IMPACT OF ARTIFICIAL INTELLIGENCE REGULATION ON ARTIFICIAL INTELLIGENCE ADOPTION AND INNOVATION

Benjamin Larsen, Copenhagen Business School
Yong Suk Lee, Stanford University
Michael Webb, Stanford University

May 2019

ABSTRACT

We examine the impact of AI regulation on manager intention to adopt AI technologies and their AI related business strategies. We conduct a randomized online survey experiment on managers in the U.S. The treatment group is informed of the core contents of the Algorithmic Accountability Act, which aims to regulate firms through mandatory self-assessments of their AI systems. We examine how exposure to AI regulation affects AI adoption, AI budgeting across different expense categories, managerial perceptions related to AI technologies, and the potential impact of AI on employees.

We find that AI regulation reduces the rate of adoption for AI technologies. At the same time regulation induces managers to allocate more funds to developing AI strategy, while reducing funds related to retraining and reskilling existing workers. Exposure to AI regulation generally has limited impact on how managers plan to adjust their workforce other than the number of their sales and service employees, which increases due to AI regulation. We find no significant impact of regulation on managerial perceptions related to the diffusion of AI technologies.

The current draft is based on a pilot experiment with one regulation treatment. However, we will be conducting a large-scale experiment in June 2019 with multiple regulation treatments. For the main survey we are collaborating with Justice Mariano-Florentino Cuéllar, who serves on the California Supreme Court. We will have the results from the main survey experiment in July 2019 and an updated draft shortly after.

Our current results reveal the trade-offs between regulation, adoption, and the training of workers when businesses are faced with additional costs of compliance related to AI and algorithmic accountability. Our main experiment will examine the nature of this trade-off and more directly assess the impact of AI regulation on AI innovation, research and development, and business development.

Keywords: artificial intelligence, regulation, adoption, innovation, survey experiment
JEL Codes: K24, L21, L51, O33, O38

1. Introduction

Artificial intelligence (AI) technologies have become increasingly widespread over the last decade. In particular, the fields of image recognition, speech recognition, and machine translation have advanced rapidly on the back of important breakthroughs in deep neural networks (Varian, 2018). In recent years, the issues of algorithmic bias, data privacy, and transparency have also gained increasing attention, raising renewed calls for policy efforts to address the consequences of technological change (Frank et al., 2019). As AI continues to diffuse, it will have important consequences for jobs, inequality, and competition. This leaves an important role for regulation in addressing the consequences of AI related diffusion and displacement.

The Algorithmic Accountability Act was proposed in The House of Representatives on April 10th 2019, with the aim of regulating large firms through mandatory self-assessments of their AI systems. This includes disclosure of firm usage of AI systems, their development process, system design and training, as well as the data gathered and in use. The Act additionally makes subject to disclosure businesses' AI systems' impact on accuracy, fairness, bias, discrimination, privacy, and security. The Act proposes to regulate firms either with gross annual receipts of $50 million or more over the last three consecutive years, or which possess or control personal information on more than 1 million consumers (Congress, 2019).

In this paper we examine the impact of AI regulation on how likely managers are to adopt AI technologies and alter their AI related business strategies. We conduct a randomized online survey experiment where the treatment group is informed of the core contents of the Algorithmic Accountability Act. Specifically, we study how managers' decision-making is affected by regulation, and how managers revise business strategies when faced with new regulation. We

look at how adjacent changes in managerial preferences resulting from new regulation affects budget allocation and strategic decision-making in terms of resource allocation.

We have implemented a pilot-scale online survey experiment based on 300 respondents from the U.S.[1] Subjects were divided randomly into treatment and control groups. The control group was given information related to managerial decisions regarding AI adoption, while the treatment group were given information related to the Algorithmic Accountability Act.

Our results indicate that exposure to regulation decreases managers' intent to adopt AI technologies in the firm's business processes. We find that AI regulation, such as the Algorithmic Accountability Act, reduces the probability of adopting AI in at least one business process by 7.1 percentage points, and in at least three business processes by 14.7 percentage points.

We also find that AI regulation increases expenditure on developing an AI strategy compatible with the company's overall business strategy. Our results indicate that exposure to AI regulation increases allocation to business strategy purposes by 4.28 percentage points. Further, we find that the increase in budget for developing AI business strategy is offset by a decrease in the budget for training or reskilling current employees on how to code and use AI technology. Exposure to AI regulation decreases AI training budgets by 3.86 percentage points. Both results are significant at the 1 percent level.

These results highlight the potential trade-offs between regulation and the diffusion and innovation of AI technologies. While our pilot reveals an inherent trade-off between AI regulation and adoption, as well as the training of workers, a large-scale survey holds the

[1] For the main survey we plan to recruit 3,000 to 5,000 respondents. After revising the survey questionnaires based on the pilot experiment, we will conduct the main survey in June of 2019.

potential to reveal a more nuanced set of findings on the nature of this trade-off, which has important implications for regulators and policymakers.

To the best of our knowledge, our paper is the first to examine the potential impact of AI regulation on AI adoption and innovation. Our findings are closely related to the literature that examines the effects of technology related regulations, especially privacy regulation. In this line of research, Goldfarb and Tucker (2012) have found that in data-driven industries, privacy regulation impacts the rate and direction of innovation. Too little privacy protection means that consumers may be reluctant to participate in market transactions where their data are vulnerable. Too much privacy regulation means that firms cannot use data to innovate. The evidence generally indicates that most attempts at government-mandated privacy regulation lead to slower technology adoption and less innovation (Goldfarb and Tucker, 2011; Miller and Tucker, 2011; Kim and Wagman, 2015).

Another related aspect is the liability risk of AI, such as algorithmic bias. Hoffman, Kahn, and Li (2018) find evidence suggesting that while AI predictions are less biased than human predictions, they may still perpetuate biases present in the data used to train them. Furthermore, it is easier to audit AI-based decisions than human decisions, which opens up the possibility of an increase in liability claims. Firms face liability risk even in situations when the bias is unintended (Agrawal, Gans, & Goldfarb, 2018b). Such risk could serve as a deterrent to the adoption of AI technologies.

Related to the economics and management literature, Brynjolfsson, Rock, and Syverson (2017) define AI as a general purpose technology, implying that technological dynamism can be linked to the widespread use of AI across a variety of sectors and industries (Bresnahan & Trajtenberg, 1995). However, machine learning technologies have not yet been widely diffused,

which means that the full effects of AI technologies will not be realized until waves of complementary innovations are developed and implemented (Brynjolfsson, Rock, and Syverson 2017). In particular, business process redesign, co-invention of new products and business models, and investments in human capital are likely all needed before the economy can experience significant AI-driven productivity gains (Brynjolfsson, Rock, & Syverson, 2018). These findings suggest that policy should be dealing not only with the consequences of AI, but also with how to support its ongoing diffusion.

Finally, there is a rapidly growing literature on the potential labor market consequences of AI (e.g., Aghion, Jones, and Jones (2017)). This literature finds that automation may lead to declines in employment and wages, at least in the short run. Our finding that AI regulation may result in a decrease of AI training within firms suggests that AI regulations may have direct impacts on labor markets, as well as on AI diffusion and the rate of innovation.

By assessing the impact of the proposed Algorithmic Accountability Act of 2019, we take a first step at examining the impacts of AI regulation on the subsequent diffusion of AI technologies and business development. The outline of the paper is as follows. In the next two sections we describe the empirical strategy, data, and sample. In section 4 we report our main results. In section 5 we offer some concluding comments.

2. The Online Survey Experiment

We conduct a randomized online survey experiment to study the effect of one regulation treatment, the introduction of the Algorithmic Accountability Act, and its perceived costs in terms of compliance related to mandatory assessment of firm usage of AI systems. Though we

examined only one treatment in the current pilot experiment, for the main survey experiment we will add several treatment variants that present different specifics related to AI regulation.

We presented both the treatment and the control groups with an introductory paragraph that contains details about the current and forecasted adoption of AI technologies:

> "Recent research has found that early adopters of AI have started to reap the benefits of their investments. First-movers have already deployed and marketed solutions across healthcare, autonomous driving, retail and so on. Forty-seven percent of companies say they have embedded at least one AI capability in their business processes. Revenues from the global AI market is expected to grow from $7.3billion in 2018, to reach $90billion by 2025."

For our control group, we then seek to balance the preceding paragraph to make it represent some of the same concerns that our treatment group is subjected to, although without any specific mentioning of regulation or any form of regulatory compliance:

> "While the potential for AI is enormous, most organizations still have a longway to go in developing the core practices that enable them to realize the potential value of AI at scale. Business executives and managers will need to think about how to incorporate AI into their business strategy, as well as the accountability of AI algorithms, biases in data, and concerns over privacy."

For the treatment group, we rephrase the second paragraph to contain the exact details of the Algorithmic Accountability Act:

> "Up until now, little oversight and regulation has been attached to the area of AI training and product deployment. New regulation put forward in the Algorithmic Accountability Act of 2019 is expected to change that. The Algorithmic Accountability Act of 2019, aims to regulate firms through mandatory assessments of their AI systems. Assessment includes disclosure of firm usage of AI systems including their development process, system design, training, and the data gathered and in use. Furthermore, the Algorithmic Accountability Act requires firm to assess and disclose the impact of their AI systems on accuracy, fairness, bias, discrimination, privacy and security. The regulation would affect firms that either are utilizing or selling AI-related products."

Following the treatment/control scenario, participants are then asked four sets of questions related to managers' inclination towards adoption of AI technologies, manager values, budget allocation, and labor. The adoption of AI technologies (i.e. machine learning, computer vision, and natural language processing) is measured as the number of business processes, going from one to ten processes, with a higher number of processes implementing AI signaling a higher degree of AI implementation and usage.

Manager values are assessed by asking the degree of importance that managers attach to: 1) Reducing labor costs with AI technologies; 2) Improving products and services using AI technologies; 3) Maintaining data privacy and transparency when using AI technologies; 4) Minimizing potential biases (e.g., racial, gender bias) in predictions made by AI technologies; 5) Potential legal and regulatory implications in the deployment of AI based products; 6) Whether AI can help make societies more equal, and; 7) Augmenting and training existing workers with AI technologies. We measure managerial values ranging on a standard Likert scale ranging from not important to very important.

We then ask managers how they would allocate budgets across six expense categories. By enforcing the allocation to add to 100 percent, we are able to examine the trade-offs managers choose due to AI regulation. We measure budget allocation by having managers fill out seven different categories with costs related to: 1) Hiring technical workers; 2) AI training for current employees; 3) Purchasing AI packages from external vendors; 4) Assessment of ethical issues related to AI use and development; 5) Computers and data centers, including purchasing or gathering data; 6) Developing AI strategy that is compatible with the company's overall business strategy.

Finally, we look at labor by asking managers and executives how they would adjust the total number of employees at their workplace across: 1) Managers; 2) Technical workers; 3) Office workers; 4) Service and sales workers, and; 5) Production workers. We specify that we are only interested in changes that would occur because of AI adoption at the workplace

3. Data and Sample

We recruited 300 managers in the US using Survey Monkey Audience for the pilot experiment. We only recruit managers because managers are better aware of the types of technologies being used at their businesses and more likely to be involved in decisions around adoption. The managers we recruited include both middle management and senior management. We did not put any restriction on industry but required the business to have at least 10 employees.

Of the 300 respondents, we dropped responses from those who indicated that they did not devote full attention to the questions. We also dropped responses from those who finished the survey in an unreasonably short time, i.e., those below the third percentile of response times. This left us with 255 responses. The median response time was 7.1 minutes.

Though survey respondent collected through online survey companies, such as Survey Monkey, are not representative samples of the population, they do represent a sample that is not much different from the general population. The growing literature that uses these types of surveys in economics documents this well (Kiziemko et al. 2015, Di Tella and Rodrik 2019). Appendix Tables 1-4 examine the state distribution of our sample respondents, their industry distribution, education, and role within their organization respectively. Since we only present the results from the pilot, we will defer a more detailed analyses on representativeness of the sample after we conduct our main survey.

Table 1 presents the results of a randomization test. We compare the mean values of key observable characteristics of the respondents. The first column presents the mean and standard errors for the total sample, the second column presents the control group, and the third column the treatment group. In the last column we present results from the t-tests that examine the difference of the means between the treatment and control group. We present the p-values. None of the mean values between the treatment group and control group are significantly different from each other.

4. Results

4.1. Impact of AI regulation on the adoption of AI technologies

Table 2 examines how AI regulation affects manager intention to adopt AI technologies. Specifically, we ask in how many business processes they would adopt AI technologies. In Panel A, the dependent variable is whether they intend to adopt AI in at least one business process, in Panel B, whether they intend to adopt AI in at least three business processes, and in Panel C, the number of business processes they intend to adopt AI. The count is top coded at 10. The estimates presented above are from OLS regressions. The results are qualitatively similar when we use logit regressions for Panel A and Panel B, and a tobit regression for Panel C. Robust standard errors are presented in parentheses.

Column 1 presents the simple bivariate relationship. Column 2 adds firm level controls: state, industry, firm size, and firm revenue fixed effects. Column 3 additionally includes individual controls: gender, race, education, age, and organizational role fixed effects. Column 4 then adds management practice controls. Management controls include management practice variables related to data use, promotion, and firing. Finally, in column 5 we include control for

the current level of AI adoption. Current AI adoption includes dummy variables indicating whether the business currently uses natural language processing, computer vision, or machine learning in any business processes.

Focusing on the full specification in column 5, the results consistently indicate that exposure to AI regulation decreases manager intent to adopt AI technologies in the firm's business processes. Exposure to AI regulation reduces the probability of adopting AI in at least one business process by 7.1 percentage points, the probability of adopting AI in at least three business processes by 14.7 percentage points, and the number of business process adopting AI by 0.64. Panel B results are significant at the 5% level. Panel A results are not statistically significant, but this may likely be due to the fact that a large number of businesses are already adopting either natural language processing, computer vision, or machine learning as can be seen in the summary statistics in Table 1. About 80% of respondents indicated that their business is using natural language processing at their business. About 70% indicated use of computer vision and 73% indicated use of machine learning.

4.2 Impact of AI regulation on AI budget allocation.

We then examine how managers intend to allocate expenses across the different expense categories. The results are displayed in Table 3. Since managers have different experiences in managing budgets, we ask what the biggest budget is that they have been responsible for in their career across six categories, which we include as fixed effects. Column 5 presents the results that control for the budget fixed effects and all the other fixed effects used in Table 2.

We first ask how many dollars they would budget for AI adoption at their company in the following year. We ask them to consider all potential costs including the costs related to hiring

technical workers, purchasing AI packages, computers and data centers, purchasing or gathering data, developing AI strategies for the business, consulting fees, and assessing the impact of AI product and services.

We then ask how they would allocate that budget across six expense categories in terms of percentage of the total AI budget. By enforcing the allocation to add to 100 percent, we are able to examine the trade-offs managers choose due to AI regulation. The six categories that the managers were to allocate expenses across were – hiring technical workforce to develop and maintain AI for your company (e.g., programmers, technicians, etc.); AI training for current employees (e.g., coding, how to use AI technology, etc.); purchase of AI packages from external vendors (e.g., AI software, analysis fees, etc.); assessment of ethical issues related to AI use and development (e.g., costs associated with assessing racial and gender bias, data privacy and misuse etc.); computing resources and data related costs for AI development (e.g., computers, cloud computing, data collection and purchase costs, etc.); developing AI strategy that is compatible with your company's overall business strategy (e.g., consulting and marketing costs, internal strategy development, etc.).

We find that AI regulation significantly increases expenditure on developing AI strategy compatible with the company's business strategy (Panel A). Focusing on the full specification in column 5, the results indicate that exposure to AI regulation increases allocation to business strategy purposes by 4.28 percentage points, and the effect is significant at the 1 percent level. We included a separate expense category for the assessment of ethical issues related to AI use and development (Panel C), but we realize that business strategy could incorporate this aspect. Nonetheless, the coefficient estimate is positive but not significant.

The increase in budget for developing AI business strategy is primarily offset by the decrease in the budget for training current employees how to code and use AI technology. Exposure to AI regulation decreases AI training budget by 3.86 percentage points. This effect is also significant at the 1 percent level. There is some evidence indicating that regulation may decrease computing hardware and data purchase (Panel B) and the purchase of AI packages from external vendors (Panel D), but the results are not statistically significant, at least in the pilot.

The main takeaway from the pilot survey and Table 3 is that regulation forces managers to expend more on business strategizing, but at the cost of developing internal human capital. This suggests that regulation may hinder AI innovation. We did not ask about R&D related to AI development in the pilot, but we plan to revise accordingly for the main survey.

4.3 Impact of AI regulation on manager perception on aspects of AI adoption in businesses

Table 4 examines whether exposure to AI regulation affected manager perceptions of various aspects when adopting AI into their businesses. In particular, we ask how importantly they would consider the following: Reducing labor costs with AI technologies; Improving products and services using AI technologies; Maintaining data privacy and transparency when using AI technologies; Minimizing potential biases (e.g., racial, gender bias) in predictions made by AI technologies; Potential legal and regulatory implications in the deployment of AI based products; Whether AI can help make societies more equal; Augmenting and training existing workers with AI technologies. At least from the pilot, we find that AI regulation has no effect on individual's manager perception on these issues. Regulation may affect how managers strategize for their business AI development, but does not fundamentally affect individual values.

4.4 The potential impact of AI regulation on labor

Finally, in Table 5, we examine how AI regulation might affect jobs. Specifically, we ask how managers would adjust the total number of managers, technical workers, office workers, service and sales workers, and production workers because of AI adoption. We realize that managers have different human resource experience and that this question might be more suitable for human resource (HR) managers. In the main survey we plan to examine this differentially for those with HR experience. For now we present the results from all 255 managers in the pilot. We find no significant effect other than for sales and service workers. Exposure to AI regulation increases the number of sales and service workers. In the main survey, we plan to separate out the sales and service workers to better understand what might be driving this result.

5. Conclusion

We examine the impact of AI regulation on manager intention to adopt AI technologies and their AI related business strategies. We conduct a randomized online survey experiment where the treatment group is informed of the core contents of the Algorithmic Accountability Act, which aims to regulate firms through mandatory self-assessments of their AI systems, including disclosure of firm usage of AI systems, the development process, the data gathered and in use, and the potential impact of the firm's AI systems on accuracy, fairness, bias, discrimination, privacy, and security. We then examine how exposure to AI regulation affects AI adoption, AI budgeting across different expense categories, managerial values or perceptions related to AI technologies, and the potential impact of AI on employees.

We find that exposure to AI regulation reduces the probability of adopting AI in at least one business process by 7.1 percentage points, and in at least three business processes by 14.7

percentage points. This implies that the intended Algorithmic Accountability Act will have a negative impact on the rate of adoption and subsequent diffusion of AI processes. The intended effect of regulation, and of the slowdown in businesses' rates of AI adoption, would be to increase algorithmic accountability and transparency, and decreasing biased algorithms as firms would be held more accountable for their use and perpetuation of AI technologies.

The unintentional consequences are that AI regulation induces managers to allocate more funds to developing AI strategy, while offsetting funds related to retraining and reskilling existing workers. This in turn is likely to have adverse effects on the labor force, as the budget allocation associated with retraining decreases. However, there is no significant impact of regulation on managerial values or perceptions related to the diffusion of AI technologies. Exposure to AI regulation generally has limited impact on how managers plan to adjust their workforce other than the number of their sales and service employees, which increases due to AI regulation.

Our results reveal the trade-offs between regulation and adoption, and the training of workers, when businesses are faced with additional costs of compliance related to AI and algorithmic accountability. Our main experiment will examine the nature of this trade-off and more directly assess the impact of AI regulation on AI innovation, research and development, and business development.

Key policy challenges will be for institutions to keep up with the abilities and needs of a world with increased exposure to, and use of, artificial intelligence technologies. While it is generally perceived that important trade-offs exists between regulation and innovation, it is important to strengthen the discussion around 1) what exactly these trade-offs entail in a practical manner, and 2) how to formulate policies accordingly, taking into consideration issues around

privacy, bias, competition, retraining, education, and so on. We hope that the present paper marks a useful first step in this direction.

References

Acemoglu, B. D., & Restrepo, P. (2018). The Race between Man and Machine : Implications of Technology for Growth , Factor Shares , and Employment †. *American Economic Review*, *108*(6), 1488–1542.

Aghion, P., Jones, B., & Jones, C. (2017). Artificial Intelligence and Economic Growth. https://doi.org/10.3386/w23928

Agrawal, A., Gans, J., & Goldfarb, A. (2018a). Economic Policy for Artificial Intelligence. *NBER Working Paper Series*, *19*, 139–159. https://doi.org/10.1086/699935

Agrawal, A., Gans, J., & Goldfarb, A. (2018b). *Prediction Machines: The Simple Economics of Artificial Intelligence*. Harvard Business Review Press.

Bessen, J. (2018). AI AND JOBS: THE ROLE OF DEMAND. *NBER Working Paper Series*. https://doi.org/10.1590/s1809-98232013000400007

Bresnahan, T. F., & Trajtenberg, M. (1995). General purpose technologies: "Engines of growth?" *Journal of Econometrics*.

Brynjolfsson, E., Rock, D., & Syverson, C. (2017). Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics, *2018*, 1–5. https://doi.org/10.3386/w24001

Brynjolfsson, E., Rock, D., & Syverson, C. (2018). The Productivity J-Curve: How Intangibles Complement General Purpose Technologies. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3346739

Chui, M., Francisco, S., Manyika, J., & Francisco, S. (2018). Notes from the AI frontier. Insights from hundreds of use cases, 36. Retrieved from https://www.mckinsey.com/mgi/

Congress. (2019). Algorithmic Accountability Act 2019, 1–15.

Frank, M. R., Autor, D., Bessen, J. E., Brynjolfsson, E., Cebrian, M., Deming, D. J., … Rahwan, I. (2019). Toward understanding the impact of artificial intelligence on labor. *Proceedings of the National Academy of Sciences*, *116*(14), 6531–6539. https://doi.org/10.1073/pnas.1900949116

Goldfarb, A., & Tucker, C. (2012). Chapter Title : Privacy and Innovation. In *Innovation Policy and the Economy* (Vol. 12, pp. 65–89).

Goldfarb, A., & Tucker, C. E. (2011). Privacy Regulation and Online Advertising. *Management Science*, *57*(1), 57–71. https://doi.org/10.1287/mnsc.1100.1246

Goolsbee, A. (2018). PUBLIC POLICY IN AN AI ECONOMY. *NBER Working Paper Series*.

Kim, J., & Wagman, L. (2015). Screening incentives and privacy protection in financial markets : a theoretical and empirical analysis. *Journal of Economics*, *46*(1), 1–22.

Miller, A. R., & Tucker, C. E. (2011). Can Health Care Information Technology Save Babies ? *Journal of Political Economy*, *119*(2), 289–324.

Varian, H. (2018). ARTIFICIAL INTELLIGENCE, ECONOMICS, AND INDUSTRIAL ORGANIZATION. *NBER Working Paper Series*, □. https://doi.org/10.1590/s1809-98232013000400007

Table 1. Randomization

	Total	Control group	Treatment group	t test of difference of means p-value
Bachelor's degree or above	0.639 (0.030)	0.642 (0.041)	0.636 (0.044)	0.91
White	0.631 (0.030)	0.657 (0.041)	0.602 (0.045)	0.36
Black	0.149 (0.022)	0.146 (0.030)	0.153 (0.033)	0.88
Asian	0.114 (0.020)	0.117 (0.028)	0.110 (0.029)	0.87
Hispanic	0.149 (0.022)	0.146 (0.030)	0.153 (0.033)	0.88
Other race	0.016 (0.008)	0.015 (0.010)	0.017 (0.012)	0.88
Female	0.584 (0.031)	0.547 (0.043)	0.627 (0.045)	0.2
Age less than 30	0.322 (0.029)	0.328 (0.040)	0.314 (0.043)	0.8
Age 30 to 45	0.396 (0.031)	0.387 (0.042)	0.407 (0.045)	0.75
Age above 45	0.282 (0.028)	0.285 (0.039)	0.280 (0.041)	0.93
Firm size less than 50 employees	0.184 (0.024)	0.197 (0.034)	0.169 (0.035)	0.57
Firm size 50-249 employees	0.239 (0.027)	0.204 (0.035)	0.280 (0.041)	0.16
Firm size 249-499 employees	0.137 (0.022)	0.139 (0.030)	0.136 (0.032)	0.94
Firm size 500-999 employees	0.161 (0.023)	0.175 (0.033)	0.144 (0.032)	0.5
Firm size 1,000-4,999 employees	0.145 (0.022)	0.161 (0.031)	0.127 (0.031)	0.45
Firm size 5,000 employees or above	0.133 (0.021)	0.124 (0.028)	0.144 (0.032)	0.64
Natural language processing in use at business	0.796 (0.025)	0.788 (0.035)	0.805 (0.037)	0.74
Computer vision in use at business	0.698 (0.029)	0.723 (0.038)	0.669 (0.043)	0.36
Machine learning in use at business	0.733 (0.028)	0.759 (0.037)	0.703 (0.042)	0.32
No. of observations	255	137	118	255

Notes: For each variable the mean is presented in the first row and the standard error of the means in the second row in parentheses. The last column presents the results from t-tests that examine the difference of the mean values between the treatment and control groups. None of the mean values are significantly different between the two groups. ***, **, and * denote statistical significant at 1%, 5%, and 10% level.

Table 2. Adoption

	(1)	(2)	(3)	(4)	(5)
			Panel A. Adopt AI in at least one business process		
AI regulation treatment	-0.0612	-0.0567	-0.0749	-0.0827	-0.0716
	(0.0448)	(0.0492)	(0.0543)	(0.0521)	(0.0496)
R-squared	0.008	0.350	0.409	0.442	0.478
			Panel B. Adopt AI in at least three business processes		
AI regulation treatment	-0.107*	-0.155**	-0.174**	-0.180***	-0.147**
	(0.0616)	(0.0636)	(0.0678)	(0.0686)	(0.0646)
R-squared	0.012	0.356	0.405	0.407	0.467
			Panel C. Number of business processes to adopt AI		
AI regulation treatment	-0.658*	-0.795**	-0.852**	-0.850**	-0.640*
	(0.346)	(0.356)	(0.365)	(0.368)	(0.346)
R-squared	0.014	0.391	0.477	0.478	0.534
Firm level controls	No	Yes	Yes	Yes	Yes
Individual controls	No	No	Yes	Yes	Yes
Management controls	No	No	No	Yes	Yes
Current AI adoption	No	No	No	No	Yes

Notes: Estimates are from OLS regressions. Robust standard errors are presented in parentheses. Firm level controls include state, industry, firm size, and firm revenue fixed effects. Individual controls include gender, race, education, age, and organizational role fixed effects. Management controls include management practice variables related to data use, promotion, and firing. Current AI adoption includes dummy variables indicating whether the business currently uses natural language processing, computer vision, or machine learning. ***, **, and * denote statistical significant at 1%, 5%, and 10% level.

Table 3. Budget

	(1)	(2)	(3)	(4)	(5)
	Panel A. Developing AI strategy compatible with company's business strategy				
AI regulation treatment	3.670*	3.733*	4.289**	4.506**	4.288**
	(1.920)	(1.924)	(1.943)	(1.948)	(1.952)
R-squared	0.290	0.400	0.413	0.427	0.439
	Panel B. Computing resources and data related costs for AI development				
AI regulation treatment	-1.363	-0.813	-0.907	-1.161	-1.385
	(1.098)	(1.170)	(1.224)	(1.228)	(1.191)
R-squared	0.358	0.422	0.445	0.456	0.475
	Panel C. Assessment of ethical issues related to AI use and development				
AI regulation treatment	0.608	0.377	0.286	0.521	0.256
	(1.154)	(1.131)	(1.140)	(1.171)	(1.185)
R-squared	0.275	0.408	0.409	0.421	0.433
	Panel D. Purchase of AI packages from external vendors				
AI regulation treatment	-1.840	-1.504	-1.614	-1.781	-1.714
	(2.013)	(2.183)	(2.257)	(2.254)	(2.197)
R-squared	0.269	0.357	0.360	0.384	0.400
	Panel E. AI training for current employees				
AI regulation treatment	-3.730***	-4.010***	-4.263***	-4.051***	-3.859***
	(1.403)	(1.354)	(1.379)	(1.416)	(1.420)
R-squared	0.304	0.434	0.439	0.445	0.459
	Panel F. Hiring technical workforce to develop and maintain AI for your company				
AI regulation treatment	2.655	2.216	2.208	1.966	2.414
	(2.129)	(2.217)	(2.254)	(2.360)	(2.311)
R-squared	0.256	0.401	0.404	0.408	0.425
Firm level controls	Yes	Yes	Yes	Yes	Yes
Individual controls	No	Yes	Yes	Yes	Yes
Managemetn controls	No	No	Yes	Yes	Yes
Current AI adoption	No	No	No	Yes	Yes
Previous budgeting experience	No	No	No	No	Yes

Notes: Estimates are from OLS regressions. Robust standard errors are presented in parentheses. Firm level controls include state, industry, firm size, and firm revenue fixed effects. Individual controls include gender, race, education, age, and role fixed effects. Management controls include management practice variables related to data use, promotion, and firing. Current AI adoption includes dummy variables indicating whether the business currently uses natural language processing, computer vision, or machine learning. Previous budgeting experience includes dummy variables that indicate the largest budget size previously managed. ***, **, and * denote statistical significant at 1%, 5%, and 10% level.

Table 4. Manager perception on AI

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Reduce labor costs	Improve productivity	Data privacy & transparency	Potential biases	Legal and regulatory implications	Social equity	Augment workers
AI regulation treatment	0.132	0.0663	-0.0526	0.150	0.0751	-0.101	-0.0504
	(0.182)	(0.170)	(0.180)	(0.193)	(0.186)	(0.197)	(0.174)
R-squared	0.383	0.428	0.410	0.377	0.365	0.400	0.449
Firm level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Management controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Current AI adoption	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Estimates are from OLS regressions. Robust standard errors are presented in parentheses. Firm level controls include state, industry, firm size, and firm revenue fixed effects. Individual controls include gender, race, education, age, and organizational role fixed effects. Management controls include management practice variables related to data use, promotion, and firing. Current AI adoption includes dummy variables indicating whether the business currently uses natural language processing, computer vision, or machine learning. ***, **, and * denote statistical significant at 1%, 5%, and 10% level.

Table 5. Labor

	(1) Managers	(2) Technical workers	(3) Office workers	(4) Sales and service workers	(5) Production workers
AI regulation treatment	-0.00457	0.0562	0.224	0.341**	0.0482
	(0.132)	(0.161)	(0.136)	(0.139)	(0.144)
Observations	246	244	247	243	239
R-squared	0.462	0.411	0.437	0.470	0.514
Firm level controls	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes
Management controls	Yes	Yes	Yes	Yes	Yes
Current AI adoption	Yes	Yes	Yes	Yes	Yes

Notes: Estimates are from OLS regressions. Robust standard errors are presented in parentheses. Firm level controls include state, industry, firm size, and firm revenue fixed effects. Individual controls include gender, race, education, age, and organizational role fixed effects. Management controls include management practice variables related to data use, promotion, and firing. Current AI adoption includes dummy variables indicating whether the business currently uses natural language processing, computer vision, or machine learning. ***, **, and * denote statistical significant at 1%, 5%, and 10% level.

Appendix Table 1. State of respondents

State	Number of respondents	Percent of respondents
Alabama	7	2.32%
Alaska	0	0.00%
Arizona	5	1.66%
Arkansas	5	1.66%
California	25	8.28%
Colorado	2	0.66%
Connecticut	3	0.99%
District of Columbia (Washington, D.C.)	2	0.66%
Delaware	0	0.00%
Florida	36	11.92%
Georgia	12	3.97%
Hawaii	2	0.66%
Idaho	0	0.00%
Illinois	16	5.30%
Indiana	11	3.64%
Iowa	1	0.33%
Kansas	2	0.66%
Kentucky	5	1.66%
Louisiana	5	1.66%
Maine	2	0.66%
Maryland	3	0.99%
Massachusetts	6	1.99%
Michigan	8	2.65%
Minnesota	1	0.33%
Mississippi	4	1.32%
Missouri	8	2.65%
Montana	0	0.00%
Nebraska	3	0.99%
Nevada	3	0.99%
New Hampshire	2	0.66%
New Jersey	16	5.30%
New Mexico	4	1.32%
New York	14	4.64%
North Carolina	10	3.31%
North Dakota	1	0.33%
Ohio	14	4.64%
Oklahoma	2	0.66%
Oregon	4	1.32%
Pennsylvania	14	4.64%
Rhode Island	2	0.66%
South Carolina	8	2.65%
South Dakota	0	0.00%
Tennessee	4	1.32%
Texas	15	4.97%
Utah	3	0.99%
Vermont	0	0.00%
Virginia	9	2.98%
Washington	1	0.33%
West Virginia	0	0.00%
Wisconsin	2	0.66%
Wyoming	0	0%
TOTAL	302	100%

Appendix Table 2. Industry of respondents

State	Number of respondents	Percent of respondents
Retail	44	14.57%
Wholesale	18	5.96%
Manufacturing	34	11.26%
Transportation and logistics	23	7.62%
Construction	28	9.27%
High tech and telecommunications	24	7.95%
Education Services	26	8.61%
Energy and resources	3	0.99%
Health Care	18	5.96%
Financial services (finance, insurance, real estate)	21	6.95%
Professional, Scientific, and Technical Services	28	9.27%
Other Services (except Public Administration)	9	2.98%
Public Administration	3	0.99%
Something else	23	7.62%
TOTAL	300	100%

Appendix Table 3. Education level of respondents

Education level	Number of respondents	Percent of respondents
Less than a high school diploma	6	1.53%
High school degree or equivalent (e.g. GED)	49	12.47%
Some college, no degree	67	17.05%
Associate degree (e.g. AA, AS)	42	10.69%
Bachelor's degree (e.g. BA, BS)	143	36.39%
Master's degree (e.g. MA, MS, MEng, MEd, MSW, MBA)	74	18.83%
Doctorate or professional degree (e.g. PhD, EdD, MD, DDS, DVM, LLB, JD)	12	3.05%
TOTAL	302	100%

Appendix Table 4. Organizational role of respondents

Role at organization	Number of respondents	Percent of respondents
Owner or Partner	85	21.63%
President/CEO/Chairperson	35	8.91%
Other C-level Executive, e.g., CFO, COO, CTO	35	8.91%
Senior Management	82	20.87%
Middle Management	118	30.03%
Project Management	38	9.67%
TOTAL	302	100%

Appendix – Survey Questionnaire

We have attached the survey questionnaire for review at the Economics of Artificial Intelligence Conference. Please do not circulate. Once we finalize the working paper after the large-scale main survey in June 2019 we will attach to the new draft.

STANFORD
UNIVERSITY

Survey of Artificial Intelligence Use in Businesses

You are invited to participate in a survey of business application of artificial intelligence technologies, such as chatbots, image recognition, and product recommendation programs. We expect that the survey will take about 8~10 minutes to complete.

This survey is being conducted by researchers at Stanford University and the survey results will be used for academic research only. Any personal information will remain confidential.

Thank you for participating in our survey.

STANFORD UNIVERSITY

Survey of Artificial Intelligence Use in Businesses

1. What best describes your role at your organization?

- ◯ Owner or Partner
- ◯ President/CEO/Chairperson
- ◯ Other C-level Executive, e.g., CFO, COO, CTO
- ◯ Senior Management
- ◯ Middle Management
- ◯ Project Management

2. Please briefly describe the type of work you do at the business for which you work.

3. What is the highest degree or level of school you have completed? If currently enrolled, mark the current degree you are enrolled in.

- ◯ Less than a high school diploma
- ◯ High school degree or equivalent (e.g. GED)
- ◯ Some college, no degree
- ◯ Associate degree (e.g. AA, AS)
- ◯ Bachelor's degree (e.g. BA, BS)
- ◯ Master's degree (e.g. MA, MS, MEng, MEd, MSW, MBA)
- ◯ Doctorate or professional degree (e.g. PhD, EdD, MD, DDS, DVM, LLB, JD)

4. Which race/ethnicity best describes you? (Please choose only one.)

- ◯ American Indian or Alaskan Native
- ◯ Asian / Pacific Islander
- ◯ Black or African American
- ◯ Hispanic
- ◯ White / Caucasian
- ◯ Multiple ethnicity / Other (please specify)

Now we will ask to what extent your workplace uses Artificial Intelligence technologies.

We will be asking about 3 Artificial Intelligence technologies:

- **Natural Language Processing**
- **Computer Vision**
- **Machine Learning**

AI technologies are different from robots or traditional data analysis. We will provide a description of each technology in each question.

STANFORD UNIVERSITY

Survey of Artificial Intelligence Use in Businesses

Natural Language Processing Use in the Workplace

5. **Natural Language Processing** is the technology that allows computers to process human speech or text, or converse with humans. In the most recent quarter at your workplace, **how many business processes used Natural Language Processing** technology?

Examples of business processes using Natural Language Processing include**sales chatbots on websites, customer service chatbots, automated speech transcription, voice recognition in apps, virtual machine assistants, etc.**

0 - No use	1 business process	2 business processes	3 business processes	4 business processes	5 business processes	6 business processes	7~9 business processes	10 or more business processes	Don't know
○	○	○	○	○	○	○	○	○	○

6. Please briefly describe for what purpose(s) this business is testing/using Natural Language Processing technology.

7. How did the introduction of Natural Language Processing affect the number of workers at your workplace? Please respond to **changes that happened because of Natural Language Processing technology only**.

	Decreased greatly	Decreased slightly	The same	Increased slightly	Increased greatly	Not relevant for this workplace
Managers	◯	◯	◯	◯	◯	◯
Technical workers (R&D workers, IT technicians, programmers, etc.)	◯	◯	◯	◯	◯	◯
Office workers (e.g., HR, accounting, secretarial workers, etc. but not in managerial positions)	◯	◯	◯	◯	◯	◯
Service and Sales workers (e.g., customer service, client service, salesperson etc.)	◯	◯	◯	◯	◯	◯
Production workers	◯	◯	◯	◯	◯	◯

STANFORD UNIVERSITY

Survey of Artificial Intelligence Use in Businesses

Computer Vision Use in the Workplace.

8. **Computer Vision** is the technology that provides image-based automatic inspection, recognition or analysis. In the most recent quarter at your workplace, **how many business processes used Computer Vision** technology?

Examples of business processes using Computer Vision include **facial recognition for security purposes, anomaly detection using video analysis, image analysis in healthcare, delivery using autonomous drones or unmanned vehicles, etc.**

0 - No use	1 business process	2 business processes	3 business processes	4 business processes	5 business processes	6 business processes	7-9 business processes	10 or more business processes	Don't know
○	○	○	○	○	○	○	○	○	○

9. Please briefly describe for what purpose(s) this business is testing/using Computer Vision technology.

10. How did the introduction of Computer Vision affect the number of workers at your workplace? Please respond to **changes that happened because of Computer Vision technology only**.

	Decreased greatly	Decreased slightly	The same	Increased slightly	Increased greatly	Not relevant for this workplace
Managers	○	○	○	○	○	○
Technical workers (R&D workers, IT technicians, programmers, etc.)	○	○	○	○	○	○
Office workers (e.g., HR, accounting, secretarial workers, etc. but not in managerial positions)	○	○	○	○	○	○
Service and Sales workers (e.g., customer service, client service, salesperson etc.)	○	○	○	○	○	○
Production workers	○	○	○	○	○	○

STANFORD UNIVERSITY

Survey of Artificial Intelligence Use in Businesses

Machine Learning Use in the Workplace

11. **Machine Learning** is based on computer algorithms that use data to improve their **predictive** performance. In the most recent quarter at your workplace, **how many business processes used Machine Learning** based technology?

Examples of business processes using Machine Learning include **product recommendation, consumer purchase behavior prediction, prediction of energy usage for better maintenance, recommending financial trading, etc.**

0 - No use	1 business process	2 business processes	3 business processes	4 business processes	5 business processes	6 business processes	7-9 business processes	10 or more business processes	Don't know
○	○	○	○	○	○	○	○	○	○

12. Please briefly describe for what purpose this business is testing/using Machine Learning technology.

13. How did the introduction of Machine Learning affect the number of workers at your workplace? Please respond to **changes that happened because of Machine Learning technology only**.

	Decreased greatly	Decreased slightly	The same	Increased slightly	Increased greatly	Not relevant for this workplace
Managers	○	○	○	○	○	○
Technical workers (R&D workers, IT technicians, programmers, etc.)	○	○	○	○	○	○
Office workers (e.g., HR, accounting, secretarial workers, etc. but not in managerial positions)	○	○	○	○	○	○
Service and Sales workers (e.g., customer service, client service, salesperson etc.)	○	○	○	○	○	○
Production workers	○	○	○	○	○	○

A 50.0%

Recent research has found that early adopters of AI have started to reap the benefits of their investments. First-movers have already deployed and marketed solutions across healthcare, autonomous driving, retail and so on. Forty-seven percent of companies say they have embedded at least one AI capability in their business processes. Revenues from the global AI market is expected to grow from $7.3billion in 2018, to reach $90billion by 2025.

While the potential for AI is enormous, most organizations still have a long way to go in developing the core practices that enable them to realize the potential value of AI at scale. Business executives and managers will need to think about how to incorporate AI into their business strategy, as well as the accountability of AI algorithms, biases in data, and concerns over privacy.

For the next questions assume you are in the position to make artificial intelligence technology investments and human resource decisions for your company.

B 50.0% Recent research has found that early adopters of AI have started to reap the benefits of their investments. First-movers have already deployed and marketed solutions across healthcare, autonomous driving, retail and so on. Forty-seven percent of companies say they have embedded at least one AI capability in their business processes. Revenues from the global AI market is expected to grow from $7.3billion in 2018, to reach $90billion by 2025.

Up until now, little oversight and regulation has been attached to the area of AI training and product deployment. New regulation put forward in the Algorithmic Accountability Act of 2019 is expected to change that. The Algorithmic Accountability Act of 2019, aims to regulate firms through mandatory assessments of their AI systems. Assessment includes disclosure of firm usage of AI systems including their development process, system design, training, and the data gathered and in use. Furthermore, the Algorithmic Accountability Act requires firm to assess and disclose the impact of their AI systems on accuracy, fairness, bias, discrimination, privacy and security. The regulation would affect firms that either are utilizing or selling AI-related products.

For the next questions assume you are in the position to make artificial intelligence technology investments and human resource decisions for your company.

14. **To what extent would you adopt AI** technologies such as machine learning, computer vision, natural language processing at your business to enhance products and services, to optimize workflow, maintenance, and internal operations, to reduce error, to make better judgements, to better compete with competitors, etc?

Please respond in terms of the **total number of business processes** in which you would **adopt any AI technology.** If your business is currently adopting AI please include those processes in the total number.

- ☐ 0 - no adoption
- ☐ 1 business process
- ☐ 2 business processes
- ☐ 3 business processes
- ☐ 4 business processes
- ☐ 5 business processes
- ☐ 6 business processes
- ☐ 7 business processes
- ☐ 8 business processes
- ☐ 9 business processes
- ☐ 10 or more business processes

15. How important would you consider the following when adopting AI into your business?

	Not important	Slightly important	Moderately important	Important	Very important
Reducing labor costs with AI technologies	○	○	○	○	○
Improving products and services using AI technologies	○	○	○	○	○
Maintaining data privacy and transparency when using AI technologies	○	○	○	○	○
Minimizing potential biases (e.g., racial, gender bias) in predictions made by AI technologies	○	○	○	○	○
Potential legal and regulatory implications in the deployment of AI based products	○	○	○	○	○
Whether AI can help make societies more equal	○	○	○	○	○
Augmenting and training existing workers with AI technologies	○	○	○	○	○

16. What is the biggest budget you have been responsible for in your career to date?

- ◯ Less than $10,000
- ◯ $10,000-$100,000
- ◯ $100,000-$500,000
- ◯ $500,000-$1,000,000
- ◯ $1,000,000-$5,000,000
- ◯ More than $5,000,000

17. Adopting AI technology could entail a variety of costs. For example, there could be costs related to hiring technical workers, purchasing AI packages, computers and data centers, purchasing or gathering data, developing AI strategies for your business, consulting fees, assessing the impact of AI product and services.

How much would you budget for AI adoption at your company in the following year? Please consider all potential costs and write in the dollar amount.

18. **What percentage** of the total AI budget would you allocate to**each of the below 6 expense categories?** Please write down the percentages in integers without the % sign. The**percentages should add up to 100.** Write down 0 for any category that you would not allocate any expenses to.

Hiring technical workforce to develop and maintain AI for your company (e.g., programmers, technicians, etc.)

AI training for current employees (e.g., coding, how to use AI technology, etc.)

Purchase of AI packages from external vendors (e.g., AI software, analysis fees, etc.)

Assessment of ethical issues related to AI use and development (e.g., costs associated with assessing racial and gender bias, data privacy and misuse etc.)

Computing resources and data related costs for AI development (e.g., computers, cloud computing, data collection and purchase costs, etc.)

Developing AI strategy that is compatible with your company's overall business strategy (e.g., consulting and marketing costs, internal strategy development, etc.)

19. What would you do to your current employees in response to the need for new skill related to AI technology?

- ◯ Keep and retrain current employees
- ◯ Keep or replace employees in equal measure
- ◯ Primarily replace current employees with new talent

20. In particular, how would you adjust the total number of the following employees at your workplace? **Please respond only to changes that would occur because of AI adoption**at your workplace going forward.

	Decrease greatly	Decrease slightly	The same	Increase slightly	Increase greatly	Not relevant for this workplace
Managers	◯	◯	◯	◯	◯	◯
Technical workers (R&D workers, IT technicians, programmers, etc.)	◯	◯	◯	◯	◯	◯
Office workers (e.g., HR, accounting, secretarial workers, etc. but not in managerial positions)	◯	◯	◯	◯	◯	◯
Service and Sales workers (e.g., customer service, client service, salesperson etc.)	◯	◯	◯	◯	◯	◯
Production workers	◯	◯	◯	◯	◯	◯

STANFORD UNIVERSITY

Survey of Artificial Intelligence Use in Businesses

Business characteristics

This is the last page. We would like to ask a little bit about the business you work for.

21. If your were to classify this business' industry, this business is mainly...

- ◯ Retail
- ◯ Wholesale
- ◯ Manufacturing
- ◯ Transportation and logistics
- ◯ Construction
- ◯ High tech and telecommunications
- ◯ Education Services
- ◯ Energy and resources
- ◯ Health Care
- ◯ Financial services (finance, insurance, real estate)
- ◯ Professional, Scientific, and Technical Services
- ◯ Other Services (except Public Administration)
- ◯ Public Administration
- ◯ something else (please specify)

22. Which State is your workplace located in?

23. What best describes the use of data to support decision making at this establishment?

- ◯ Decision making does not use data
- ◯ Decision making relies slightly on data
- ◯ Decision making relies moderately on data
- ◯ Decision making relies heavily on data
- ◯ Decision making relies entirely on data

24. What is the primary way employees are promoted at this business?

- ◯ Promotions were based solely on performance and ability
- ◯ Promotions were based partly on performance and ability and partly on other factors (for example, tenure or family connections)
- ◯ Promotions were based mainly on factors other than performance and ability (for example, tenure or family connections)
- ◯ Employees are not normally promoted

25. In the past year, what typically happened to under-performing employees at your workplace?

- ◯ Reassigned or dismissed within 6 months of identifying employee under-performance
- ◯ Reassigned or dismissed after 6 months of identifying employee under-performance
- ◯ Under-performing employees are not normally reassigned or dismissed
- ◯ No under-performing employees were identified in the past year

26. How many employees does this business usually have? If the business has multiple establishments, please respond in regards to your current workplace

- ◯ less than 50
- ◯ 50-249
- ◯ 250-499
- ◯ 500-999
- ◯ 1,000-4,999
- ◯ 5,000 or above

27. What is your company's annual revenue?

- ◯ Less than $100K
- ◯ $100K to $499K
- ◯ $500K to $999,999K
- ◯ $1M to $4.9MM
- ◯ $5MM to $9.9MM
- ◯ $10MM to $49.9MM
- ◯ $50MM to $99.9MM
- ◯ $100MM to $499.9MM
- ◯ $500MM to $999,999B
- ◯ $1B or more

28. The final question is a request for feedback about the responses you provided so far. **It is vital to our study that we only include responses from people who devoted their full attention to this study. This will not affect in any way the payment you will receive for taking this survey.**

In your honest opinion, should we use your responses, or should we discard your responses since you did not devote your full attention to the questions so far?

- ◯ Yes, I have devoted full attention to the questions so far and I think you should use my responses for your study.
- ◯ No, I have not devoted full attention to the questions so far and I think you should not use my responses for your study.