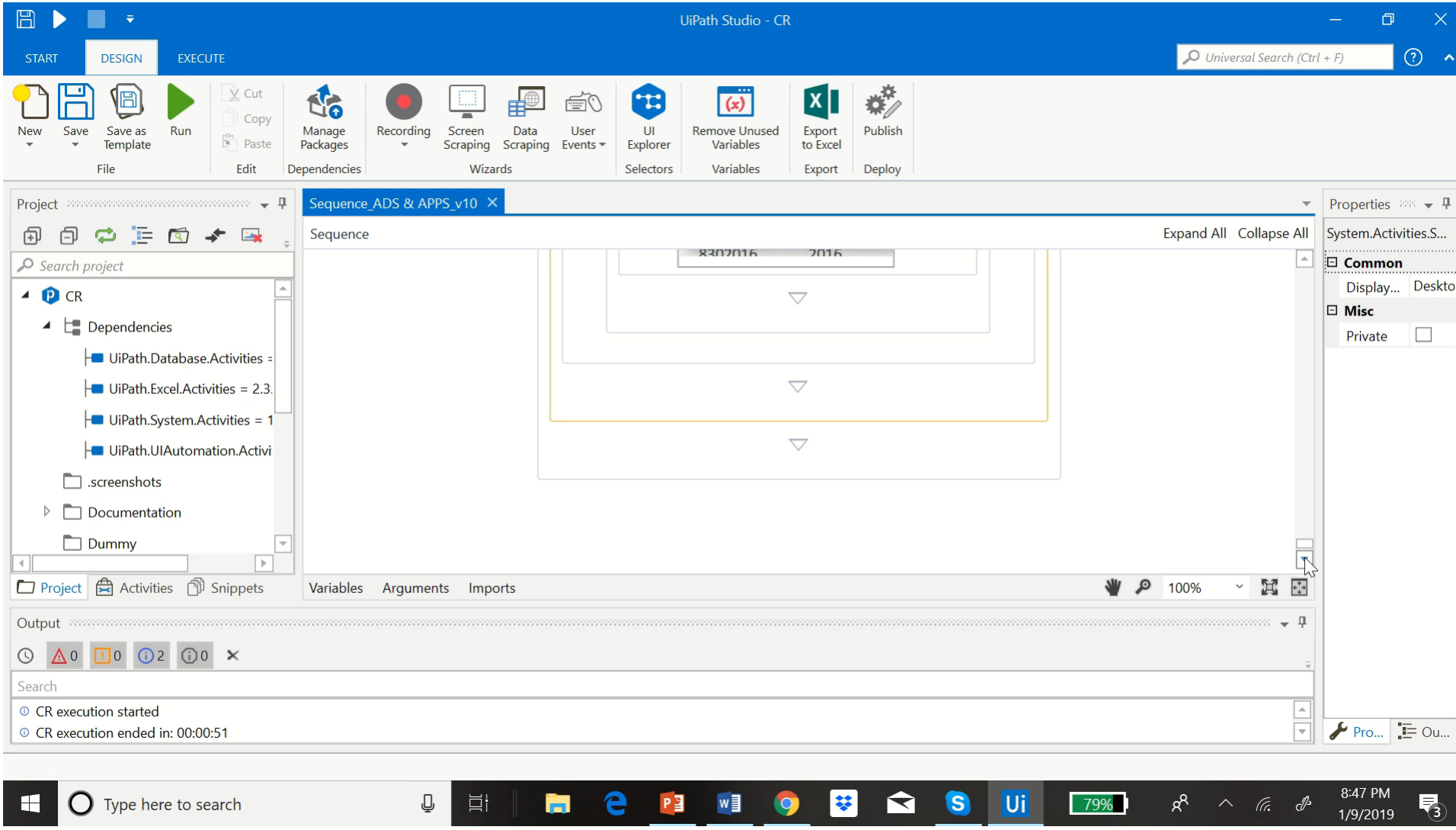
Application of RAPA Framework (1)



Application of RAPA Framework – Process Understanding and ADS (2)



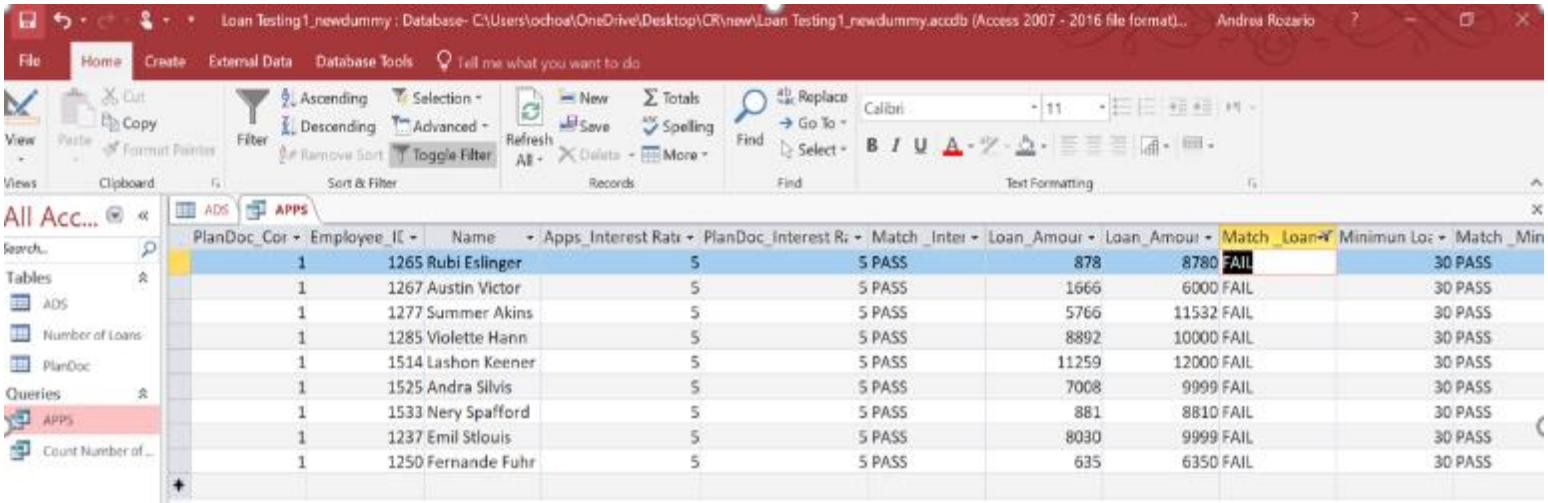
Application of RAPA Framework – Audit Apps (3)



Application of RAPA Framework – Feedback and Evaluation (4)

- **Efficiency:** RAPA spends 51 seconds executing tasks
  - Less time and scalable

- **Effectiveness:** Seeded errors were detected
  - More precise measure of RoMM and timelier detection on more audit engagements
  - Overall effectiveness: spend more time on riskier areas



Contributions

- Explores the potential for an audit production line with RPA
  - Proposing a framework for RAPA
  - Applying the framework to an audit sub-process

Limitations and Future Research

- Framework was applied to a small audit sub-process
- Preliminary assessments were made for efficiency and effectiveness

Essay Three

Reengineering the Audit with Blockchain and Smart Contracts

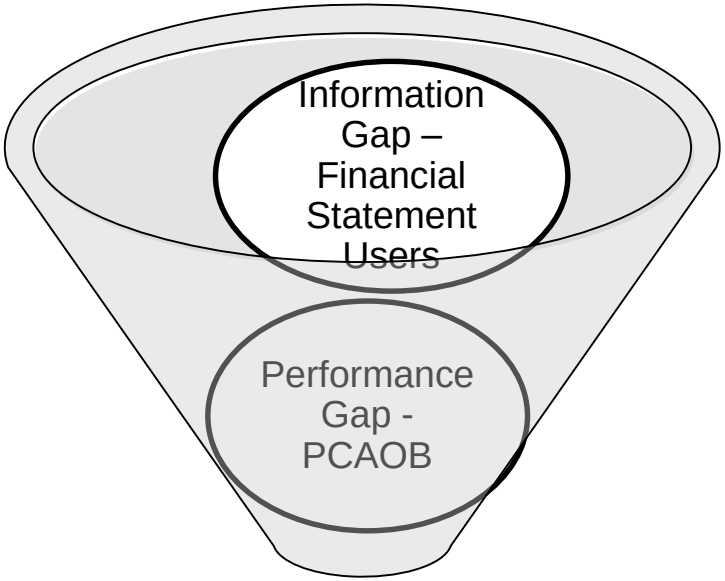
Why blockchain for auditing?

- Lower risk of management override than in an ERP system, no "super user" role in blockchain and it is difficult to alter records (Ibrahim 2017; Glaser 2017; Olsen et al. 2019)
- Secure platform for third party monitoring, "guard the guards", and enhance trust in the capital markets (Alles et al. 2004)
  - Mitigate the risk of manipulation of audit workpapers
  - Proactive inspection process to detect deficiencies near real-time
- Optimize the use of blockchain for auditing given its increasing adoption

Objectives

- **How can auditors leverage blockchain and smart contracts as audit data analytic tools to enhance audit quality?**
- Map the characteristics of blockchain that can enhance audit evidence to PCAOB requirements
- Propose an external audit blockchain supported by a variety of smart audit procedures
- Propose novel functions for the PCAOB and a holistic audit framework
- Discuss the issues related to the application of these technologies

Motivation



BLOCKCHAIN NEWS FEBRUARY 14, 2017 17:28

'Big Four' Giant Deloitte Completes Successful Blockchain Audit

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Get exclusive analysis and cryptocurrency insights on Hackernoon for just $16 per month.

Multinational services firm and one of the so-called "Big Four" accounting firms Deloitte has announced the completion of its latest blockchain endeavor. The firm scrutinized permissioned blockchain protocols and applications with professional auditing standards.

The aim of the project, Deloitte said, was to "enhance the utility and trust of a permissioned blockchain system" by putting it through both professional audit and assurance standards.

PwC Has an Answer for the Blockchain: Audit It

Accounting firm unveils new service for clients' use of blockchain

PricewaterhouseCoopers LLP says its new service will facilitate and encourage companies' use of the blockchain, a still-raw technology that faces a host of obstacles to adoption. PHOTO: MATT CARDY/GETTY IMAGES

By
Michael Rapoport
Updated March 15, 2018 10:00 a.m. ET
18 COMMENTS

If blockchain technology can validate transactions the way an auditor traditionally does, what's left for an auditor to do?

PricewaterhouseCoopers LLP's answer: Validate the validators.

Expectations gap

Increasing adoption of blockchain

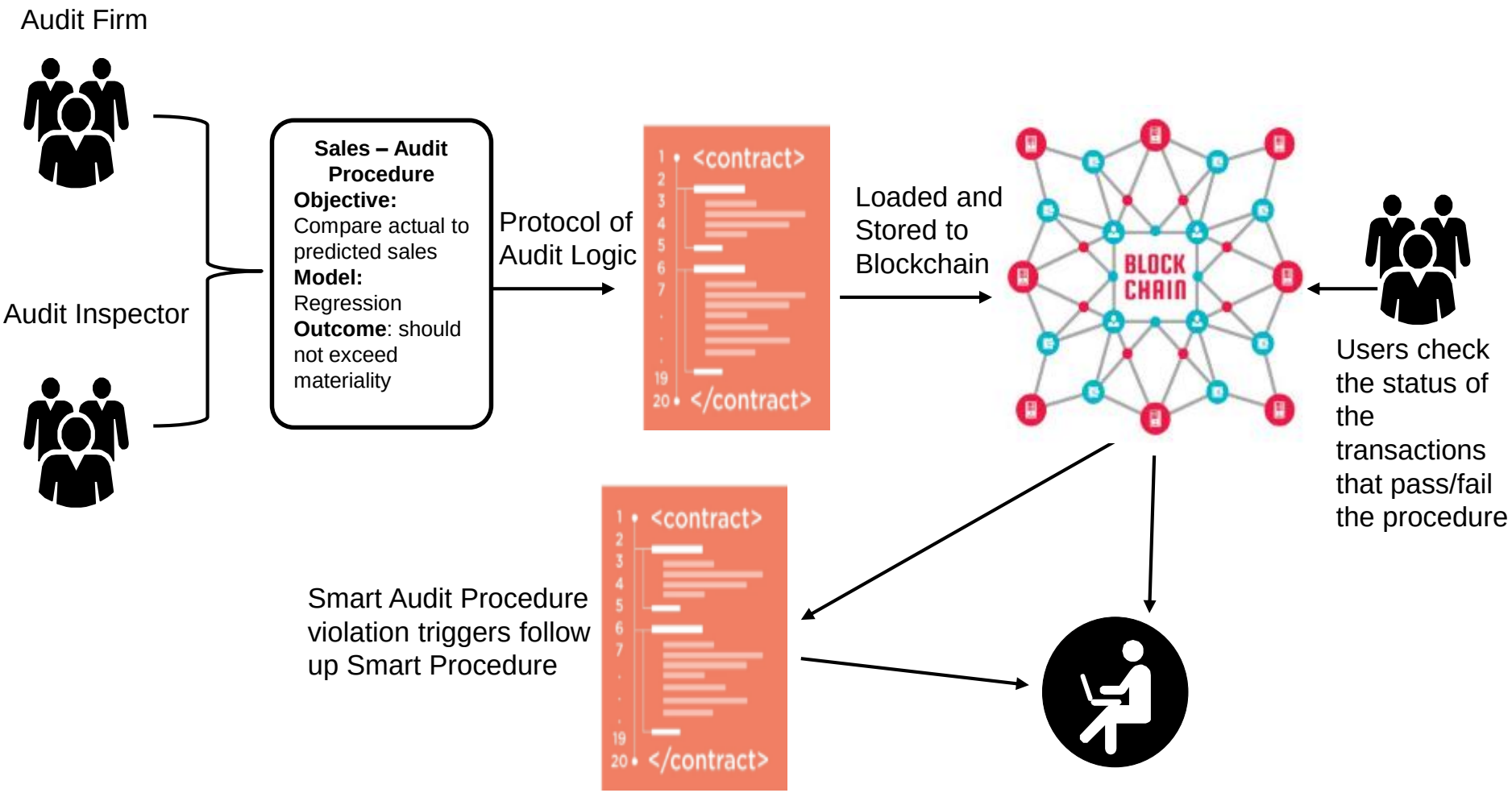
Important to explore how auditors can leverage blockchain and smart contracts to narrow gap

Blockchain can Improve the Reliability of Internal and External Audit Evidence

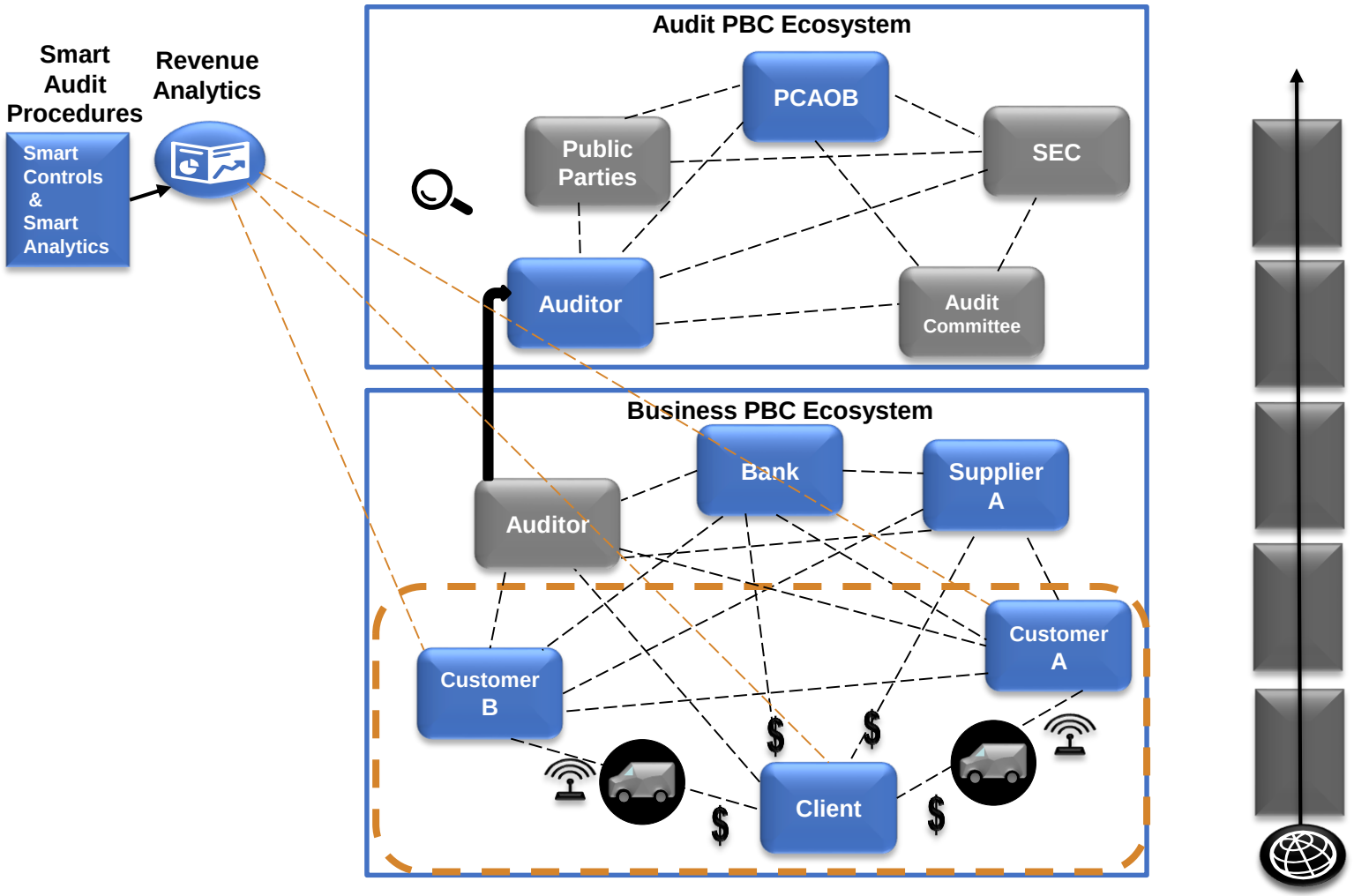
- Requirements of audit evidence: **sufficiency, relevance and reliability** (PCAOB AS 1105 2010)

Challenges of Gathering Audit Evidence	Blockchain Attributes	Blockchain Benefits
Traceable origins of sources (veracity)	Decentralization Immutability Accountability	Data Integrity to improve the **reliability** of audit evidence
Disaggregated data sources (variety)	Decentralization	One distributed depository for financial and nonfinancial data to improve the accuracy and timeliness of audit procedures and obtain a deeper understanding of the client

Blockchain Audit Evidence and Smart Audit Procedures can Improve Audit Quality and Reporting



Interlinked Blockchain Ecosystems



Evolving the role of the PCAOB

- The PCAOB oversees audit firms to ensure audits are conducted in accordance with GAAS
  - Seeks to improve their inspection process
  - Expected to enhance efficiency by relying on technology

- New role for PCAOB as an active node on the audit blockchain to **validate** smart audit procedures and **review** their results

- Issues such as the performance of inadequate audit procedures can be mitigated

Holistic Audit Approach for Revenue

Risk	Assertions	Risk Assessment	Substantive Analytics	Tests of Controls	On BC?
Fictitious or erroneous revenue transactions are entered into the system	**Occurrence**	Cognitive analytics is used to read and analyze terms of pdf legal contracts, such as amount, approvals, contracting parties			No
		Rules-based system is configured to automatically match the terms of legal contracts to the terms in legal smart contracts			No
		Smart Control is configured to automatically match legal smart contract code from previous audit period to legal smart contract code of current audit period			Yes
		Smart Analytic is configured to predict benchmark for current weekly revenue using revenue, locational, and temperature data from previous weeks		Smart Control is configured to automatically match location and temperature of goods that are being delivered to expected location and temperature of goods	Yes
		Smart Control is configured to automatically match revenue, invoice, and shipment amount from the client's blockchain			Yes
		Not applicable	Not applicable	Smart Control is configured to automatically match the access level of customer node	Yes
		Not applicable	Not applicable	Smart Control is configured to automatically match customer name per legal smart contract to customer name on active digital wallets	Yes
Revenue transactions are not recorded in the correct period	**Cut-off**	Not necessary, the record of the transaction and transaction event itself are triggered at the same time			Yes
		Although not necessary to verify **cut-off** on BC, the following procedure, which is used to verify occurrence, can serve as a secondary test to verify the cut-off assertion: Smart Control is configured to automatically match sales order, sales invoice, and shipment amount from the client's blockchain			Yes
Revenue is not recorded	**Complete-ness**	Not necessary, reconciliations occur as transactions are validated and then posted			Yes
		Although not necessary to verify **completeness** on BC, the following procedure, which is used to verify occurrence, can serve as a secondary test to verify the completeness assertion: Smart Control is configured to automatically match sales order, sales invoice, and shipment amount from the client's blockchain			Yes
Revenue returns are not recognized	**Occurrence**	Inspect and evaluate revenue return estimates			No

Issues and Future Research

Limitation	Future Research
Computational power	Why do users of private and permissioned blockchains opt out of using centralized databases?
Storage capabilities	Which methods can meet the demand to store big data on the blockchain?
Cybersecurity risk	How to design and implement a continuous monitoring system to reduce the risk of collusion on the blockchain network?
Litigation risk	How much transparency should be provided to financial statement users while maintaining an acceptable level of audit litigation risk?
Vulnerability of smart contracts	What are the quality processes that public accounting firms should have in place to ensure smart audit procedures are free of error?
Regulatory acceptance	How will the oversight model of financial statement audits be disrupted?
Economics	Would blockchain and smart contracts be developed in-house, or would it be outsourced?

Contributions

- Explores the evolution of auditing in light of blockchain of smart contracts by:
  - Proposing an external audit blockchain supported by smart audit procedures
  - Discussing the issues related to the application of these technologies

Limitations and Future Research

- Existing audit risks were considered, new audit risks may emerge

- Described purpose, usefulness, and challenges of the external audit blockchain

Conclusion

Contributions

- Provides insights into the impact of technological innovations on auditing
- Explores the use of social media information and disruptive technologies to evolve auditing
- Describes the potential for such innovations to improve audit efficiency and effectiveness

Limitations and Future Research Directions

- Parallel comparison of proposed audit tools to traditional audit tools is not conducted
- Impact of these tools on audit judgment is not examined

"For audit, innovation will drive quality"

KPMG Audit Partner
Roger O'Donnell

THANK YOU!

Introduction

Analytical Procedures

- Develop account expectation
  - Less reliable
  - More reliable but not timely!
  - External Nonfinancial Information from Social Media
- Compare account expectation to actual
- Determine whether difference is significant

PCAOB AS 2110

Prior Literature (1)

Informativeness of Nonfinancial Information from the Internet

- Google search queries related to influenza nowcasts influenza outbreaks 1 to 2 weeks before the CDC (Ginsberg et al. 2009)

- Da et al. (2011) demonstrate that the increase in google search queries of a firm's most popular product is a strong predictor of positive revenue surprises

- Tang (2017) investigates the predictive power of Twitter information generated by consumers and finds that it is predictive of future sales

Research Design (4)

Model Comparison

- MAPE (Mean Absolute Percentage Error) is used to evaluate **prediction performance** of each model

- False positive and false negative error percentages are used to evaluate the **error detection performance** of each model
  - Seed errors into the dependent variable
  - Estimate prediction intervals
  - Apply statistical investigation rule
  - Procedure is repeated 10 times to reduce bias

Results (1)

RQ 1A & RQ 1B: Prediction Performance – 24 industries

	Twitter Consumer Interest				Twitter Consumer Satisfaction			
Model	(1) vs. (5)	(2) vs. (7)	(3) vs. (9)	(4) vs. (11)	(1) vs. (6)	(2) vs. (8)	(3) vs. (10)	(4) vs. (12)
Traditional - SAP	16 of 24	16 of 24	16 of 24	14 of 24	15 of 24	14 of 24	12 of 24	15 of 24
Continuous - SAP	19 of 24	21 of 24	18 of 24	22 of 24	14 of 24	20 of 24	14 of 24	22 of 24

RQ 1B: Prediction Performance of Continuous Substantive Analytical Models with TCI and without TCI (Models 5, 7, 9 and 11 and 1, 2, 3, and 4)

TCI outperforms benchmark for:

	(1)	(5)			(2)	(7)			(3)	(9)			(4)	(11)		
	Saletst-1	Saletst-1+TweetCI			Saletst-1+GDPt-1	Saletst-1+TweetCI+GDPt-1			Saletst-1+AR	Saletst-1+AR+TweetCI			Saletst-1+AR+GDPt-1	Salest12+AR+TweetCI+GDPt-1		
2-Digit SIC	MAPE1	MAPE5	Difference B/W	p-value	MAPE2	MAPE7	Difference B/W	p-value	MAPE3	MAPE9	Difference B/W	p-value	MAPE4	MAPE11	Difference B/W	p-value
20	0.1015	0.0921	0.0094 B	0.000	0.0855	0.0545	0.0310 B	0.000	0.083	0.078	0.005 B	0.000	0.079	0.040	0.039 B	0.000
21	0.0577	0.0565	0.0012 B	0.001	0.0492	0.0199	0.0292 B	0.001	0.058	0.056	0.001 B	0.001	0.047	0.019	0.028 B	0.001
23	0.1439	0.1370	0.0069 B	0.000	0.1271	0.0576	0.0695 B	0.000	0.101	0.086	0.015 B	0.000	0.091	0.045	0.046 B	0.000
28	0.0735	0.0733	0.0001 B	0.224	0.0547	0.0346	0.0200 B	0.000	0.045	0.046	-0.001 W	0.043	0.046	0.030	0.016 B	0.000
29	0.0578	0.0573	0.0005 B	0.034	0.0825	0.1403	-0.0578 W	0.000	0.055	0.058	-0.003 W	0.000	0.055	0.079	-0.024 W	0.000
30	0.0498	0.0508	-0.0010 W	0.001	0.0349	0.0211	0.0137 B	0.001	0.037	0.037	0.000 B	0.001	0.035	0.022	0.013 B	0.001
31	0.1686	0.1681	0.0005 B	0.034	0.1411	0.0816	0.0595 B	0.000	0.128	0.124	0.003 B	0.034	0.107	0.064	0.042 B	0.000
35	0.1193	0.1105	0.0088 B	0.000	0.1057	0.0493	0.0564 B	0.000	0.070	0.072	-0.002 W	0.000	0.066	0.043	0.022 B	0.000
36	0.1020	0.0955	0.0064 B	0.000	0.1090	0.0385	0.0705 B	0.000	0.095	0.094	0.002 B	0.137	0.104	0.039	0.065 B	0.000
37	0.1122	0.1121	0.0001 B	0.254	0.0879	0.0808	0.0071 B	0.137	0.106	0.105	0.001 B	0.841	0.080	0.071	0.009 B	0.841
39	0.3305	0.3007	0.0298 B	0.000	0.3411	0.0723	0.2688 B	0.000	0.213	0.209	0.004 B	0.077	0.180	0.075	0.105 B	0.000
42	0.0754	0.0415	0.0339 B	0.001	0.0560	0.0182	0.0378 B	0.001	0.060	0.044	0.016 B	0.001	0.053	0.020	0.033 B	0.001
44	0.1499	0.1396	0.0103 B	0.034	0.1525	0.0184	0.1341 B	0.000	0.155	0.144	0.011 B	0.000	0.152	0.018	0.134 B	0.000
45	0.0745	0.0647	0.0098 B	0.000	0.0646	0.0540	0.0106 B	0.000	0.070	0.062	0.008 B	0.000	0.062	0.045	0.016 B	0.000
47	0.1753	0.1294	0.0459 B	0.001	0.1318	0.0404	0.0914 B	0.001	0.128	0.126	0.002 B	0.001	0.125	0.040	0.084 B	0.001
48	0.0305	0.0288	0.0018 B	0.000	0.0301	0.0200	0.0101 B	0.000	0.030	0.029	0.002 B	0.000	0.030	0.020	0.010 B	0.000
53	0.1947	0.1184	0.0764 B	0.001	0.1801	0.0418	0.1383 B	0.001	0.190	0.125	0.065 B	0.001	0.181	0.043	0.138 B	0.001
55	0.1088	0.0978	0.0110 B	0.034	0.1212	0.0336	0.0875 B	0.000	0.093	0.076	0.017 B	0.000	0.069	0.041	0.028 B	0.000
57	0.1206	0.1042	0.0163 B	0.034	0.0986	0.0673	0.0313 B	0.034	0.102	0.103	-0.001 W	0.034	0.106	0.068	0.038 B	0.034
58	0.0687	0.0669	0.0017 B	0.000	0.0555	0.0416	0.0139 B	0.000	0.063	0.058	0.005 B	0.000	0.055	0.039	0.016 B	0.000
59	0.2546	0.2515	0.0031 B	0.000	0.2451	0.0740	0.1710 B	0.077	0.253	0.251	0.002 B	0.000	0.243	0.063	0.180 B	0.000
70	0.0530	0.0543	-0.0013 W	0.000	0.0498	0.0639	-0.0141 W	0.034	0.053	0.052	0.001 B	0.034	0.049	0.045	0.004 B	0.034
73	0.0849	0.0800	0.0049 B	0.437	0.0732	0.0300	0.0431 B	0.000	0.076	0.075	0.001 B	0.003	0.071	0.031	0.040 B	0.000
75	0.1525	0.0922	0.0602 B	0.001	0.1469	0.0143	0.1326 B	0.001	0.090	0.075	0.015 B	0.001	0.092	0.011	0.081 B	0.001

19 industries | 21 industries | 18 industries | 22 industries

RQ 1B: Prediction Performance of Continuous Substantive Analytical Models with TCS and without TCS (Models 6, 8, 10 and 12 and 1, 2, 3, and 4)

TCS outperforms benchmark for:

	(1)	(6)			(2)	(8)			(3)	(10)			(4)	(12)		
	Saletst-1	Saletst-1+TweetCS			Saletst-1+GDPt-1	Saletst-1+TweetCS+GDPt-1			Saletst-1+AR	Saletst-1+AR+TweetCS			Saletst-1+AR+GDPt-1	Saletst-1+AR+TweetCS+GDPt-1		
2-Digit SIC	MAPE1	MAPE6	Difference	B/W	p-value	MAPE2	MAPE8	Difference	B/W	p-value	MAPE3	MAPE10	Difference	B/W	p-value	MAPE4	MAPE12	Difference	B/W	p-value
20	0.1015	0.0883	0.0132	B	0.000	0.0855	0.0576	0.0280	B	0.000	0.0828	0.0797	0.0031	B	0.000	0.0792	0.0421	0.0372	B	0.000
21	0.0577	0.0591	-0.0014	W	0.001	0.0492	0.0242	0.0249	B	0.001	0.0576	0.0584	-0.0008	W	0.001	0.0472	0.0201	0.0271	B	0.001
23	0.1439	0.1364	0.0075	B	0.000	0.1271	0.0577	0.0694	B	0.000	0.1013	0.0977	0.0036	B	0.000	0.0908	0.0435	0.0473	B	0.000
28	0.0735	0.0706	0.0028	B	0.224	0.0547	0.0336	0.0211	B	0.000	0.0455	0.0453	0.0001	B	0.398	0.0459	0.0291	0.0168	B	0.000
29	0.0578	0.0463	0.0116	B	0.000	0.0825	0.1715	-0.0889	W	0.000	0.0551	0.0558	-0.0006	W	0.000	0.0553	0.0730	-0.0178	W	0.000
30	0.0498	0.0449	0.0049	B	0.001	0.0349	0.0216	0.0132	B	0.001	0.0372	0.0370	0.0002	B	0.001	0.0351	0.0222	0.0129	B	0.001
31	0.1686	0.1559	0.0127	B	0.000	0.1411	0.0842	0.0570	B	0.000	0.1276	0.1245	0.0031	B	0.034	0.1067	0.0627	0.0440	B	0.000
35	0.1193	0.1218	-0.0025	W	0.000	0.1057	0.0465	0.0592	B	0.000	0.0695	0.0731	-0.0036	W	0.000	0.0655	0.0425	0.0230	B	0.000
36	0.1020	0.1180	-0.0161	W	0.003	0.1090	0.0471	0.0619	B	0.022	0.0954	0.1081	-0.0126	W	0.000	0.1036	0.0443	0.0592	B	0.000
37	0.1122	0.1430	-0.0308	W	0.254	0.0879	0.0819	0.0060	B	0.398	0.1058	0.0972	0.0086	B	0.000	0.0798	0.0672	0.0126	B	0.883
39	0.3305	0.3384	-0.0080	W	0.000	0.3411	0.0625	0.2786	B	0.000	0.2132	0.2157	-0.0025	W	0.077	0.1797	0.0621	0.1176	B	0.000
42	0.0754	0.0637	0.0117	B	0.001	0.0560	0.0144	0.0415	B	0.001	0.0605	0.0522	0.0083	B	0.001	0.0532	0.0189	0.0343	B	0.001
44	0.1499	0.1486	0.0013	B	0.034	0.1525	0.0192	0.1332	B	0.000	0.1548	0.1517	0.0030	B	0.034	0.1523	0.0195	0.1328	B	0.000
45	0.0745	0.0642	0.0103	B	0.000	0.0646	0.0528	0.0118	B	0.000	0.0697	0.0627	0.0070	B	0.000	0.0616	0.0466	0.0149	B	0.000
47	0.1753	0.1597	0.0156	B	0.001	0.1318	0.0439	0.0879	B	0.001	0.1278	0.1323	-0.0045	W	0.001	0.1249	0.0436	0.0813	B	0.001
48	0.0305	0.0337	-0.0032	W	0.000	0.0301	0.0236	0.0065	B	0.000	0.0304	0.0306	-0.0002	W	0.034	0.0299	0.0237	0.0062	B	0.000
53	0.1947	0.1740	0.0207	B	0.001	0.1801	0.0402	0.1399	B	0.001	0.1899	0.1523	0.0375	B	0.001	0.1810	0.0399	0.1411	B	0.001
55	0.1088	0.1019	0.0070	B	0.000	0.1212	0.0333	0.0879	B	0.000	0.0931	0.0844	0.0087	B	0.034	0.0692	0.0375	0.0317	B	0.000
57	0.1206	0.1025	0.0181	B	0.034	0.0986	0.0612	0.0374	B	0.034	0.1020	0.0988	0.0031	B	0.034	0.1063	0.0605	0.0458	B	0.034
58	0.0687	0.0587	0.0100	B	0.000	0.0555	0.0410	0.0145	B	0.000	0.0626	0.0565	0.0062	B	0.000	0.0550	0.0395	0.0155	B	0.000
59	0.2546	0.2558	-0.0012	W	0.077	0.2451	0.0691	0.1760	B	0.599	0.2532	0.2543	-0.0011	W	0.077	0.2430	0.0627	0.1803	B	0.000
70	0.0530	0.0657	-0.0127	W	0.000	0.0498	0.0565	-0.0067	W	0.034	0.0532	0.0530	0.0003	B	0.034	0.0491	0.0455	0.0036	B	0.034
73	0.0849	0.0822	0.0027	B	0.065	0.0732	0.0305	0.0427	B	0.000	0.0762	0.0755	0.0007	B	0.054	0.0714	0.0328	0.0387	B	0.000
75	0.1525	0.1528	-0.0004	W	0.001	0.1469	0.0163	0.1306	B	0.001	0.0901	0.1006	-0.0105	W	0.001	0.0919	0.0146	0.0773	B	0.001

14 industries | 20 industries | 18 industries | 22 industries

RQ 2B: Error Detection Performance of Continuous Substantive Analytical Models with TCI and without TCI (Models 5 and 1)

TCI outperforms benchmark for:

Error Detection Ability - Alpha = 0.33													
		(1)		(5)									
		Benchmark - Salest-1		Twitter - CI		Benchmark - CI				(1:1)	(1:2)	(1:1)	(1:2)
2-Digit SIC	Number of Observations	False Positive	False Negative	False Positive	False Negative	Difference - FP	Difference - FN	Better Model - FP	Better Model - FN	Benchmark Total Cost /TCI Total Cost	Benchmark Total Cost /TCI Total Cost	Better Model - Cost Ratio	Better Model - Cost Ratio
20	144	44.72%	18.01%	43.99%	17.37%	0.73%	0.64%	TCI	TCI	1.02	1.03	TCI	TCI
21	12	47.86%	5.00%	50.00%	0.00%	-2.14%	5.00%	Benchmark	TCI	1.06	1.16	TCI*	TCI*
23	36	45.09%	2.50%	47.11%	10.00%	-2.02%	-7.50%	Benchmark	Benchmark	0.83	0.75	Benchmark	Benchmark
28	72	43.97%	11.07%	45.00%	13.21%	-1.03%	-2.14%	Benchmark	Benchmark	0.95	0.93	Benchmark	Benchmark
29	24	45.67%	16.67%	41.94%	28.33%	3.73%	-11.67%	TCI	Benchmark	0.89	0.80	Benchmark*	Benchmark*
30	12	50.00%	0.00%	47.86%	5.00%	2.14%	-5.00%	TCI	Benchmark	0.95	0.86	Benchmark*	Benchmark*
31	24	42.40%	6.67%	43.87%	6.67%	-1.47%	0.00%	Benchmark	-	0.97	0.97	Benchmark*	Benchmark*
35	24	42.84%	15.00%	42.85%	16.67%	-0.01%	-1.67%	Benchmark	Benchmark	0.97	0.96	Benchmark	Benchmark
36	48	43.58%	16.57%	42.39%	21.90%	1.18%	-5.33%	TCI	Benchmark	0.94	0.89	Benchmark*	Benchmark*
37	84	45.15%	15.44%	43.63%	17.94%	1.52%	-2.50%	TCI	Benchmark	0.98	0.96	Benchmark*	Benchmark*
39	36	44.35%	7.50%	43.10%	23.00%	1.25%	-15.50%	TCI	Benchmark	0.78	0.67	Benchmark*	Benchmark*
42	12	42.68%	10.00%	32.87%	20.00%	9.82%	-10.00%	TCI	Benchmark	1.00	0.86	Benchmark*	Benchmark*
44	24	40.03%	20.00%	40.51%	28.33%	-0.49%	-8.33%	Benchmark	Benchmark	0.87	0.82	Benchmark	Benchmark
45	96	45.84%	14.67%	44.55%	16.12%	1.30%	-1.45%	TCI	Benchmark	1.00	0.98	Benchmark*	Benchmark*
47	12	45.79%	15.00%	47.62%	0.00%	-1.83%	15.00%	Benchmark	TCI	1.28	1.59	TCI*	TCI*
48	24	41.17%	13.33%	39.88%	20.00%	1.29%	-6.67%	TCI	Benchmark	0.91	0.85	Benchmark*	Benchmark*
53	12	34.08%	35.00%	39.53%	10.00%	-5.45%	25.00%	Benchmark	TCI	1.39	1.75	TCI*	TCI*
55	24	45.40%	8.33%	45.67%	16.67%	-0.27%	-8.33%	Benchmark	Benchmark	0.86	0.79	Benchmark	Benchmark
57	24	46.60%	6.67%	45.40%	8.33%	1.20%	-1.67%	TCI	Benchmark	0.99	0.97	Benchmark*	Benchmark*
58	180	45.09%	13.83%	44.76%	14.81%	0.33%	-0.97%	TCI	Benchmark	0.99	0.98	Benchmark*	Benchmark*
59	36	42.80%	16.50%	39.00%	25.50%	3.80%	-9.00%	TCI	Benchmark	0.92	0.84	Benchmark*	Benchmark*
70	24	45.54%	13.33%	42.99%	18.33%	2.55%	-5.00%	TCI	Benchmark	0.96	0.91	Benchmark*	Benchmark*
73	60	37.50%	27.68%	38.13%	27.08%	-0.64%	0.60%	Benchmark	TCI	1.00	1.01	Benchmark*	TCI*
75	12	48.10%	10.00%	33.68%	30.00%	14.42%	-20.00%	TCI	Benchmark	0.91	0.73	Benchmark*	Benchmark*

*Better model determined based on the ratio of costs of FP and FN errors.

14 indus-tries

5 indus-tries

4 indus-tries

5 indus-tries

RQ 2B: Error Detection Performance of Continuous Substantive Analytical Models with TCI and without TCI (Models 7 and 2)

TCI outperforms benchmark for:

Error Detection Ability - Alpha = 0.33

		(2)		(7)									
		Benchmark - Salest-1 & GDPt-1		Twitter - CI & GDPt-1		Benchmark - CI				(1:1)	(1:2)	(1:1)	(1:2)
2-Digit SIC	Number of Observations	False Positive	False Negative	False Positive	False Negative	Difference - FP	Difference - FN	Better Model - FP	Better Model - FN	Benchmark Total Cost /TCI Total Cost	Benchmark Total Cost /TCI Total Cost	Better Model - Cost Ratio	Better Model - Cost Ratio
20	144	43.27%	17.98%	41.72%	21.66%	1.56%	-3.67%	TCI	Benchmark	0.97	0.93	Benchmark*	Benchmark*
21	12	39.53%	10.00%	45.00%	0.00%	-5.47%	10.00%	Benchmark	TCI	1.10	1.32	TCI*	TCI*
23	36	46.16%	6.50%	44.53%	11.50%	1.63%	-5.00%	TCI	Benchmark	0.94	0.88	Benchmark*	Benchmark*
28	72	43.68%	15.83%	40.86%	20.24%	2.83%	-4.40%	TCI	Benchmark	0.97	0.93	Benchmark*	Benchmark*
29	24	49.07%	6.67%	42.09%	30.00%	6.98%	-23.33%	TCI	Benchmark	0.77	0.61	Benchmark*	Benchmark*
30	12	36.73%	20.00%	39.53%	10.00%	-2.80%	10.00%	Benchmark	TCI	1.15	1.29	TCI*	TCI*
31	24	40.85%	6.67%	39.22%	6.67%	1.63%	0.00%	TCI	-	1.04	1.03	TCI*	TCI*
35	24	44.15%	13.33%	42.55%	10.00%	1.60%	3.33%	TCI	TCI	1.09	1.13	TCI	TCI
36	48	44.23%	16.00%	41.56%	22.95%	2.67%	-6.95%	TCI	Benchmark	0.93	0.87	Benchmark*	Benchmark*
37	84	42.88%	19.55%	43.96%	16.19%	-1.08%	3.36%	Benchmark	TCI	1.04	1.07	TCI*	TCI*
39	36	46.86%	2.50%	42.70%	14.00%	4.16%	-11.50%	TCI	Benchmark	0.87	0.73	Benchmark*	Benchmark*
42	12	40.18%	20.00%	32.87%	20.00%	7.31%	0.00%	TCI	-	1.14	1.10	TCI*	TCI*
44	24	44.29%	16.67%	45.54%	13.33%	-1.24%	3.33%	Benchmark	TCI	1.04	1.08	TCI*	TCI*
45	96	45.00%	19.02%	44.89%	16.73%	0.10%	2.29%	TCI	TCI	1.04	1.06	TCI	TCI
47	12	45.52%	10.00%	47.62%	0.00%	-2.10%	10.00%	Benchmark	TCI	1.17	1.38	TCI*	TCI*
48	24	42.70%	13.33%	39.87%	18.33%	2.83%	-5.00%	TCI	Benchmark	0.96	0.91	Benchmark*	Benchmark*
53	12	47.62%	0.00%	40.18%	20.00%	7.44%	-20.00%	TCI	Benchmark	0.79	0.59	Benchmark*	Benchmark*
55	24	48.11%	13.33%	46.72%	10.00%	1.38%	3.33%	TCI	TCI	1.08	1.12	TCI	TCI
57	24	43.87%	6.67%	46.47%	3.33%	-2.60%	3.33%	Benchmark	TCI	1.01	1.08	TCI*	TCI*
58	180	45.44%	18.19%	45.15%	19.76%	0.29%	-1.57%	TCI	Benchmark	0.98	0.97	Benchmark*	Benchmark*
59	36	42.40%	7.50%	44.35%	7.50%	-1.94%	0.00%	Benchmark	-	0.96	0.97	Benchmark*	Benchmark*
70	24	44.44%	20.00%	43.00%	20.00%	1.44%	0.00%	TCI	-	1.02	1.02	TCI*	TCI*
73	60	33.89%	29.76%	36.70%	26.79%	-2.82%	2.98%	Benchmark	TCI	1.00	1.03	TCI*	TCI*
75	12	46.05%	20.00%	34.08%	35.00%	11.97%	-15.00%	TCI	Benchmark	0.96	0.83	Benchmark*	Benchmark*
								16 indus-tries	10 indus-tries			13 indus-tries	13 indus-tries

*Better model determined based on the ratio of costs of FP and FN errors.

RQ 2B: Error Detection Performance of Continuous Substantive Analytical Models with TCI and without TCI (Models 9 and 3)

TCI outperforms benchmark for:

Error Detection Ability - Alpha = 0.33													
		(3)		(9)									
		Benchmark - Salest-1 & AR		Twitter - CI & AR		Benchmark - CI				(1:1)	(1:2)	(1:1)	(1:2)
2-Digit SIC	Number of Observations	False Positive	False Negative	False Positive	False Negative	Difference - FP	Difference - FN	Better Model - FP	Better Model - FN	Benchmark Total Cost /TCI Total Cost	Benchmark Total Cost /TCI Total Cost	Better Model - Cost Ratio	Better Model - Cost Ratio
20	144	44.21%	17.00%	43.52%	17.66%	0.69%	-0.66%	TCI	Benchmark	1.00	0.99	TCI*	Benchmark*
21	12	47.86%	5.00%	50.00%	0.00%	-2.14%	5.00%	Benchmark	TCI	1.06	1.16	TCI*	TCI*
23	36	44.53%	12.50%	40.75%	17.50%	3.78%	-5.00%	TCI	Benchmark	0.98	0.92	Benchmark*	Benchmark*
28	72	37.85%	25.86%	37.73%	23.36%	0.12%	2.50%	TCI	TCI	1.04	1.06	TCI	TCI
29	24	42.55%	10.00%	45.40%	10.00%	-2.85%	0.00%	Benchmark	-	0.95	0.96	Benchmark*	Benchmark*
30	12	42.97%	15.00%	42.97%	15.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
31	24	39.71%	15.00%	39.71%	15.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
35	24	38.36%	21.67%	39.88%	20.00%	-1.52%	1.67%	Benchmark	TCI	1.00	1.02	TCI*	TCI*
36	48	43.58%	18.00%	44.30%	18.00%	-0.71%	0.00%	Benchmark	-	0.99	0.99	Benchmark*	Benchmark*
37	84	43.59%	16.69%	43.50%	14.19%	0.08%	2.50%	TCI	TCI	1.04	1.07	TCI	TCI
39	36	42.90%	19.00%	38.77%	20.50%	4.14%	-1.50%	TCI	Benchmark	1.04	1.01	TCI*	TCI*
42	12	32.87%	20.00%	36.37%	15.00%	-3.50%	5.00%	Benchmark	TCI	1.03	1.10	TCI*	TCI*
44	24	42.69%	11.67%	43.14%	21.67%	-0.45%	-10.00%	Benchmark	Benchmark	0.84	0.76	Benchmark	Benchmark
45	96	45.00%	19.13%	44.44%	13.62%	0.56%	5.52%	TCI	TCI	1.10	1.16	TCI	TCI
47	12	42.97%	15.00%	47.62%	0.00%	-4.65%	15.00%	Benchmark	TCI	1.22	1.53	TCI*	TCI*
48	24	39.71%	16.67%	39.88%	20.00%	-0.17%	-3.33%	Benchmark	Benchmark	0.94	0.91	Benchmark	Benchmark
53	12	47.86%	5.00%	40.18%	20.00%	7.68%	-15.00%	TCI	Benchmark	0.88	0.72	Benchmark*	Benchmark*
55	24	46.72%	10.00%	47.86%	6.67%	-1.14%	3.33%	Benchmark	TCI	1.04	1.09	TCI*	TCI*
57	24	46.60%	6.67%	45.40%	8.33%	1.20%	-1.67%	TCI	Benchmark	0.99	0.97	Benchmark*	Benchmark*
58	180	46.24%	10.96%	45.34%	15.42%	0.89%	-4.46%	TCI	Benchmark	0.94	0.89	Benchmark*	Benchmark*
59	36	43.00%	20.50%	43.87%	18.00%	-0.87%	2.50%	Benchmark	TCI	1.03	1.05	TCI*	TCI*
70	24	47.98%	10.00%	44.29%	15.00%	3.70%	-5.00%	TCI	Benchmark	0.98	0.92	Benchmark*	Benchmark*
73	60	40.54%	21.85%	40.60%	23.51%	-0.07%	-1.67%	Benchmark	Benchmark	0.97	0.96	Benchmark	Benchmark
75	12	40.82%	30.00%	29.42%	30.00%	11.40%	0.00%	TCI	-	1.19	1.13	TCI*	TCI*

*Better model determined based on the ratio of costs of FP and FN errors.

11 indus-tries

9 indus-tries

12 indus-tries

11 indus-tries

RQ 2B: Error Detection Performance of Continuous Substantive Analytical Models with TCI and without TCI (Models 11 and 4)

TCI outperforms benchmark for:

Error Detection Ability - Alpha = 0.33													
		(4)		(11)									
2-Digit SIC	Number of Observations	Benchmark - Salest-1 & AR & GDPt-1		Twitter - CI & AR & GDPt-1		Benchmark - CI		Better Model - FP	Better Model - FN	(1:1)	(1:2)	(1:1)	(1:2)
		False Positive	False Negative	False Positive	False Negative	Difference - FP	Difference - FN			Benchmark Total Cost /TCI Total Cost	Benchmark Total Cost /TCI Total Cost	Better Model - Cost Ratio	Better Model - Cost Ratio
20	144	43.80%	18.80%	42.68%	20.90%	1.12%	-2.10%	TCI	Benchmark	0.98	0.96	Benchmark*	Benchmark*
21	12	42.39%	5.00%	36.01%	10.00%	6.38%	-5.00%	TCI	Benchmark	1.03	0.94	TCI*	Benchmark*
23	36	45.27%	7.50%	45.27%	7.50%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
28	72	40.64%	26.19%	39.50%	24.76%	1.14%	1.43%	TCI	TCI	1.04	1.04	TCI	TCI
29	24	41.47%	18.33%	43.87%	6.67%	-2.40%	11.67%	Benchmark	TCI	1.18	1.37	TCI*	TCI*
30	12	36.73%	20.00%	36.73%	20.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
31	24	42.40%	6.67%	40.85%	6.67%	1.55%	0.00%	TCI	-	1.03	1.03	TCI*	TCI*
35	24	38.19%	20.00%	36.95%	28.33%	1.24%	-8.33%	TCI	Benchmark	0.89	0.84	Benchmark*	Benchmark*
36	48	42.33%	23.33%	40.78%	23.33%	1.55%	0.00%	TCI	-	1.02	1.02	TCI*	TCI*
37	84	43.46%	13.89%	44.56%	10.97%	-1.10%	2.92%	Benchmark	TCI	1.03	1.07	TCI*	TCI*
39	36	33.33%	32.50%	35.67%	29.50%	-2.34%	3.00%	Benchmark	TCI	1.01	1.04	TCI*	TCI*
42	12	32.87%	20.00%	32.87%	20.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
44	24	45.67%	16.67%	46.85%	13.33%	-1.18%	3.33%	Benchmark	TCI	1.04	1.07	TCI*	TCI*
45	96	44.62%	18.28%	43.55%	18.34%	1.07%	-0.06%	TCI	Benchmark	1.02	1.01	TCI*	TCI*
47	12	45.52%	10.00%	47.62%	0.00%	-2.10%	10.00%	Benchmark	TCI	1.17	1.38	TCI*	TCI*
48	24	41.31%	15.00%	39.87%	18.33%	1.44%	-3.33%	TCI	Benchmark	0.97	0.93	Benchmark*	Benchmark*
53	12	47.62%	0.00%	39.85%	15.00%	7.77%	-15.00%	TCI	Benchmark	0.87	0.68	Benchmark*	Benchmark*
55	24	42.99%	18.33%	41.47%	18.33%	1.52%	0.00%	TCI	-	1.03	1.02	TCI*	TCI*
57	24	46.34%	0.00%	45.13%	3.33%	1.21%	-3.33%	TCI	Benchmark	0.96	0.89	Benchmark*	Benchmark*
58	180	45.16%	15.92%	45.02%	17.00%	0.15%	-1.09%	TCI	Benchmark	0.98	0.97	Benchmark*	Benchmark*
59	36	41.06%	22.00%	40.95%	19.50%	0.11%	2.50%	TCI	TCI	1.04	1.06	TCI	TCI
70	24	46.98%	16.67%	44.44%	20.00%	2.54%	-3.33%	TCI	Benchmark	0.99	0.95	Benchmark*	Benchmark*
73	60	38.13%	27.08%	41.17%	22.14%	-3.04%	4.94%	Benchmark	TCI	1.03	1.08	TCI*	TCI*
75	12	43.55%	25.00%	25.10%	35.00%	18.46%	-10.00%	TCI	Benchmark	1.14	0.98	TCI*	Benchmark*

*Better model determined based on the ratio of costs of FP and FN errors.

15 indus-tries

8 indus-tries

14 indus-tries

12 indus-tries

RQ 2A: Error Detection Performance for Continuous Substantive Analytical Models with TCS and without TCS (Models 6 and 1)

TCS outperforms benchmark for:

Error Detection Ability - Alpha = 0.33													
		(1)		(6)									
		Benchmark - Salest-1		Twitter - CS		Benchmark - CS				(1:1)	(1:2)	(1:1)	(1:2)
2-Digit SIC	Number of Observations	False Positive	False Negative	False Positive	False Negative	Difference - FP	Difference - FN	Better Model - FP	Better Model - FN	Benchmark Total Cost /TCS Total Cost	Benchmark Total Cost /TCS Total Cost	Better Model - Cost Ratio	Better Model - Cost Ratio
20	144	44.72%	18.01%	44.00%	17.85%	0.73%	0.16%	TCS	TCS	1.01	1.01	TCS	TCS
21	12	47.86%	5.00%	41.14%	35.00%	6.72%	-30.00%	TCS	Benchmark	0.69	0.52	Benchmark*	Benchmark*
23	36	45.09%	2.50%	45.99%	2.50%	-0.90%	0.00%	Benchmark	-	0.98	0.98	Benchmark*	Benchmark*
28	72	43.97%	11.07%	43.63%	13.69%	0.34%	-2.62%	TCS	Benchmark	0.96	0.93	Benchmark*	Benchmark*
29	24	45.67%	16.67%	45.67%	16.67%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
30	12	50.00%	0.00%	48.10%	10.00%	1.90%	-10.00%	TCS	Benchmark	0.86	0.73	Benchmark*	Benchmark*
31	24	42.40%	6.67%	39.22%	6.67%	3.18%	0.00%	TCS	-	1.07	1.06	TCS*	TCS*
35	24	42.84%	15.00%	42.84%	15.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
36	48	43.58%	16.57%	44.22%	14.95%	-0.64%	1.62%	Benchmark	TCS	1.02	1.03	TCS*	TCS*
37	84	45.15%	15.44%	45.04%	12.44%	0.12%	3.00%	TCS	TCS	1.05	1.09	TCS	TCS
39	36	44.35%	7.50%	42.60%	11.50%	1.75%	-4.00%	TCS	Benchmark	0.96	0.90	Benchmark*	Benchmark*
42	12	42.68%	10.00%	32.87%	20.00%	9.82%	-10.00%	TCS	Benchmark	1.00	0.86	Benchmark*	Benchmark*
44	24	40.03%	20.00%	41.31%	15.00%	-1.29%	5.00%	Benchmark	TCS	1.07	1.12	TCS*	TCS*
45	96	45.84%	14.67%	43.91%	17.46%	1.94%	-2.80%	TCS	Benchmark	0.99	0.95	Benchmark*	Benchmark*
47	12	45.79%	15.00%	48.33%	15.00%	-2.55%	0.00%	Benchmark	-	0.96	0.97	Benchmark*	Benchmark*
48	24	41.17%	13.33%	39.54%	11.67%	1.63%	1.67%	TCS	TCS	1.06	1.08	TCS	TCS
53	12	34.08%	35.00%	42.97%	15.00%	-8.89%	20.00%	Benchmark	TCS	1.19	1.43	TCS*	TCS*
55	24	45.40%	8.33%	44.01%	8.33%	1.39%	0.00%	TCS	-	1.03	1.02	TCS*	TCS*
57	24	46.60%	6.67%	41.32%	16.67%	5.27%	-10.00%	TCS	Benchmark	0.92	0.80	Benchmark*	Benchmark*
58	180	45.09%	13.83%	44.41%	15.14%	0.68%	-1.30%	TCS	Benchmark	0.99	0.97	Benchmark*	Benchmark*
59	36	42.80%	16.50%	42.80%	15.50%	0.00%	1.00%	TCS	TCS	1.02	1.03	TCS	TCS
70	24	45.54%	13.33%	44.29%	16.67%	1.24%	-3.33%	TCS	Benchmark	0.97	0.93	Benchmark*	Benchmark*
73	60	37.50%	27.68%	39.29%	23.04%	-1.79%	4.64%	Benchmark	TCS	1.05	1.09	TCS*	TCS*
75	12	48.10%	10.00%	48.10%	10.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*

*Better model determined based on the ratio of costs of FP and FN errors.

15 indus-tries

8 indus-tries

10 indus-tries

10 indus-tries

RQ 2B: Error Detection Performance of Continuous Substantive Analytical Models with TCS and without TCS (Models 8 and 2)

TCS outperforms benchmark for:

Error Detection Ability - Alpha = 0.33													
		(2)		(8)									
2-Digit SIC	Number of Observations	Benchmark - Salest-1 & GDPt-1		Twitter - CS & GDPt-1		Benchmark - CS				(1:1)	(1:2)	(1:1)	(1:2)
		False Positive	False Negative	False Positive	False Negative	Difference - FP	Difference - FN	Better Model - FP	Better Model - FN	Benchmark Total Cost /TCS Total Cost	Benchmark Total Cost /TCS Total Cost	Better Model - Cost Ratio	Better Model - Cost Ratio
20	144	43.27%	17.98%	43.88%	15.18%	-0.60%	2.80%	Benchmark	TCS	1.04	1.07	TCS*	TCS*
21	12	39.53%	10.00%	39.21%	5.00%	0.32%	5.00%	TCS	TCS	1.12	1.21	TCS	TCS
23	36	46.16%	6.50%	44.25%	5.00%	1.91%	1.50%	TCS	TCS	1.07	1.09	TCS	TCS
28	72	43.68%	15.83%	41.90%	20.07%	1.79%	-4.24%	TCS	Benchmark	0.96	0.92	Benchmark*	Benchmark*
29	24	49.07%	6.67%	49.07%	6.67%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
30	12	36.73%	20.00%	40.50%	25.00%	-3.77%	-5.00%	Benchmark	Benchmark	0.87	0.85	Benchmark	Benchmark
31	24	40.85%	6.67%	40.85%	6.67%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
35	24	44.15%	13.33%	41.17%	13.33%	2.99%	0.00%	TCS	-	1.05	1.04	TCS*	TCS*
36	48	44.23%	16.00%	44.86%	14.67%	-0.63%	1.33%	Benchmark	TCS	1.01	1.03	TCS*	TCS*
37	84	42.88%	19.55%	44.40%	16.97%	-1.53%	2.58%	Benchmark	TCS	1.02	1.05	TCS*	TCS*
39	36	46.86%	2.50%	47.78%	5.00%	-0.92%	-2.50%	Benchmark	Benchmark	0.94	0.90	Benchmark	Benchmark
42	12	40.18%	20.00%	37.45%	30.00%	2.72%	-10.00%	TCS	Benchmark	0.89	0.82	Benchmark*	Benchmark*
44	24	44.29%	16.67%	44.44%	20.00%	-0.14%	-3.33%	Benchmark	Benchmark	0.95	0.92	Benchmark	Benchmark
45	96	45.00%	19.02%	44.30%	18.86%	0.70%	0.16%	TCS	TCS	1.01	1.01	TCS	TCS
47	12	45.52%	10.00%	45.52%	10.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
48	24	42.70%	13.33%	41.01%	10.00%	1.69%	3.33%	TCS	TCS	1.10	1.14	TCS	TCS
53	12	47.62%	0.00%	45.26%	5.00%	2.36%	-5.00%	TCS	Benchmark	0.95	0.86	Benchmark*	Benchmark*
55	24	48.11%	13.33%	46.85%	13.33%	1.25%	0.00%	TCS	-	1.02	1.02	TCS*	TCS*
57	24	43.87%	6.67%	42.40%	6.67%	1.47%	0.00%	TCS	-	1.03	1.03	TCS*	TCS*
58	180	45.44%	18.19%	44.24%	15.14%	1.20%	3.05%	TCS	TCS	1.07	1.10	TCS	TCS
59	36	42.40%	7.50%	45.36%	10.00%	-2.96%	-2.50%	Benchmark	Benchmark	0.90	0.88	Benchmark	Benchmark
70	24	44.44%	20.00%	43.14%	21.67%	1.30%	-1.67%	TCS	Benchmark	0.99	0.98	Benchmark*	Benchmark*
73	60	33.89%	29.76%	37.35%	24.82%	-3.46%	4.94%	Benchmark	TCS	1.02	1.07	TCS*	TCS*
75	12	46.05%	20.00%	50.00%	0.00%	-3.95%	20.00%	Benchmark	TCS	1.32	1.72	TCS*	TCS*

*Better model determined based on the ratio of costs of FP and FN errors.

12 industries

10 industries

13 industries

13 industries

RQ 2B: Error Detection Performance of Continuous Substantive Analytical Models with TCS and without TCS (Models 10 and 3)

TCS outperforms benchmark for:

Error Detection Ability - Alpha = 0.33													
		(3)		(10)									
2-Digit SIC	Number of Observations	Benchmark - Salest-1 & AR		Twitter - CS & AR		Benchmark - CS				(1:1)	(1:2)	(1:1)	(1:2)
		False Positive	False Negative	False Positive	False Negative	Difference - FP	Difference - FN	Better Model - FP	Better Model - FN	Benchmark Total Cost /TCS Total Cost	Benchmark Total Cost /TCS Total Cost	Better Model - Cost Ratio	Better Model - Cost Ratio
20	144	44.21%	17.00%	44.77%	13.40%	-0.56%	3.60%	Benchmark	TCS	1.05	1.09	TCS*	TCS*
21	12	47.86%	5.00%	46.31%	25.00%	1.55%	-20.00%	TCS	Benchmark	0.74	0.60	Benchmark*	Benchmark*
23	36	44.53%	12.50%	43.59%	12.50%	0.95%	0.00%	TCS	-	1.02	1.01	TCS*	TCS*
28	72	37.85%	25.86%	38.37%	24.79%	-0.52%	1.07%	Benchmark	TCS	1.01	1.02	TCS*	TCS*
29	24	42.55%	10.00%	41.01%	10.00%	1.54%	0.00%	TCS	-	1.03	1.03	TCS*	TCS*
30	12	42.97%	15.00%	46.05%	20.00%	-3.07%	-5.00%	Benchmark	Benchmark	0.88	0.85	Benchmark	Benchmark
31	24	39.71%	15.00%	42.70%	13.33%	-2.99%	1.67%	Benchmark	TCS	0.98	1.00	Benchmark*	TCS*
35	24	38.36%	21.67%	38.36%	21.67%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
36	48	43.58%	18.00%	44.44%	22.00%	-0.86%	-4.00%	Benchmark	Benchmark	0.93	0.90	Benchmark	Benchmark
37	84	43.59%	16.69%	42.79%	17.53%	0.80%	-0.83%	TCS	Benchmark	1.00	0.99	Benchmark*	Benchmark*
39	36	42.90%	19.00%	41.89%	19.00%	1.01%	0.00%	TCS	-	1.02	1.01	TCS*	TCS*
42	12	32.87%	20.00%	32.87%	20.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
44	24	42.69%	11.67%	42.55%	10.00%	0.14%	1.67%	TCS	TCS	1.03	1.06	TCS	TCS
45	96	45.00%	19.13%	43.07%	22.76%	1.93%	-3.63%	TCS	Benchmark	0.97	0.94	Benchmark*	Benchmark*
47	12	42.97%	15.00%	45.52%	10.00%	-2.55%	5.00%	Benchmark	TCS	1.04	1.11	TCS*	TCS*
48	24	39.71%	16.67%	37.83%	11.67%	1.88%	5.00%	TCS	TCS	1.14	1.19	TCS	TCS
53	12	47.86%	5.00%	40.18%	20.00%	7.68%	-15.00%	TCS	Benchmark	0.88	0.72	Benchmark*	Benchmark*
55	24	46.72%	10.00%	45.54%	13.33%	1.19%	-3.33%	TCS	Benchmark	0.96	0.92	Benchmark*	Benchmark*
57	24	46.60%	6.67%	42.40%	6.67%	4.19%	0.00%	TCS	-	1.09	1.08	TCS*	TCS*
58	180	46.24%	10.96%	44.41%	15.41%	1.83%	-4.45%	TCS	Benchmark	0.96	0.91	Benchmark*	Benchmark*
59	36	43.00%	20.50%	42.30%	27.00%	0.70%	-6.50%	TCS	Benchmark	0.92	0.87	Benchmark*	Benchmark*
70	24	47.98%	10.00%	45.54%	13.33%	2.45%	-3.33%	TCS	Benchmark	0.98	0.94	Benchmark*	Benchmark*
73	60	40.54%	21.85%	42.29%	20.24%	-1.75%	1.61%	Benchmark	TCS	1.00	1.02	Benchmark*	TCS*
75	12	40.82%	30.00%	45.79%	15.00%	-4.97%	15.00%	Benchmark	TCS	1.17	1.33	TCS*	TCS*

*Better model determined based on the ratio of costs of FP and FN errors.

14 industries

8 industries

10 industries

12 industries

RQ 2B: Error Detection Performance of Continuous Substantive Analytical Models with TCS and without TCS (Models 12 and 4)

TCS outperforms benchmark for:

Error Detection Ability - Alpha = 0.33													
		(4)		(12)									
2-Digit SIC	Number of Observations	Benchmark - Salest-1 & AR & GDPt-1		Twitter - CS & AR & GDPt-1		Benchmark - CS				(1:1)	(1:2)	(1:1)	(1:2)
		False Positive	False Negative	False Positive	False Negative	Difference - FP	Difference - FN	Better Model - FP	Better Model - FN	Benchmark Total Cost /TCS Total Cost	Benchmark Total Cost /TCS Total Cost	Better Model - Cost Ratio	Better Model - Cost Ratio
20	144	43.80%	18.80%	44.42%	16.58%	-0.62%	2.21%	Benchmark	TCS	1.03	1.05	TCS*	TCS*
21	12	42.39%	5.00%	39.21%	5.00%	3.18%	0.00%	TCS	-	1.07	1.06	TCS*	TCS*
23	36	45.27%	7.50%	42.80%	16.50%	2.47%	-9.00%	TCS	Benchmark	0.89	0.80	Benchmark*	Benchmark*
28	72	40.64%	26.19%	40.43%	22.62%	0.21%	3.57%	TCS	TCS	1.06	1.09	TCS	TCS
29	24	41.47%	18.33%	41.47%	18.33%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
30	12	36.73%	20.00%	40.50%	25.00%	-3.77%	-5.00%	Benchmark	Benchmark	0.87	0.85	Benchmark	Benchmark
31	24	42.40%	6.67%	41.00%	8.33%	1.40%	-1.67%	TCS	Benchmark	0.99	0.97	Benchmark*	Benchmark*
35	24	38.19%	20.00%	38.19%	20.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
36	48	42.33%	23.33%	40.13%	25.62%	2.20%	-2.29%	TCS	Benchmark	1.00	0.97	Benchmark*	Benchmark*
37	84	43.46%	13.89%	43.04%	13.42%	0.42%	0.47%	TCS	TCS	1.02	1.02	TCS	TCS
39	36	33.33%	32.50%	31.95%	32.50%	1.38%	0.00%	TCS	-	1.02	1.01	TCS*	TCS*
42	12	32.87%	20.00%	32.87%	20.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
44	24	45.67%	16.67%	45.67%	16.67%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
45	96	44.62%	18.28%	42.93%	21.01%	1.69%	-2.73%	TCS	Benchmark	0.98	0.96	Benchmark*	Benchmark*
47	12	45.52%	10.00%	45.52%	10.00%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
48	24	41.31%	15.00%	41.01%	10.00%	0.30%	5.00%	TCS	TCS	1.10	1.17	TCS	TCS
53	12	47.62%	0.00%	45.26%	5.00%	2.36%	-5.00%	TCS	Benchmark	0.95	0.86	Benchmark*	Benchmark*
55	24	42.99%	18.33%	42.99%	18.33%	0.00%	0.00%	-	-	1.00	1.00	Benchmark*	Benchmark*
57	24	46.34%	0.00%	42.40%	6.67%	3.94%	-6.67%	TCS	Benchmark	0.94	0.83	Benchmark*	Benchmark*
58	180	45.16%	15.92%	43.88%	16.22%	1.29%	-0.31%	TCS	Benchmark	1.02	1.01	TCS*	TCS*
59	36	41.06%	22.00%	39.11%	27.00%	1.95%	-5.00%	TCS	Benchmark	0.95	0.91	Benchmark*	Benchmark*
70	24	46.98%	16.67%	44.44%	20.00%	2.54%	-3.33%	TCS	Benchmark	0.99	0.95	Benchmark*	Benchmark*
73	60	38.13%	27.08%	38.75%	26.19%	-0.62%	0.89%	Benchmark	TCS	1.00	1.01	TCS*	TCS*
75	12	43.55%	25.00%	45.52%	10.00%	-1.97%	15.00%	Benchmark	TCS	1.23	1.43	TCS*	TCS*

*Better model determined based on the ratio of costs of FP and FN errors.

14 indus-tries

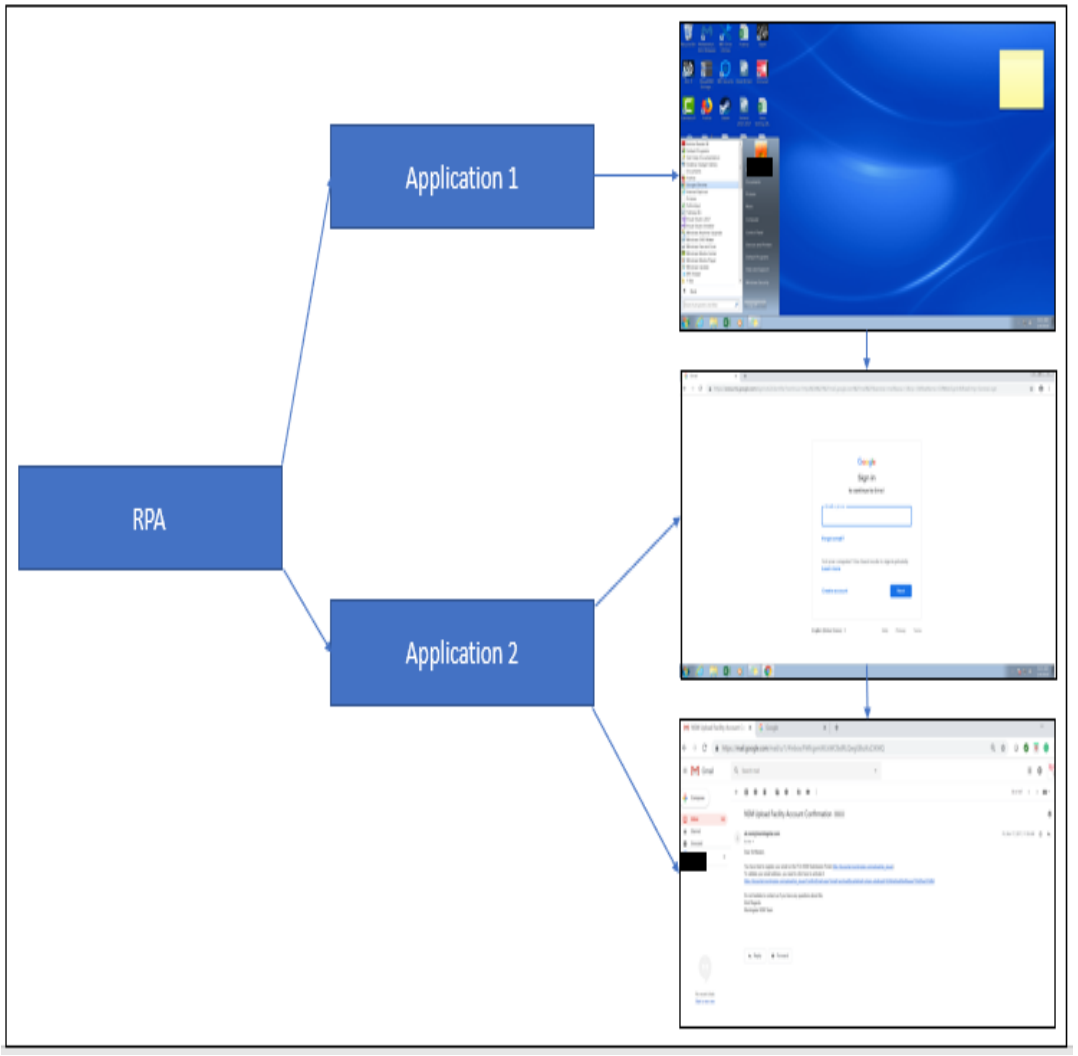
6 indus-tries

9 indus-tries

9 indus-tries

Introduction

- RPA is “a type of software that mimics the activity of a human being in carrying out a task within a process. It can do repetitive stuff more quickly, accurately, and tirelessly than humans, freeing them to do other tasks” (McKinsey 2016)



Background on RPA & Process Redesign

RPA

- RPA has been applied to various industries including telecommunications, financial services, retail, and manufacturing (Lacity et al. 2015; Seasongood 2016)

Process Redesign

- Process redesign refers to changing old rules in a process to new rules (Davenport and Short 1990; Hammer 1990)

- Most cases of process redesign focused on “evolutionary” implementations (Davenport and Stoddard 1994; Jarvenpaa and Stoddard 1998)

Hammer 1990

1) **organizing outcomes around tasks:** have one person perform all the tasks in the process
2) **have those who use the output of a process, perform the process:** have individuals who need the result of the process do it themselves
3) **subsume information processing work into the real work that produces the information:** move work from one person/department to another
4) **treat geographically dispersed resources as though they were centralized:** use databases, telecommunications networks and standardized processing systems to get the benefits of coordination while maintaining flexibility
5) **put the decision point where the work is performed, and build control into the process:** people who do the work should make decisions
6) **capture information once and at the source:** eliminate data redundancy

Davenport and Short 1990

1) **Developing the business vision and process objective:** automate process to reduce costs, reduce time in performing the task, improve output quality, and quality of work life
2) **Identifying process to be redesigned:** identify business process to automate
3) **Understanding and measuring existing processes:** understand and measure to target areas that need to be improved
4) **Identifying IT levers:** understand the role and capabilities of IT
5) **Designing and building a prototype of the new process:** apply automation vision

Application of APA Framework (3)

Audit Data Standardization

	A	B	C	D
1	Standard Name	Column Name Per Report	Data Type	Report
2	Employee_ID	SSN	NUMERICA	Annual Loan Balance
3	Name	Participant Name	TEXT	Annual Loan Balance
4	Loan_Number	Loan ID	NUMERICA	Annual Loan Balance
5	Loan_Amount	Loan Amount	NUMERICA	Annual Loan Balance
6	Interest_Rate	Int Rate	Percentage	Annual Loan Balance
7	Date_Opened	Date Opened	DATE	Annual Loan Balance
8	Year_Opened	Date Opened2	DATE	Annual Loan Balance
9	Employee_ID	SSN	NUMERICA	Check Register
10	Name	PAYEE	TEXT	Check Register
11	Loan_Amount_R2	NET AMT	NUMERICA	Check Register

1) Link to Standard Field

	A	B	C	D	E	F
1	SSN	Participant Name	Loan ID	Int Rate	Date Oper	Loan Amo
2	XXX-XX-1234	Farrah Stambaugh	LOAN 11	5	6132016	9199
3	XXX-XX-1235	Cecelia Kendra	LOAN 04	5	3302016	3739
4	XXX-XX-1236	Alba Moseley	LOAN 02	5	8182016	5160
5	XXX-XX-1237	Emil Stlouis	LOAN 03	5	1222016	8030
6	XXX-XX-1238	Taren Farrelly	LOAN 02	5	8082016	13202
7	XXX-XX-1239	Tiana Harstad	LOAN 03	5	8302016	8793
8	XXX-XX-1240	Bette Wildt	LOAN 02	5	12232016	10462
9	XXX-XX-1241	Gustavo Kocher	LOAN 03	5	5102016	10572
10	XXX-XX-1242	Latrina Pickel	LOAN 02	5	7202016	1412
11	XXX-XX-1243	Irena Wease	LOAN 03	5	6272016	14191
12	XXX-XX-1244	Aide Nuckles	LOAN 11	5	9062016	179
13	XXX-XX-1245	Ester Mullings	LOAN 04	5	4252016	1761
14	XXX-XX-1246	Russ Cushman	LOAN 02	5	2222016	14938
15	XXX-XX-1247	Allena Aldridge	LOAN 03	5	7192016	5426
16	XXX-XX-1248	Hermila Faw	LOAN 02	5	6272016	1579
17	XXX-XX-1249	Gerry Osby	LOAN 03	5	12292016	9025
18	XXX-XX-1250	Fernande Fuhr	LOAN 02	5	10102016	635
19	XXX-XX-1251	Maris Vicente	LOAN 03	5	12232016	13225
20	XXX-XX-1252	Natashia Maag	LOAN 02	5	2022016	14613
21	XXX-XX-1253	Odis Douglass	LOAN 03	5	12052016	7663
22	XXX-XX-1254	Letitia Gambrel	LOAN 11	5	6022016	7063

Link to Standard Field | Annual Loan Balance | Check Register | Lo

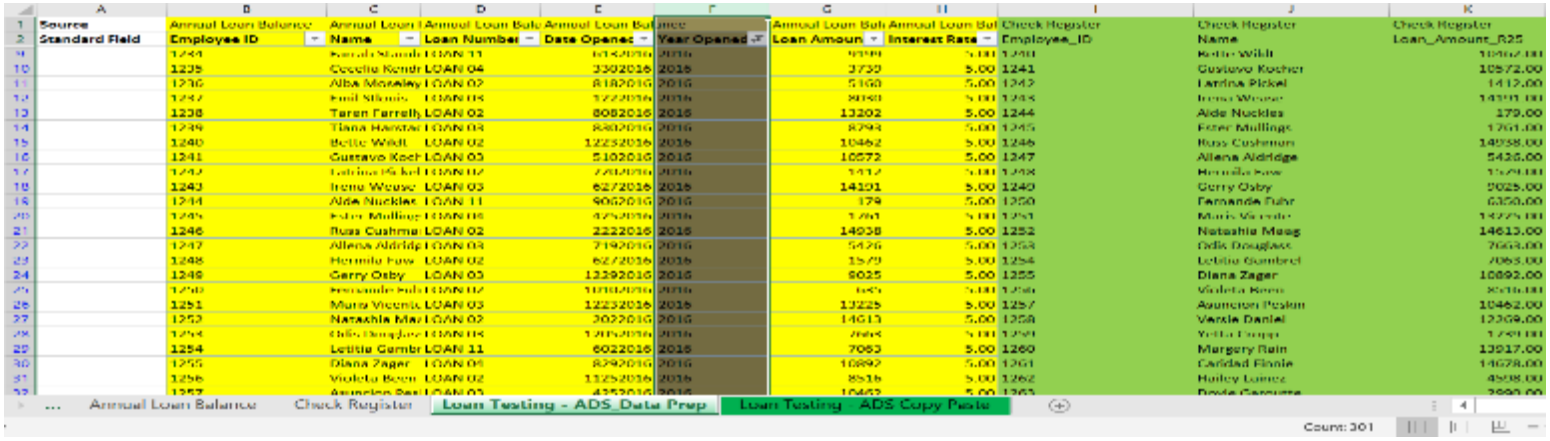
	A	B	C	D	E	F
1	SSN	PAYEE	AMOUNT			
2	XXX-XX-1234	Farrah Sta	9199			
3	XXX-XX-1235	Cecelia Ke	3739			
4	XXX-XX-1236	Alba Mose	5160			
5	XXX-XX-1237	Emil Stlou	9999			
6	XXX-XX-1238	Taren Farr	13202			
7	XXX-XX-1239	Tiana Har	8793			
8	XXX-XX-1240	Bette Wild	10462			
9	XXX-XX-1241	Gustavo K	10572			
10	XXX-XX-1242	Latrina Pic	1412			
11	XXX-XX-1243	Irena Wea	14191			
12	XXX-XX-1244	Aide Nuck	179			
13	XXX-XX-1245	Ester Mull	1761			
14	XXX-XX-1246	Russ Cush	14938			
15	XXX-XX-1247	Allena Ald	5426			
16	XXX-XX-1248	Hermila Fa	1579			
17	XXX-XX-1249	Gerry Osb	9025			
18	XXX-XX-1250	Fernande	6350			
19	XXX-XX-1251	Maris Vice	13225			
20	XXX-XX-1252	Natashia M	14613			
21	XXX-XX-1253	Odis Doug	7663			
22	XXX-XX-1254	Letitia Gar	7063			

Link to Standard Field | Annual Loan Balance | Check

2) Company Reports

Application of APA Framework (3) cont'd

Audit Data Standardization

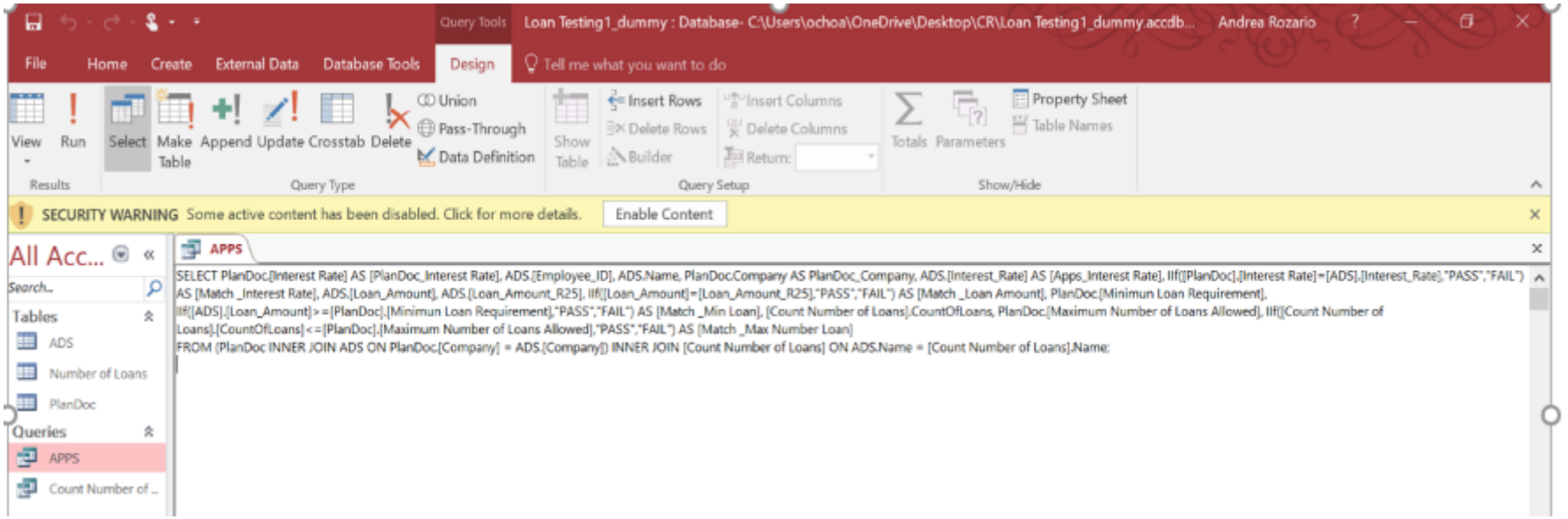


3) Loan Testing – ADS Data Prep

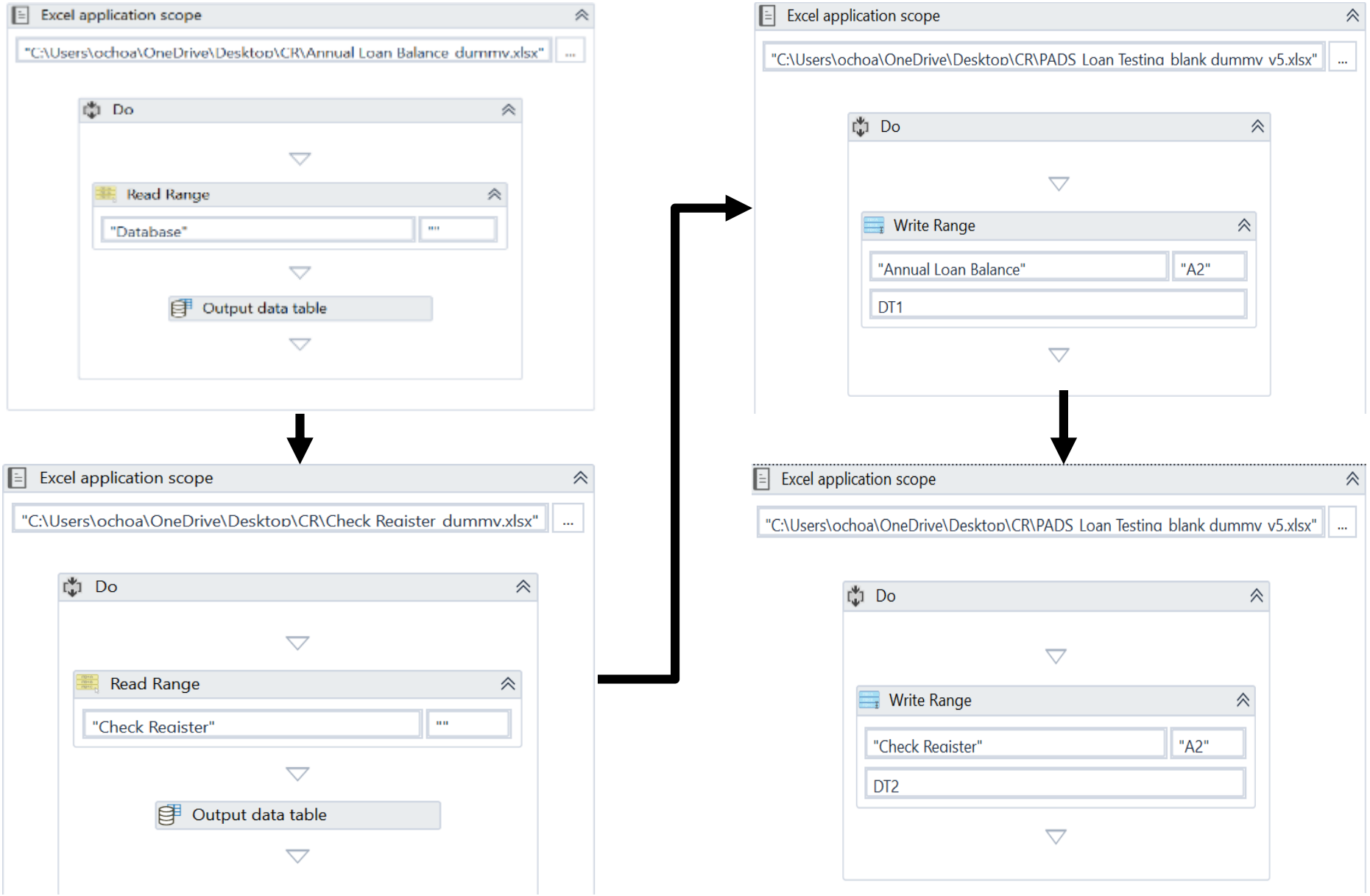
Company	Employee ID	Name	Loan Number	Date Opened	Year Opened	Loan Amount	Interest Rate	Loan Amount R25
1	1234	Farrah Stambaugh	LOAN 11	6132016	2016	9199	5	9199
1	1235	Cecelia Kendra	LOAN 04	3302016	2016	3739	5	3739
1	1236	Alba Moseley	LOAN 02	8182016	2016	5160	5	5160
1	1237	Emil Stlouis	LOAN 03	1222016	2016	8030	5	9999
1	1238	Taren Farrelly	LOAN 02	8082016	2016	13202	5	13202
1	1239	Tiana Harstad	LOAN 03	8302016	2016	8793	5	8793
1	1240	Bette Wildt	LOAN 02	12232016	2016	10462	5	10462
1	1241	Gustavo Kocher	LOAN 03	5102016	2016	10572	5	10572
1	1242	Latrina Pickel	LOAN 02	7202016	2016	1412	5	1412
1	1243	Irena Wease	LOAN 03	6272016	2016	14191	5	14191
1	1244	Aide Nuckles	LOAN 11	9062016	2016	179	5	179
1	1245	Ester Mullings	LOAN 04	4252016	2016	1761	5	1761
1	1246	Russ Cushman	LOAN 02	2222016	2016	14938	5	14938
1	1247	Allena Aldridge	LOAN 03	7192016	2016	5426	5	5426
1	1248	Hermila Faw	LOAN 02	6272016	2016	1579	5	1579
1	1249	Gerry Osby	LOAN 03	12292016	2016	9025	5	9025
1	1250	Fernande Fuhr	LOAN 02	10102016	2016	635	5	6350
1	1251	Maris Vicente	LOAN 03	12232016	2016	13225	5	13225
1	1252	Natashia Maag	LOAN 02	2022016	2016	14613	5	14613
1	1253	Odis Douglass	LOAN 03	12052016	2016	7663	5	7663
1	1254	Letitia Gambrel	LOAN 11	6022016	2016	7063	5	7063

4) Loan Testing – ADS Copy Paste

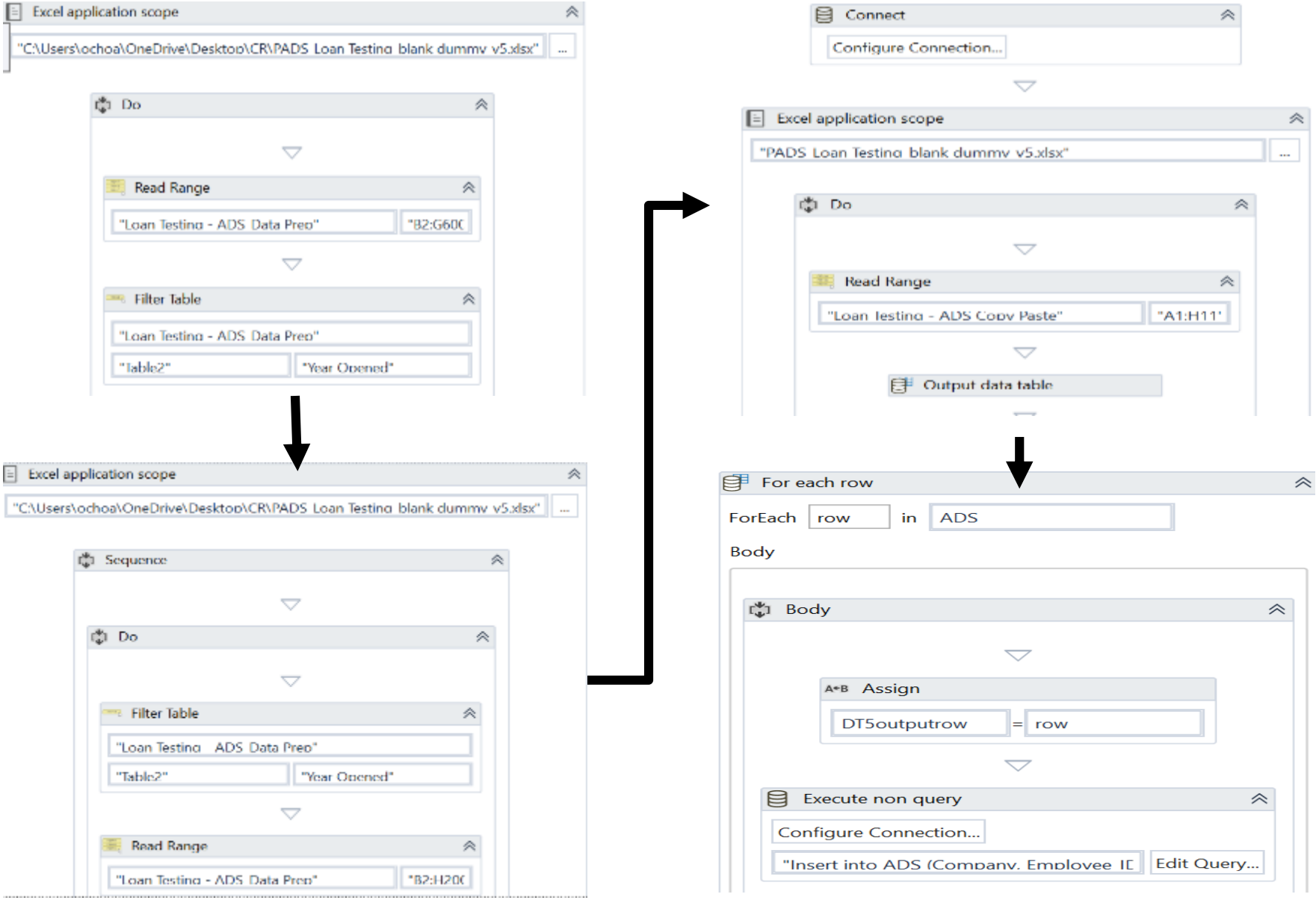
Audit Apps Prototyping – Microsoft Access App



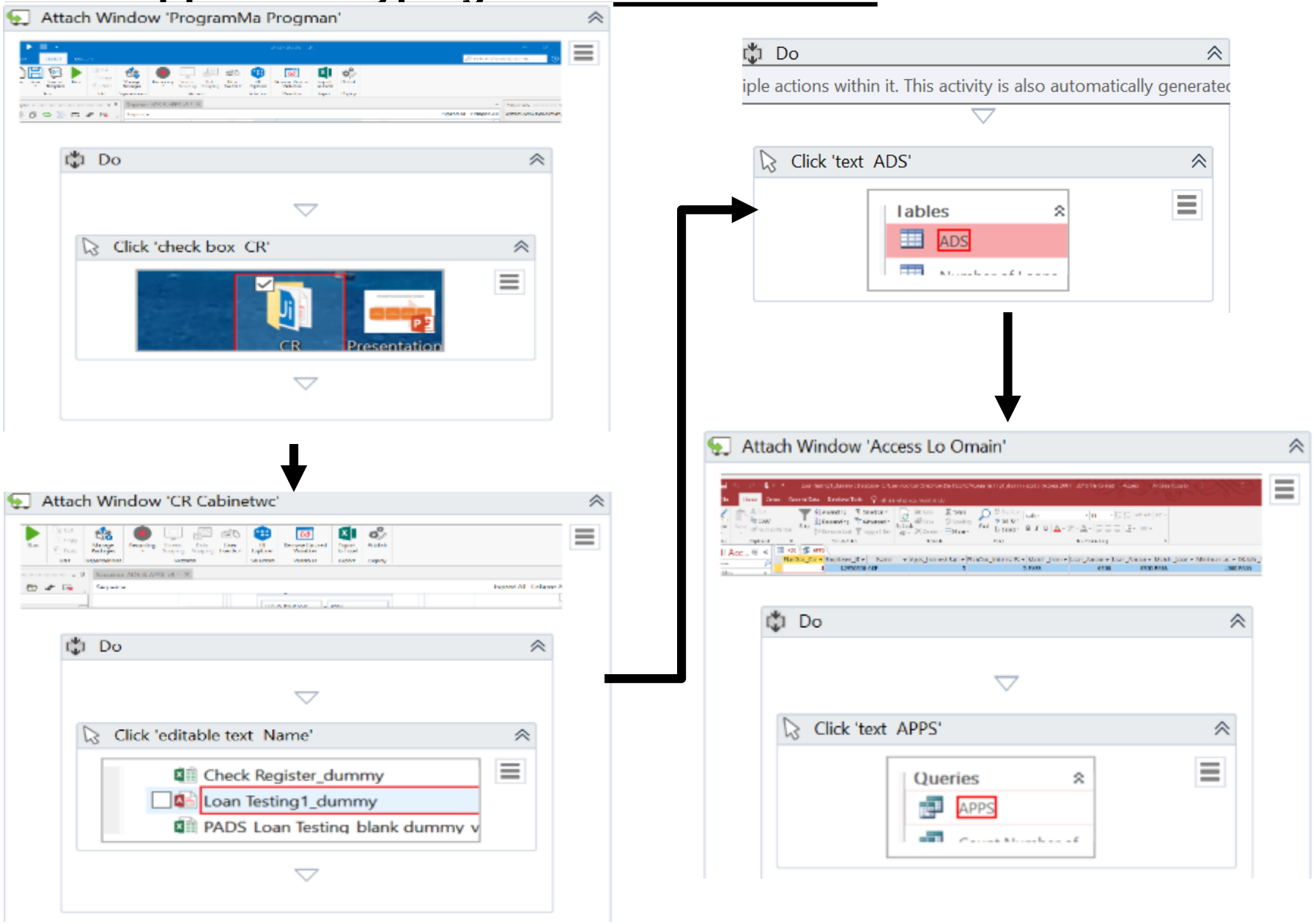
Audit Apps Prototyping – UiPath Workflow



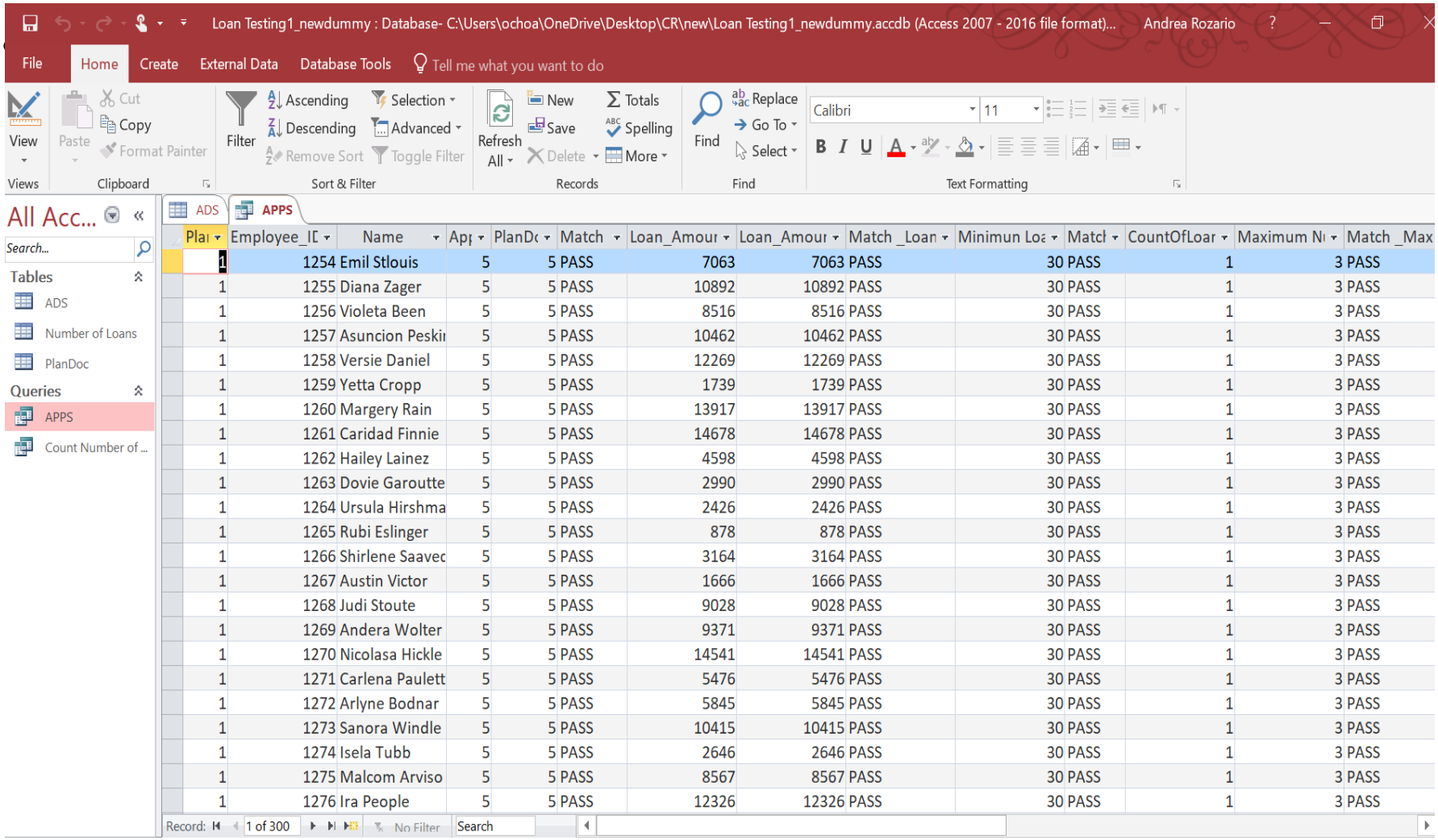
Audit Apps Prototyping – UiPath Workflow



Audit Apps Prototyping – UiPath Workflow



Results



Plan	Employee_ID	Name	App	PlanDoc	Match	Loan_Amount	Loan_Amount	Match _Loan	Minimun Loa	Match	CountOfLoan	Maximum Nu	Match _Max
1	1254	Emil Stlouis	5	5	PASS	7063	7063	PASS	30	PASS	1	3	PASS
1	1255	Diana Zager	5	5	PASS	10892	10892	PASS	30	PASS	1	3	PASS
1	1256	Violeta Been	5	5	PASS	8516	8516	PASS	30	PASS	1	3	PASS
1	1257	Asuncion Peskin	5	5	PASS	10462	10462	PASS	30	PASS	1	3	PASS
1	1258	Versie Daniel	5	5	PASS	12269	12269	PASS	30	PASS	1	3	PASS
1	1259	Yetta Cropp	5	5	PASS	1739	1739	PASS	30	PASS	1	3	PASS
1	1260	Margery Rain	5	5	PASS	13917	13917	PASS	30	PASS	1	3	PASS
1	1261	Caridad Finnie	5	5	PASS	14678	14678	PASS	30	PASS	1	3	PASS
1	1262	Hailey Lainez	5	5	PASS	4598	4598	PASS	30	PASS	1	3	PASS
1	1263	Dovie Garoutte	5	5	PASS	2990	2990	PASS	30	PASS	1	3	PASS
1	1264	Ursula Hirshma	5	5	PASS	2426	2426	PASS	30	PASS	1	3	PASS
1	1265	Rubi Eslinger	5	5	PASS	878	878	PASS	30	PASS	1	3	PASS
1	1266	Shirlene Saavec	5	5	PASS	3164	3164	PASS	30	PASS	1	3	PASS
1	1267	Austin Victor	5	5	PASS	1666	1666	PASS	30	PASS	1	3	PASS
1	1268	Judi Stoute	5	5	PASS	9028	9028	PASS	30	PASS	1	3	PASS
1	1269	Andera Wolter	5	5	PASS	9371	9371	PASS	30	PASS	1	3	PASS
1	1270	Nicolasa Hickle	5	5	PASS	14541	14541	PASS	30	PASS	1	3	PASS
1	1271	Carlena Paulett	5	5	PASS	5476	5476	PASS	30	PASS	1	3	PASS
1	1272	Arlyne Bodnar	5	5	PASS	5845	5845	PASS	30	PASS	1	3	PASS
1	1273	Sanora Windle	5	5	PASS	10415	10415	PASS	30	PASS	1	3	PASS
1	1274	Isela Tubb	5	5	PASS	2646	2646	PASS	30	PASS	1	3	PASS
1	1275	Malcom Arviso	5	5	PASS	8567	8567	PASS	30	PASS	1	3	PASS
1	1276	Ira People	5	5	PASS	12326	12326	PASS	30	PASS	1	3	PASS

Introduction

- Blockchain is a decentralized, distributed, and secure ledger originally developed for Bitcoin transactions
- Types of blockchain databases: public (permissionless), private (permissioned)
- Smart contracts autonomously execute the tasks for terms of contracts but can be useful in an auditing context
- Blockchain and smart contracts can change the way audits are performed and disseminated

Source: https://medium.com/@matteozago/50-examples-of-how-blockchains-are-taking-over-the-world-427ebf488a4b

Exploring an External Audit Blockchain Ecosystem for Revenue