ATTACHMENT H

Department of Commerce
United States Census Bureau
Annual Survey of Manufactures (ASM)
OMB Control No. 0607-0449

Robotics Use

Letter of Support from Weatherhead School of Management Case Western Reserve University
Letter of Support from Robotic Industries Association (RIA)
Letter of Support from Manufacturing Institute (MI)
Development of Survey Questions on Robotics Expenditures and Use in the U.S. Manufacturing Establishments paper from the Center for Economic Studies (CES)

WEATHERHEAD
SCHOOL OF MANAGEMENT
CASE WESTERN RESERVE
UNIVERSITY

Dr. Ron Jarmin
Associate Director
Economic Directorate
U.S. Census Bureau
4700 Silver Hill Road
Washington, D.C.20233

Dear Ron:

I am writing to support the Census Bureau's efforts to update the Annual Survey of Manufacturers (ASM) to include the collection of data on expenditure on robots. Over the past several years I have been deeply engaged in research (through my affiliations with Case Western and the National Bureau of Economic Research) and policy work (including appointments as a Senior Economist on the Council of Economic Advisers and as the Chief Economist of the Department of Commerce). I believe that robots may well represent the next wave of transformative technologies, a wave that will dramatically alter the U.S. manufacturing sector. This data collection is vital to understand these important trends.

A number of recent reports have highlighted the dramatic effect that industrial robots have already had and will likely have in the future. For example, according to CEA's 2016 *Economic Report of the President*, robots have led to a 10% increase in economic growth. Moreover, CEA reports that the number of industrial robots has doubled in recent years. However, the data used by CEA, and other academic studies to date, is highly aggregated (country-2-digit industry code-year) and all from the same source, the International Federation of Robotics. Collecting establishment level data on robot expenditures would allow for replication of existing work, but at the establishment and firm level.

The introduction of robots into the workplace likely has heterogeneous effects on the workforce. In some cases robots likely substitute for labor, but in other cases robots likely complement labor. Establishment-level data would allow for a close examination of the conditions under which each happens, which may be useful to policy makers who could then design better policies, such as better targeting funds for re-training.

In summary, I fully support having the next Annual Survey of Manufacturers include a question about robot expenditures.

Sincerely,

Susan Helper

Susan Helper
Carlton Professor of Economics
Weatherhead School of Management
Case Western Reserve University
Cleveland OH 44106
(216) 368-5541

Robotic Industries Association

900 Victors Way, Suite 140 ▪ Ann Arbor, Michigan 48108, USA
Telephone: +1 734-994-6088 Fax: +1 734-994-3338

February 15, 2017

Dr. Ron Jarmin
Associate Director
Economic Directorate
U.S. Census Bureau
4700 Silver Hill Road Washington, D.C. 20233

Dear Dr. Jarmin,

The Robotic Industries Association (RIA) is pleased to provide this letter of support for the Census Bureau's collection of basic robotic use and expenditure data as part of the Annual Survey of Manufacturers (ASM) and the Economic Census.

Robotics has already changed the world, but more fundamental change is clearly ahead. It is much easier to see the outline of the eventual new world than to know how soon it will arrive. We hear a lot these days about things like smart cities, smart mining, and smart farming. Let's remember that this all due to smart people. In the robotics industry, we take a perspective that goes beyond technology for technology's sake. We strive to understand the impact of our work on people's lives, and to make the world better instead of worse.

In order to gain this understanding, we need to have good data. While the RIA and its international affiliate, the International Federation of Robotics (IFR), collect statistics from robot manufacturers on the sales of robots into key industries, geographies, and applications, it is also important to collect information from their customers. Currently, this is an area with little visibility. The IFR estimates that some 230,000 robots are installed in the U.S. today, and that number will continue growing. The U.S. Census Bureau's implementation of the proposed questions would give us a new level of detail to analyze which type of firms are adopting robots, which sub-sectors they do business in, and the impact robots are having on employment.

Several of RIA's 435 member companies are examples of how when companies improve their competitiveness through the implementation of advanced robotics, they are saving jobs and creating ripples of positive change and economic impact in their workplace and communities. RIA's parent organization, the Association for Advancing Automation (A3), has created a video series called "Why I Automate," which is dedicated to showcasing these companies' stories and proliferating their message. With the addition of basic robotic use and expenditure questions to

Robotic Industries Association

900 Victors Way, Suite 140 ▪ Ann Arbor, Michigan 48108, USA
Telephone: +1 734-994-6088 Fax: +1 734-994-3338

the ASM and the Economic Census, we could dig deeper into which industries are benefiting from robots the most, and more effectively drive employment growth in those sectors.

A great example of a company that has become more competitive through robotics is RIA member, Vickers Engineering of New Troy, Michigan. A medium-sized prototype and production supplier of CNC machining to automotive and other industries, Vickers had trouble finding and keeping people to do dull and repetitive jobs. They tried robotics and discovered that this saved the cost of constant hiring and retraining for positions people didn't want. Then, because of lower costs, improved productivity and greater product quality, they were able to win business that they couldn't win before. As a result, they hired more people than they had before they started using robotics. Capturing basic data on robotic investments by companies like Vickers Engineering would help us strengthen this message, which is why RIA strongly supports the implementation of this proposal.

In summary, RIA supports the inclusion of the basic robot use and expenditure questions in the next Annual Survey of Manufacturers and Economic Census. With the growing importance of robotics and automation in our society today, we believe it is the right time to begin collecting this type of information. Please feel free to contact me at jburnstein@robotics.org or (734) 994-6088 if you have any questions.

Sincerely,

Jeff Burnstein
President
Robotic Industries Association (RIA)

MANUFACTURING Institute

January 18, 2017

Dr. Ron Jarmin
Associate Director
Economic Directorate
U.S. Census Bureau
4700 Silver Hill Road
Washington, DC 20233

Dear Dr. Jarmin:

I am writing to lend my support for the Census Bureau's collection of basic robotic use and expenditure data as part of the Annual Survey of Manufactures (ASM) and the Economic Census.

The Manufacturing Institute and the National Association of Manufacturers makes frequent use of ASM and Economic Census reports to provide perspective on the critical issues facing manufacturing with a special emphasis on understanding workforce needs, national and international competitiveness. In this regard, use of robots and their impact remains an area that is poorly understood due to lack of data.

Industrial robots are on the verge of revolutionizing manufacturing. A recent PwC study[1] commissioned by The Manufacturing Institute shows that robots are becoming smarter, faster and cheaper. We estimate there are 230,000 robots in the US alone and the forecast is for increased use. Existing data show that advanced industrial robotics are widespread in the automotive industry; and are increasingly widespread in other industries including food and beverage, consumer goods, pharma and metals, amongst other. As their costs continue to decline, robots are now within the reach of small and medium-sized companies. We therefore expect robots to become increasingly pervasive. Simply understanding which firms and industries are adopting and which are not would be useful in this regard.

The introduction of robots into the workplace has deep implications for workforce composition, productivity, and wages. Some types of jobs, repetitive and dangerous jobs in production lines and warehouses, are being replaced by the introduction of robots. At the same time robots appear to be complementary to labor in many cases and also create opportunities for other types of jobs. The same PwC report shows robotic-intense

[1] "The new hire: How a new generation of robots is transforming manufacturing" PwC in conjunction with Manufacturing Institute, September 2014.

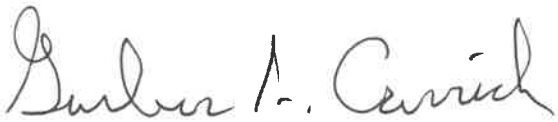
733 10th Street, NW, Washington, DC 20001 P 202.637.3426 F 202.637.3182 http://www.themanufacturinginstitute.org

manufacturing sectors in the U.S. employ more STEM workers including mechanical and industrial engineers. Manufacturers believe robots offer new opportunities for humans that are able to manage the robotic workplace and work alongside robots.

The new proposed questions would enable us to establish the extent to which firms use robots, across small, medium and large firms, across different geographies, and across different manufacturing sub-sectors. These questions would shed light on workforce composition shifts and needs. They would also shed light on the impact of robots on productivity, innovation and product life-cycles. With the increased use of robotics, the Manufacturing Institute believes that these questions would significantly enhance the understanding of manufacturing firms, their competitiveness and possibly barriers to their growth.

In summary, I fully support having the next Annual Survey of Manufactures and Economic Census include the basic robot use and expenditure questions. Please feel free to contact me at gcarrick@nam.org or (202) 637-3491 if you have any questions. Thanks again for considering this important set of questions.

Sincerely,



Gardner A. Carrick
Vice President, Strategic Initiatives

Development of Survey Questions on Robotics Expenditures and Use in U.S. Manufacturing Establishments

by

Catherine Buffington
U.S. Census Bureau

Javier Miranda
U.S. Census Bureau

Robert Seamans
NYU Stern School of Business

CES 18-44 October, 2018

Abstract

The U.S. Census Bureau in partnership with a team of external researchers developed a series of questions on the use of robotics in U.S. manufacturing establishments. The questions include: (1) capital expenditures for new and used industrial robotic equipment in 2018, (2) number of industrial robots in operation in 2018, and (3) number of industrial robots purchased in 2018. These questions are to be included in the 2018 Annual Survey of Manufactures. This paper documents the background and cognitive testing process used for the development of these questions.

* Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed. The Census Bureau developed the ASM robotics capital expenditures content in partnership with an external research team that includes Rob Seamans (NYU), Sue Helper (Case Western Reserve University) and Erik Brynjolfsson (MIT). A grant from the National Science Foundation (NSF) (NSF grant #1748045) supported the cognitive testing of the survey content. Robert Seamans also acknowledges support for this project from the Hewlett Foundation (Hewlett grant #6324). We thank Kristina McElheran and Kristin Stettler for helpful comments and review of this paper.

1. Introduction

There have recently been dramatic increases in the technical capabilities of artificial intelligence (AI) and robotics. For example, according to the AI Index, error rates for image recognition has dropped from 29 percent to less than 3 percent between 2010 and 2017, surpassing human performance levels.[3] The Electronic Frontier Foundation (EFF) notes similarly dramatic improvement in the performance of AI with respect to real-time video games, abstract strategy games (e.g., Chess, Go), video recognition, reading comprehension, translation, and other categories.[4] These advancements have led both to excitement about the capability of AI and robotics to boost economic growth and to concern about the fate of human workers in a world in which computer algorithms can perform many of the functions that a human can (e.g., Frey and Osborne 2017, Furman 2016).

Recent academic research, using national level data on worldwide robotics shipments, suggests that robotics may have been responsible for about a tenth of the increase in gross domestic product (GDP) between 1993 and 2007 (Graetz and Michaels 2015). Since then, worldwide demand for robotics has nearly tripled between 2010 and 2016 (Furman and Seamans 2018), and the number and share of robotics-oriented patents have both also increased (CEA 2016). Thus, robots may now be contributing even more to GDP growth than in the past.

However, even as these technologies may be contributing to GDP growth at a national level, we lack an understanding about how and when robotics, AI and other advanced technologies contribute to firm level productivity, the conditions under which these technologies complement or substitute for labor, how these technologies affect new firm formation, and how they shape regional economies. We lack an understanding of these issues because, to date, there is a lack of firm-level data on the use of robotics and AI (Raj and Seamans 2018; McElheran 2018). Indeed, a recent National Academies of Science Report (NAS 2017) calls for more data collection on the effects of automation, including AI and robots, on the economy.

In an effort to better understand the effects of robotics on the US economy, a team of Census employees and university researchers worked to develop questions on robotics capital expenditures by U.S. manufacturing plants. This paper documents the background and cognitive testing process used for the development of these questions for the 2018

[3] AI Index, November 2017; available: https://aiindex.org/2017-report.pdf
[4] See AI Progress Measurement from Electronic Frontier Foundation for more details, available at https://www.eff.org/ai/metrics.

Annual Survey of Manufactures. The team consisted of Erik Brynjolfsson (MIT), Catherine Buffington (Census), Susan Helper (Case Western), Javier Miranda (Census) and Robert Seamans (NYU). The questions are to be included in the 2018 Annual Survey of Manufactures. The questions include: (1) capital expenditures for new and used industrial robotic equipment in 2018, (2) number of industrial robots in operation in 2018, and (3) number of industrial robots purchased in 2018. These questions were arrived at following an extensive cognitive testing process, the details of which are described in the sections that follow.

The paper proceeds as follows. Section 2 covers historic and current data sources for robotics equipment in the United States. Section 3 discusses the robotics questions, the cognitive testing process the questions underwent, and outcome of the testing process. Section 4 concludes.

2. Historic and Current Data Sources for Robotics

2.1. Historic Data

Beginning in the late 1980s, the Census Bureau conducted a Survey of Manufacturing Technology (SMT) in collaboration with the Department of Defense. The purpose of the SMT was to measure the presence, use, and planned use of advanced technologies in the manufacturing sector. The Survey was in the field in years 1988, 1991 and 1993 but was discontinued for funding reasons. The Department of Defense used the data to assess the diffusion of technology. Other Federal agencies used the data to gauge competitiveness of the U.S. manufacturing sector. The data were also used by the private sector in market analysis, competitiveness assessments, and planning. The data were used in multiple academic studies, including Dunne (1994), McGuckin et al (1996), Doms et al (1997), Lewis (2005) and Luque and Miranda (2000) to address questions related to productivity growth, skill based technical change, earnings and capital-labor substitution amongst others.

Beginning in 2003 and discontinued in 2015 due to budgetary reasons, the Census Bureau collected related expenditures data in the Information and Communication Technology Survey (ICTS), a supplement to the Annual Capital Expenditures Survey (ACES). The ICTS collected data on non-capitalized and capitalized business spending for information and communication technology (ICT) equipment and computer software. The Census Bureau has also collected data on the establishments' use of computer networks and electronic commerce (e-commerce) via a supplement to the Annual Survey of

Manufactures (ASM).[5] The data from the supplement has been used in research examining the effect of IT-related expenditures on firm level outcomes (McElheran 2015).

2.2. Current Data

The Census Bureau does not currently collect expenditures data for robotic equipment. Capital expenditures data are collected on several survey instruments including the Annual Survey of Manufactures and ACES, making them candidates for this type of collection.

For academic, practitioner, and policy purposes, current data on the use of robotics are derived from two sources of data: the International Federation of Robotics (IFR) Robot Shipment Data and the European Manufacturing Survey (EMS). The IFR has been recording information regarding worldwide robot stock and shipment figures since 1993. The IFR collects these data from its members, who are typically large robot manufacturers such as FANUC, KUKA, and Yaskawa. The data are broken up by country, year, industry and technological application. The IFR defines an industrial robot as an "automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications."[6] Geographical information in the IFR is often aggregated (e.g., data exist for the United States, but not an individual state or region within the United States). The IFR utilizes its own industry classifications when organizing the data, rather than relying on broadly used identifiers such as the North American Industry Classification System (NAICS). Mapping IFR data to other datasets (such as BLS or Census data) first requires cross-referencing IFR classifications to other identifiers. While the IFR data are useful for some purposes, particularly examining the adoption of robotics by industry and country, the aggregated nature of the data obscures differences occurring within industries and across regions, making it difficult to uncover when and how robots might serve as substitutes or complements to labor, their impact on productivity and competitiveness and obscuring the differential effects of adoption within industries or countries.

The European Manufacturing Survey (EMS) has been organized and executed periodically by a number of research organizations and universities across Europe since 2001, and is currently one of the only firm-level datasets examining the adoption of robotics. The overall objective of the EMS is to provide empirical evidence regarding the use and impact of technological innovation in manufacturing at the firm level. The EMS accomplishes this via a survey of a random sample of manufacturing firms with at least twenty employees across seven European countries (Austria, France, Germany, Spain,

[5] https://www.census.gov/content/dam/Census/library/publications/2002/econ/1999-e-stats-mcd/initial-report.pdf
[6] https://ifr.org/standardisation

Sweden, Switzerland and the Netherlands). While some aspects of the survey vary across countries, the core set of questions inquires about whether the firm uses robots, the intensity of robot usage, and reinvestment in new robot technology.[7] Data currently exists for five survey rounds: 2001-2002, 2003-2004, 2006-2007, 2009-2010 and 2012-2013, and have been used in reports created by the European Commission to analyze the use of robotics and its impact on labor patterns, including wages, productivity and offshoring.

As of now, the EMS appears to be one of the few data sources that are capturing the use of robots and automation at the firm-level. This provides opportunities to analyze micro-effects of robotics technology on firm productivity and labor, and to analyze firm decision-making following adoption. However, the survey is performed at the firm rather than establishment level, and the sample size of 3,000 is quite small. In contrast, the Census' Annual Survey of Manufactures (ASM) surveys 50,000 establishments annually and 300,000 every five years.

Raj and Seamans (2018) document how data from the IFR and EMS have been used by researchers to study the effects of robots on productivity growth and employment. The authors highlight a number of challenges with the data. Notably, the EMS data does not cover U.S. manufacturing establishments and the IFR data, while covering the U.S., are aggregated to the industry level, making it impossible to study how robots are affecting firms and regions.

2.3. The Annual Survey of Manufactures and Robotics Data Collection

The Annual Survey of Manufactures (ASM) has many characteristics that make it a good candidate for the collection of capital expenditures data for robotics. The ASM contains a large representative sample of U.S. manufacturing establishments, a significant share of which continue across the survey's sample rotation. The ASM and the Census of Manufactures (CM) collect detailed measures of establishments' (versus firms') inputs and outputs at the location of production which allows for measuring differences in geographic variation in production, differences in product mix within large companies, and important variation within as well as between firms. These, combined with the availability of historic microdata, make possible studies of the effect of robotics at manufacturing plants and associated labor outcomes in a way that is not possible on other survey platforms.

The ASM samples and surveys about 50,000 establishments annually from the universe of establishments with at least one employee that are active and classified in the manufacturing sector. In years ending in 2 or 7, ASM data are collected as part of the

[7] The EMS defines industrial robots using the ISO definition "An industrial robot is officially defined by ISO (Standard 8373:1994) as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes." See: http://www.1aufbau.de/isi-wAssets/docs/i/de/publikationen/ems1e.pdf

Census of Manufactures, which in 2012 included about 290,000 active employer manufacturing establishments (U.S. Census Bureau 2018a). The ASM microdata are available back to 1973 for approved research projects in the Federal Statistical Research Data Centers (FSRDC). The ASM samples using a probability measure proportionate to size, with establishments meeting certain criteria (e.g., size as measured by value of shipments) being included in the sample with certainty (U.S. Census Bureau 2018b). These certainty cases, numbering around 15,600 in 2014, generate a large de facto panel that typically continues across the five-year sample rotation as many of these establishments continue to surpass the size threshold.

The ASM currently collects information on capital expenditures for new and used depreciable assets for the reporting period and the year prior to the reporting period (see Figure 1). Assets are broken down into new and used buildings and other structures as well as new and used machinery and equipment. Machinery and equipment are further broken down into vehicles intended for highway use, computer and other peripheral processing equipment, and a residual 'other' category. The CM includes the same capital expenditures data items as the ASM but also collects beginning- and end-of-year asset measures and the gross value of all sold, retired, destroyed, etc. assets, allowing for the construction of establishment-level annual capital stocks (see Figure 2). Importantly, approximately 75% of the assets reported by establishment in 2016 fall in the 'other' category.

3. Content and the Cognitive Testing Process and Outcome

3.1. Background

In April 2017, the Census Bureau received a proposal to add robotics questions to the ASM (see Miranda and Seamans 2017). The proposal included questions that ask establishments to report their expenditures on robotic arms or other robotic equipment, as well as expenditures used for the integration of robotics into specific applications such as assembly and loading or unloading of parts. The proposal suggested these be added as additional categories in the breakdown of capital expenditures on the ASM.

In addition to the proposal, letters of support were obtained by Seamans and Miranda from the Robotics Industries Association (RIA) and the National Association of Manufacturers' Manufacturing Institute (NAM). The letters express that, in the face of declining costs of robotics and expectations of dramatic increases in the use of robotics in U.S. manufacturing, the collection of robotics expenditures data by establishments and firms is necessary in order to better understand the impact of robotics on U.S. businesses and workers. Current data collected from the producers of robotic equipment by the RIA and its international affiliate, the International Federation of Robotics (IFR), are important,

but there are no equivalent data collections from the users of robotic equipment; this proposed collection would fill this data gap.

3.2. Content Review

When considering survey content proposals, the Census Bureau must ensure the proposed content is appropriate with respect to the Census Bureau's mission and position within the larger Federal Statistical System; that the content is consistent within the survey instrument on which it would appear; and that the content is optimal when weighing the benefit of the collection against the burden placed on reporting businesses. Content proposals undergo internal review to ensure appropriateness and consistency within the instrument, as well as the benefit of the collection. The process of cognitive testing is used to ensure that the questions are clear, understandable, and answerable, and to estimate the reporting burden that the proposed content imposes.

The Survey Director for and other staff who work on the ASM reviewed the proposal to ensure the appropriateness to the survey instrument and to determine the potential location of the proposed content. It was determined that, upon successful testing, the proposed content would be added as a "Special Inquiry" at the end of the ASM. Inclusion of the robotics content within the Capital Expenditures section of the survey is not possible at this time given the experimental nature of the collection and the constraints of the production schedule of the ASM.

The initial content proposal was reviewed internally by subject matter experts working in technology and capital expenditures measurement as well as former staff who had worked extensively with the SMT. Subject matter experts also reviewed external data sources and ensured that no other private entity nor statistical agency was collecting this information. Changes based on internal review were incorporated into the survey instrument, including language referring to other one-time costs associated with the equipment. Multiple definitions of robotic equipment were developed for review and testing. Reviewers mentioned the need for expenditures data along with a corresponding stock measure of capital, leading to the addition of an asset question along with the proposed expenditures question. Reviewers also stated that knowing the value of robotic equipment might be difficult for respondents, and thus proposed asking the respondent to estimate how many robots are used at the establishment and their average price in order to allow for the estimation of the gross value of robotic equipment at the plant. The draft content resulting from this internal review process was the basis for the first round of cognitive testing (see Figures 3a and 3b).

3.3. Cognitive Testing

3.3.1. Overview

Census Bureau Statistical Quality Standard A2 requires that all new survey content undergo cognitive testing prior to inclusion on a Census Bureau survey instrument. The result of this cognitive testing should be an understanding of the quality of the proposed data collection as well as the burden imposed on the respondent. Cognitive testing for business survey instruments is generally comprised of two stages. In the first stage, often referred to as the exploratory round of testing, interviews are conducted with potential survey respondents to examine whether the respondent understands the question, whether the records kept at the business support the data collection, and whether the measurement concepts embodied in the question reflect the economic activity and/or record keeping practices of the business. The first round of testing for the ASM robotics capital expenditures questions included not only a cognitive portion but also an early stage scoping portion that included probes designed to learn about the use of robotics at the company, record keeping for the robotics acquisition, use and maintenance of robotics at the company, and language or terminology used by the respondent when discussing robotics. After the first round of testing, proposed survey content is revised based on cognitive, record keeping, or other considerations uncovered during the exploratory phase. This revised content is the basis for a second stage of cognitive testing, often referred to as the confirmatory round. In the confirmatory round, changes made to the instrument based on the first round of cognitive testing are (in-)validated, typically resulting in the final draft content.

Cognitive testing interviews are scheduled and conducted by a staff member from the Data Collection Methodology and Research Branch within the Economic Statistical Methods Division of the Census Bureau. Subject matter experts may attend as observers and are available if subject matter questions arise from the respondent. Each round of cognitive testing typically includes about twenty respondents, ten in each of two locations. Generally, distinct locations are selected in order to generate variability in both geography and industrial mix. Phone interviews may be used to supplement in-person interviews and are useful when a willing participant is unavailable during the scheduled testing period or when additional diversity of geography or industry is required in the face of budget or time constraints. Materials used in cognitive testing are submitted to and approved in advance by the Office of Management and Budget (OMB) as is required under the Paperwork Reduction Act. The number of interviews and the respondent burden, as measured by time spent recruiting and interviewing, is estimated and reported in the materials submitted to OMB. Cognitive interviews each last approximately one hour and are confidential under the

same law (Title 13 U.S.C.) that governs the Census Bureau's collection of information from businesses.

3.3.2. Selection of cases for cognitive testing

The set of establishments in scope for cognitive testing included all active employers classified as manufacturers in the 2016 ASM. Establishments were also required to have reported complete contact information including respondent name, business address, and phone number. In order to maximize the probability of contacting establishments using robotics for our cognitive testing sample, we used robotics shipments data provided to Seamans by the RIA to generate a list of 3- and 4-digit NAICS industries that were most likely to use robotic equipment. Then, using County Business Patterns data we tabulated establishment counts by core-based statistical area (CBSA) and these targeted industries. These tabs were used to select CBSAs with a good balance of robot-using industries and the related set of establishments most likely to use robotics (see Buffington, Miranda and Seamans, 2017).[8] Tables 1 and 2 show the list of top 11 robot intensive industries and the ranking of top CBSAs respectively based on this analysis.

Based on this analysis, we selected Detroit and Chicago as the locations for our first round of testing. A day was also spent visiting businesses in the Philadelphia/central New Jersey area in order to diversify across industries. Based on the same analysis, we selected Los Angeles, Dallas/Fort Worth and Houston as the locations for the second round of testing. The first round of cognitive testing was conducted in September 2017 and the second round over late January into February 2018. Recruiting for these interviews proved difficult with a high number of refusals as well as difficulty in locating manufacturers with robotic equipment, limiting the number of cases per location to less than the usual ten. Including some establishments without robotics equipment was desirable in order to ensure that manufacturers not using robotics would not mistakenly report expenditures, but we were most interested in interviewing those that did use robotics. Buffington, Helper, Miranda and Seamans served as observers in many of the cognitive interviews to serve as subject matter experts while in the field but also to apply subject matter expertise to revisions that resulted from the testing process.

[8] The RIA data provides robot shipment counts and value of shipments by industry for years 2012 through 2017. We used this information to estimate robot intensity use by industry as well as the likelihood that a random establishment would use robots in that industry. Our methodology involved the following steps. First we computed the number of units shipped per establishment by industry and year. Establishment counts for 2016 were approximated by straight line imputation of CBP by industry based on the 2012-2015 growth trend. We then estimated the cumulative number of robot units in 2017 for the average establishment by industry and year. We accounted for differences between the industry codes used by the Census and the industry codes used by RIA.

3.3.3. Round 1 Cognitive Testing Recommendations and Findings

The first round of testing took place in September 2017 in Detroit and Chicago, with a supplemental trip to central New Jersey and the greater Philadelphia area. See Figures 3a and 3b for the tested content. The content included an extended definition of industrial robotic equipment based on ISO 8373:2012 used by the RIA and IFR (International Federation of Robotics 2016). This definition was used to provide clear technical guidance from an authoritative source as well as to limit the scope of the data reported to that of the RIA and IFR in order to support future data benchmarking. Two versions of the extended definition were tested. Figure 3a includes the version of the definition that was preferred after testing; the other tested version did not include the term 'industrial' when referring to robots.

In total, four questions and two definitions were tested in the first round. One set of questions used dollars as the unit of measurement and the other set used pieces of robotic equipment as the unit of measurement. Both pairs of questions sought a capital stock measure as well as an expenditures or flow measure. Figure 3a presents the dollar-based questions. The first question (A.) asks about the gross value of robotic equipment at the end of the year and the second question (B.) asks about expenditures on new and used robotic equipment. These questions were based on the "ASSETS, CAPITAL EXPENDITURES, RETIREMENTS, AND DEPRECIATION" section of the 2012 ASM and the "CAPITAL EXPENDITURES" section of the 2016 ASM, respectively. Figure 3b presents the alternate question pair. The questions included the number of industrial robots in use at the plant, the average price, and the number of robots purchased in that year. After testing for these question pairs and definitions was complete, the cognitive testing staff produced a report including Findings and Recommendations (See Table 3).

Generally, the response to the proposed content was positive. Respondents on average reported that the term "industrial robotic equipment" was preferred (see Findings 1 and 11) to "robotics" or "robotics equipment". Typically, respondents understood what was meant by robotic equipment, but many agreed that a list of examples or a list of equipment to include and exclude would be useful (see Finding 11). Companies typically purchase, not lease, robotic equipment and most expense the equipment using generally accepted accounting principles (GAAP) or other guidelines (Findings 5 and 4). Respondents had access to records that included the information required to answer these questions, but these records were not identified or flagged as robotic equipment in their asset registers (Finding 2). Because larger establishments and/or companies generally have larger asset registers and because these questions would require research using the asset register, the burden of responding to these questions generally would increase along with company size (Finding 12). (Herrell and Stettler (2017)). However, several large respondents indicated that they

could add a flag to their registers to identify robotic equipment if they knew the ASM survey questions would recur, and that this step would reduce their reporting burden. Others commented that they could call a plant manager, who could easily estimate; thus, providing the instruction that estimates are acceptable would reduce their reporting burden as well. The phrase "other one-time expenses" did not create any cognitive issues, and respondents typically reported that other one-time expenses including installation charges and software were typically included on the invoices for robotic equipment purchases.

The questions concerning gross value of assets and capital expenditures on industrial robotic equipment resulted in mixed test results. The term "gross value" had a variety of interpretations. Some respondents thought the question was asking for current market value, while others thought the question was asking for net book value or purchase price. For those respondents who took the term to mean current market value, they stated this was difficult or impossible to report. Respondents noted that net book value and purchase price could be easily obtained from records, but many questioned whether net book value was informative as in many instances depreciation would drive this value to zero before the end of the useful life of the equipment. Purchase price also had drawbacks, namely the lack of information about vintage and depreciation (see Finding 8). Based on these findings as well as additional internal review for consistency with the ASM survey instrument, the decision was made to drop the gross value question. Apart from the respondent burden issue, the capital expenditures question tested well (see Findings 2 and 9).

The questions using counts of robotic equipment and average price were generally understood, and in most cases respondents could answer for both how many were in place and how many were purchased in the reporting year. Respondents did feel questions about price were burdensome and questioned the usefulness of average price data. Just as with respondents with large asset registers, the ability of respondents to answer these questions and the burden imposed on the respondent increased with the size of the establishment and/or company. The testing staff recommended that in the second round of testing specifically stating that individual pieces of robotic equipment should be counted separately, regardless of whether they were working in conjunction with another piece of robotic equipment. For example, a robotic welding cell may contain several individual robot arms (See Finding 10).

3.3.4. Round 2 Cognitive Testing Recommendations and Findings

Figure 4 shows the survey content used in the second round of cognitive testing. In order to present something closer to what the respondents would see when using the Census Bureau's online reporting software, the test instrument was changed to reflect online formatting and design elements. Material changes to the instrument include the

changes to the definition as recommended by the first round of cognitive testing (the consistent use of the term "industrial robotic equipment" throughout the instrument), the use of the term "adaptable" instead of the word "multipurpose", the inclusion of a bulleted list of examples of robotic equipment considered in-scope, and a specific list of equipment that should be excluded from reporting. These examples and lists of equipment to exclude were used to address common questions or issues that arose in the first round of testing but also to scope the question using the same delineations as the IFR. The gross value question meant to measure the stock of robotic equipment at the establishment was dropped, as was the question asking about the average price of robotic equipment. Instead, the draft survey content included the dollar-based question for capital expenditures and the count-based questions for capital stock ("how many industrial robots were used"). The count-based question for expenditures was also retained ("how many industrial robots were purchased"). Prior to the capital expenditures on robotics question, the cognitive testing staff also added a reference back to the total value of capital expenditures that would be reported by the respondent in an earlier survey question. Instructions for how to count robotic equipment that might be integrated into another piece of equipment or cell with other robotic equipment was also included. Finally, a "check if none" box was added for each of the questions as well as a prior year reporting box.

Findings and recommendations from the second round of testing can be found in Table 4. Respondents generally understood the definition, instructions, and questions as written (see Finding 1). Some respondents believed that Computer Numerically Controlled (CNC) machining equipment and Automated Guided Vehicles (AGVs) should be included as robotic equipment despite the exclude instruction (see Finding 2). As in the first round of testing, respondents' records did include the information on capital expenditures and other one-time expenses associated with robotics but reporting this information was found to be not without burden (see Finding 3). The count questions were not difficult or burdensome for respondents at establishments that did not use robotics or had a small number of robots, but burden increased with the increase in the use of robotics at the plant such that the testing staff believes that data collected from large establishments will be of poor quality, if reported at all (see Finding 4). Furthermore, some respondents were reluctant to report for each piece of robotic equipment in the count questions regardless of instructions to do so (see Finding 5). Respondents reported different guidelines and dollar thresholds used for depreciating capital equipment, while at least one reported expensing robotic equipment as maintenance in instances where the robotics were replacing a failed part in a larger system or integrated equipment (Finding 6). Because of the small sample size for the first two rounds of cognitive testing, owing in large part due to difficulty in finding establishments with robotic equipment and willing to participate in cognitive interviews, especially with regard to large companies, the testing staff recommended additional research including a

third round of cognitive testing, as well as debriefing interviews to be conducted after the 2018 ASM is conducted (Finding 7).

3.3.5. Round 3 Cognitive Testing

Although two rounds of cognitive testing are typical, because we had not exhausted the number of visits or time constraint as approved by OMB for testing, we revised the instrument based on findings from the second round and participated in a limited third round of (confirmatory) testing. An additional four interviews were conducted by phone in late April 2018, with three of these being follow up calls to respondents who had participated in the earlier rounds of testing and had agreed to review the modified instrument.

A shaded text box was drawn around the definition in order to cue the respondent that this was informational; white space was added for readability and to separate concepts within the information block. A sentence was added to clarify language around robotic cells and rail systems, and a sentence was added to clarify how semiconductor manufacturers should treat track systems, as these specific issues arose during the second round of testing (see Figure 5a).

Research in the cognitive testing field suggests it might be desirable to replace lengthy instructions in survey instruments with equivalent check box versions formulated in the form of questions in order to lessen the cognitive burden and to force the respondent to slow down and pay attention to important concepts (Snijkers et al (2013)). Based on this, the cognitive testing staff recommended the inclusion of a series of text boxes to capture the heterogeneity of industrial robotic equipment that a manufacturing plant might use. The check boxes list the types of robotic equipment included in the second round content and additional types of robotic equipment not previously listed (see Figure 5b). This format also allows us to request information about "other" types of robotic equipment not listed which might be in use at the plant.

The instructions were modified further to reduce confusion and provide more clear and consistent guidance. Specifically, instructions for the robotics capital expenditures question making reference to the establishment's total capital expenditures reported elsewhere in the survey was removed. The question header was changed to reflect language used elsewhere in the ASM. Explicit instructions for reporting by question number were added, as well as instructions to address and recognize the inability to break out the cost of robotic equipment from integrated equipment purchases reported by some respondents (see Figure 5c).

The cognitive testing staff did not produce a full report given the small sample available in the third round. However, they did make recommendations based on their experience and the interviews conducted (See Table 5). First, a simplification was recommended in the initial description of robotic equipment. The instruction that a robot can be "part of a rail system" was replaced with "incorporated into another piece of equipment" as further research indicated that rail systems used in semiconductor manufacturing are implementations of Automated Materials Handling Systems and should be excluded[9]. This simpler language was also found to be easier to understand. Second, the checkbox question tested well but the recommendation was that it should not be included if the list of robotic equipment was not exhaustive. Third, the testing staff recommended that the terms "new and used", taken from the ASM capital expenditures section, should not be included as it created confusion with the concept of counting equipment *used* at the plant. Finally, they recommended that because equipment may be capitalized or expensed, it would be beneficial to clarify the count questions in order to specify whether only equipment being capitalized should be included in order to align with the concepts in the first question.

The instrument was finalized in July 2018; see Figures 6a-6c for the content that was submitted to OMB for clearance in October 2018. The instructions were simplified as described above. The checkbox question was rejected as it would create additional reporting burden for ASM respondents. Further white space was added between questions 1, 2, and 3 and instructions just prior to questions 1 and 2 were customized for each type of question. The language "new and used" was retained in the capital expenditures question in order to maintain continuity with the earlier ASM question, and the potentially confusing term "USED" in question 2 was changed to "IN OPERATION". Last, a new comment box was added to each of the count questions (e.g., "If you are unable to provide the number of industrial robots PURCHASED in 2018, please explain.") in order for respondents to provide additional information if they are unable to report on the count questions.

4. Conclusion

Robotics will likely have a large effect on our economy and society, but additional data on the use of robotics is needed. The U.S. Census Bureau does not currently collect any data on robotics, but it has collected similar data in the past via the Survey of Manufacturing

[9] Rail systems in semiconductor manufacturing include autonomous vehicles used to move materials between locations (Kim 2008). Autonomous vehicles as well as more generally robotic logistical systems are classified as service robots (International Federation of Robotics 2016).

Technology. In Europe, the European Manufacturing Survey collects firm level data on the use of robotics.

To address the need for data on robotics, our research team, which was comprised of internal Census employees and external university researchers, developed questions on robotics for inclusion in the Census' Annual Survey of Manufactures. The questions include: (1) capital expenditures for new and used industrial robotic equipment in 2018, (2) number of industrial robots in operation in 2018, and (3) number of industrial robots purchased in 2018. These questions were arrived at following an extensive cognitive testing process, the details of which are described within.

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Table 1. List of Top 11 Robot Intensive Industries

Beverages
Chemical products, pharmaceuticals, cosmetics
Basic metals (e.g. iron, steel, aluminum, copper, chrome etc.)
Industrial machinery
Household appliances
Electronic components/devices
Semiconductors, LCD, LED
Computers and peripheral equipment
Information communication equipment domestic and professional
Motor vehicles, motor vehicles engines and bodies
Parts and accessories for motor vehicles

Source: Authors' calculations based on RIA data.

Table 2. Ranking CBSA areas based on Robot Intensity Use

CBSA code	CBSA title	Number of Robot Intensive Industries	Number of Top 11 Robot Intensive Industries
14460	Boston-Cambridge-Newton, MA-NH	16	11
31080	Los Angeles-Long Beach-Anaheim, CA	16	11
16980	Chicago-Naperville-Elgin, IL-IN-WI	15	10
19100	Dallas-Fort Worth-Arlington, TX	15	10
33460	Minneapolis-St. Paul-Bloomington, MN-WI	15	10
35620	New York-Newark-Jersey City, NY-NJ-PA	15	10
38060	Phoenix-Mesa-Scottsdale, AZ	15	10
40140	Riverside-San Bernardino-Ontario, CA	15	10
41740	San Diego-Carlsbad, CA	15	10
41860	San Francisco-Oakland-Hayward, CA	15	10
12060	Atlanta-Sandy Springs-Roswell, GA	14	9
12420	Austin-Round Rock, TX	14	9
19740	Denver-Aurora-Lakewood, CO	14	9
19820	Detroit-Warren-Dearborn, MI	14	9
26420	Houston-The Woodlands-Sugar Land, TX	14	9
33100	Miami-Fort Lauderdale-West Palm Beach, FL	14	9
37980	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	14	9
38900	Portland-Vancouver-Hillsboro, OR-WA	14	9
41940	San Jose-Sunnyvale-Santa Clara, CA	14	9
42660	Seattle-Tacoma-Bellevue, WA	14	9
45300	Tampa-St. Petersburg-Clearwater, FL	14	9
12580	Baltimore-Columbia-Towson, MD	13	8
26900	Indianapolis-Carmel-Anderson, IN	13	8

15380	Buffalo-Cheektowaga-Niagara Falls, NY	12	7
16740	Charlotte-Concord-Gastonia, NC-SC	12	7
17140	Cincinnati, OH-KY-IN	12	7
17460	Cleveland-Elyria, OH	12	7
28140	Kansas City, MO-KS	12	7
40900	Sacramento--Roseville--Arden-Arcade, CA	12	7
41180	St. Louis, MO-IL	12	7
41620	Salt Lake City, UT	12	7
18140	Columbus, OH	10	6
24340	Grand Rapids-Wyoming, MI	11	6
33340	Milwaukee-Waukesha-West Allis, WI	11	6
34980	Nashville-Davidson–Murfreesboro--Franklin, TN	11	6
35300	New Haven-Milford, CT	11	6
36740	Orlando-Kissimmee-Sanford, FL	11	6
46140	Tulsa, OK	11	6
49340	Worcester, MA-CT	10	6
10420	Akron, OH	10	5
13820	Birmingham-Hoover, AL	10	5
14500	Boulder, CO	10	5
14860	Bridgeport-Stamford-Norwalk, CT	10	5
19380	Dayton, OH	10	5
24860	Greenville-Anderson-Mauldin, SC	10	5
25540	Hartford-West Hartford-East Hartford, CT	10	5
29820	Las Vegas-Henderson-Paradise, NV	9	5
31140	Louisville/Jefferson County, KY-IN	9	5
37100	Oxnard-Thousand Oaks-Ventura, CA	10	5
38300	Pittsburgh, PA	10	5
47900	Washington-Arlington-Alexandria, DC-VA-MD-WV	9	5

Source: Authors' calculations based on County Business Patterns data.

Table 3. Findings and Recommendations from Round 1 of Cognitive Testing

Findings	Recommendations	Accepted
1) Respondents had definitional differences between Robots, Robotic Equipment, and Industrial Robotic Equipment.	We recommend using the term "robotic equipment" or "industrial robotic equipment" throughout the survey, although when a question asks about a singular unit of robotic equipment, such as asking for the number on hand at a location, it is unclear whether "robot" should be used, or something like "piece of robotic equipment." Another alternative would be using "robotic equipment" as the main term, but defining "robot" as an individual unit and using that for count questions.	Y
2) Records have most of the information we need, but cannot sort robotic equipment from other equipment.	No recommendation. "Estimates are acceptable" may be useful for respondents who feel that going through records would be too burdensome.	NA
3) Servicing of the equipment varies by company.	No recommendation.	NA
4) Most companies capitalize robotic equipment, based on GAAP or other requirements.	No recommendation.	NA
5) Most companies purchase rather than lease; leased equipment may pose a problem for reporting costs.	Census should be aware that respondents may treat leased equipment differently than purchased based on what's available in their records, and that responses may differ as a result.	NA
6) Robotics equipment is currently reported as "Other" capital expenditures on the ASM by all respondents we spoke with.	No recommendation.	NA

Findings	Recommendations	Accepted
7) Determining what an individual "robot" is could be problematic.	Definitions should clarify what exactly an individual "robot" or piece of "robotic equipment" is and how to count it, regarding either of the above situations. We make the following recommendations, based on our understanding of what can be commonly understood and applied across respondents: Each individual robot or piece of robotic equipment that was purchased should count as an individual robot, regardless of whether it was working in conjunction with another robot on a specific task. If a piece of robotic equipment was affixed to a piece of non-robotic equipment, only the value of the robotic equipment should be counted.	Y
8) Gross Value version of question had varying interpretations.	We recommend not asking the gross value of the robotic equipment, due to the difficulty respondents had interpreting the question and the questionable usefulness of the data.	Y
9) Total capital expenditures somewhat clear, but some slight confusion.	In the second round of testing, probe respondents on what they may include as "other one-time costs." It may be helpful to conduct interviews with a handful of robotics manufacturers and system integrators, with the purpose of learning what they included in the sales price of robotic equipment.	Y and N

Findings	Recommendations	Accepted
10) Count and average purchase price were generally understood; questionable usefulness of average purchase price.	The count question generally tested well, and could be reported for both the number on hand and the number purchased in 2017. Census should determine whether it is more useful to know the number on hand or the number currently in use, or both, and phrase the question(s) accordingly. Add specific instructions on this issue to the question, and probe respondents in Round 2 on whether these instructions are clear and/or appropriate. For the sake of ease of reporting and creating consistency between respondents, we suggest the following: --Each individual robot or piece of robotic equipment that was purchased should count as an individual robot, regardless of whether it was working in conjunction with another robot on a specific task. --If a piece of robotic equipment was affixed to a piece of non-robotic equipment, only the value of the robotic equipment should be counted. Average purchase price had issues, with some respondents feeling that it added burden (having to calculate the average), that it was not asked elsewhere on the ASM and is thus an unusual task for them, and some questioned the usefulness of the data. For those reasons, we recommend not asking about the average purchase price.	Y
11) Definition with "industrial" in it was preferable to most respondents.	The version of the definitions/instructions using "industrial" should be used. Ensure that terminology is kept consistent between the instructions/definition and the question itself. Remove the term "multipurpose" completely, or replace it with something such as "physically adaptable to different applications" Consider adding bulleted lists of include, exclude, and examples.	Y
12) Estimated difficulty and burden of questions.	Continue to probe in Round 2 about the estimated burden and difficulty of these questions, and any estimation strategies, particularly for larger companies.	NA
13) Neither of the questions or definitions tested perfectly; a revised version should be used in another round of testing.	[Provided revised questions and definition]	Y

NOTE: This table was developed based on Herrell and Stettler (2017).

Table 4. Findings and Recommendations from Round 2 of Cognitive Testing

Findings	Recommendations	Accepted
1) Respondents generally understood what the questions were asking for, and for the most part, did not have trouble with the instructions or definitions, but changes could be made.	Reformat the instructions into a short series of instructions, followed by a question [that turns instructions into a series of check boxes].	Y
2) Several respondents took issue with Computer Numerical Control (CNC) machinery and Automated Guided Vehicles (AGVs) being excluded.	Although we did not talk to any respondents who would do so, it is possible that other respondents would feel compelled to report CNC machinery as robotics. The recommendation from Question 1 would allow such respondents to select Other, and use the specify line to include what they deem to be robotic equipment	N
3) As in Round 1, most respondents have the capital expenditures for robotics included in their capital expenditures, but cannot identity them as robotics easily.	In addition to the note that says "estimates are acceptable," we recommend providing a checkbox next to the answer field allowing respondents to indicate that their answer is an estimate, thus providing further assurances that we are accepting of estimates for this particular question.	N
4) Count of robots is feasible for companies with few or no robots, but may be too burdensome for respondents in larger companies and extremely difficult to get accurate figures.	Our first recommendation would be to not collect the data on the count of respondents. Based on the interviews we have conducted, we think that large companies will have tremendous issues, if not outright inability, to provide accurate numbers. Even with the limited number of large companies that we have interviewed, we have not found any company of any size that flags purchases by whether or not they are robotic, and we therefore think that it is unlikely that any company would have an automated method to pull data specifically in regards to industrial robotic equipment. We recognize that there are some benefits to starting to collect the data, and under the intended plan to ask the questions only as a special inquiry, we do not strongly object. However, we do not believe that the data from the initial collection should be published.	N
5) Some respondents would provide a count that differed from our instructions, even though they understood what they were being instructed to do.	See recommendation for Finding#4 above.	N

Findings	Recommendations	Accepted
6) Companies have different requirements for what meets capital expenditures requirements; not all companies follow GAAP.	No recommendation.	NA
7) Because of the small sample size from these rounds of testing, particularly in regards to large companies, more research should be done on the topic.	We strongly recommend conducting debriefing interviews after these questions are fielded, to learn more about respondents' behaviors when they are actually required to go through their records or contact plant managers to provide the data that is being asked for.	Y
8) The new tax bill will likely not impact how respondents maintain their accounting records nor how they report on Census surveys; respondents did not know how it would impact their investment in robotics.	No recommendation.	NA

NOTE: This table was developed based on Herrell and Stettler (2018a).

Table 5. Recommendations from Round 3 of Cognitive Testing

Topics	Recommendations	Accepted
Instructions	Consider changing the line about robotic cells to read "An industrial robot may be incorporated into another piece of equipment."	Y
Checkbox question	Leave the checkbox question as is, but ensure the list of options is mostly comprehensive. If it is not feasible to have a comprehensive list, exclude this question.	N
Capital expenditures and number of purchased/used questions	Remove "new and used" from the capital expenditures question. Add clarifying instructions to line 3, regarding whether only capitalized purchases should be included.	N

NOTE: This table was developed based on Herrell and Stettler (2018b).

Figure 1. Annual Survey of Manufactures Capital Expenditures Content

Capital Expenditures

What were the capital expenditures for new and used depreciable assets spent in 2016 for ...

Capital expenditures for new and used buildings and other structures (Exclude land.) (Report in thousands of dollars)	
Prior year capital expenditures for new and used buildings and other structures (Exclude land.) (Report in thousands of dollars)	
Capital expenditures for new and used machinery and equipment (Report in thousands of dollars)	
Prior year capital expenditures for new and used machinery and equipment (Report in thousands of dollars)	
Total capital expenditures, new and used depreciable assets in 2016 (Add values reported for CAPEX_BUILD and CAPEX_MACH.) (Report in thousands of dollars)	
Prior year total capital expenditures, new and used depreciable assets in 2015 (Add values reported for CAPEX_BUILD_PY and CAPEX_MACH_PY.) (Report in thousands of dollars)	

What was the breakdown of expenditures for new and used machinery and equipment by type?

Capital expenditures for automobiles, trucks, etc. for highway use (Report in thousands of dollars)	
Prior year capital expenditures for automobiles, trucks, etc. for highway use (Report in thousands of dollars)	
Capital expenditures for computers and peripheral data processing equipment (Report in thousands of dollars)	
Prior year capital expenditures for computers and peripheral data processing equipment (Report in thousands of dollars)	
Capital expenditures for all other expenditures for machinery and equipment (Report in thousands of dollars)	
Prior year capital expenditures for all other expenditures for machinery and equipment (Report in thousands of dollars)	
Total capital expenditures for machinery and equipment by type (Add values reported for CAPEX_MACH_AUTO, CAPEX_MACH_COMP and CAPEX_MACH_OTH. Total should equal value reported for CAPEX_MACH.) (Report in thousands of dollars)	
Prior year total capital expenditures for machinery and equipment by type (Add values reported for CAPEX_MACH_AUTO_PY, CAPEX_MACH_COMP_PY and CAPEX_MACH_OTH_PY. Total should equal value reported for CAPEX_MACH_PY.) (Report in thousands of dollars)	

Figure 2. 2017 Census of Manufactures Capital Expenditures Content

ITEM 13: ASSETS, CAPITAL EXPENDITURES, AND RETIREMENTS

Include:

- Dollar value of assets, capital expenditures, and retirements
- Buildings, structures, and equipment used directly or indirectly by this establishment to produce the goods and services reported in **Item 5**, line A and **Item 22**

	Check if None	2017
A. What was the gross value of depreciable assets (**acquisition costs**) at the beginning of the year?	☐	$,000.00
B. What were the capital expenditures for new and used depreciable assets in 2017 for:		
1. New and used buildings and other structures? **Exclude:** • The value of land on which structures stand	☐	$,000.00
2. New and used machinery and equipment?		
a. Automobiles, trucks, etc. for highway use?	☐	$,000.00
b. Computers and peripheral data processing equipment?	☐	$,000.00
c. All other expenditures for machinery and equipment?	☐	$,000.00
TOTAL (Add lines B1 and B2a through B2c.)	☐	$,000.00
C. What was the gross value of depreciable assets sold, retired, scrapped, destroyed, etc.?	☐	$,000.00
D. What was the value of depreciable assets at the end of the year? (Add lines A, B1, B2a through B2c and subtract line C.)	☐	$,000.00

Figure 3a. Survey Content Draft for Round 1 of Cognitive Testing

INDUSTRIAL ROBOTIC EQUIPMENT ASSETS AND EXPENDITURES

An industrial robot is an automatically controlled, reprogrammable, and multipurpose machine that is used in industrial automation operations.

Industrial robots may be mobile, incorporated into stand-alone stations, or integrated into the production line.

Industrial robots are commonly used in operations such as welding, material handling, machine tending, dispensing, and pick and place.

Report the dollar value.

	2017		
	$ Bil.	Mil.	Thou.
A. Gross value of industrial robotic equipment at the end of 2018.			
B. Capital expenditures in 2018 for new and used industrial robotic equipment, including software, installation and other one-time costs.			

Figure 3b. Survey Content Draft for Round 1 of Cognitive Testing

INDUSTRIAL ROBOTIC EQUIPMENT

An industrial robot is an automatically controlled, reprogrammable, and multipurpose machine that is used in industrial automation operations.

Industrial robots may be mobile, incorporated into stand-alone stations, or integrated into the production line.

Industrial robots are commonly used in operations such as welding, material handling, machine tending, dispensing, and pick and place.

A. Number of industrial robots used at this plant in 2018. . . . . .

B. Average purchase price of industrial robots used at this plant in 2018 (include software, installation and other one-time costs). . . . . .

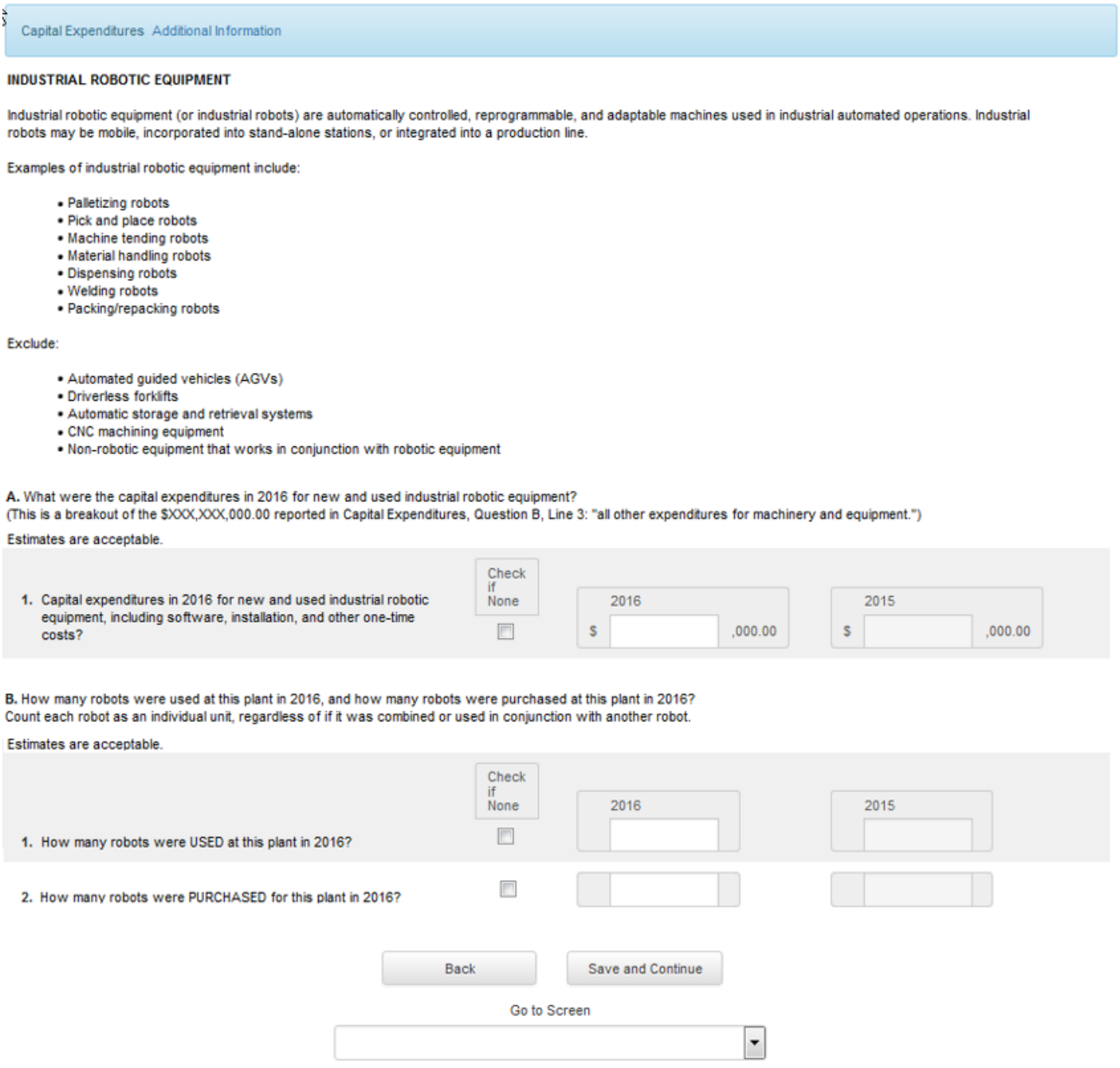
2017		
$ Bil.	Mil.	Thou.

C. Number of industrial robots purchased for this plant in 2018. . .

D. Average purchase price of industrial robots purchased for this plant in 2018 (include software, installation and other one-time costs). . . . . .

2017		
$ Bil.	Mil.	Thou.

Figure 4. Survey Content Draft for Round 2 of Cognitive Testing



Capital Expenditures Additional Information

INDUSTRIAL ROBOTIC EQUIPMENT

Industrial robotic equipment (or industrial robots) are automatically controlled, reprogrammable, and adaptable machines used in industrial automated operations. Industrial robots may be mobile, incorporated into stand-alone stations, or integrated into a production line.

Examples of industrial robotic equipment include:

- Palletizing robots
- Pick and place robots
- Machine tending robots
- Material handling robots
- Dispensing robots
- Welding robots
- Packing/repacking robots

Exclude:

- Automated guided vehicles (AGVs)
- Driverless forklifts
- Automatic storage and retrieval systems
- CNC machining equipment
- Non-robotic equipment that works in conjunction with robotic equipment

A. What were the capital expenditures in 2016 for new and used industrial robotic equipment?
(This is a breakout of the $XXX,XXX,000.00 reported in Capital Expenditures, Question B, Line 3: "all other expenditures for machinery and equipment.")

Estimates are acceptable.

	Check if None	2016	2015
1. Capital expenditures in 2016 for new and used industrial robotic equipment, including software, installation, and other one-time costs?	☐	$,000.00	$,000.00

B. How many robots were used at this plant in 2016, and how many robots were purchased at this plant in 2016?
Count each robot as an individual unit, regardless of if it was combined or used in conjunction with another robot.

Estimates are acceptable.

	Check if None	2016	2015
1. How many robots were USED at this plant in 2016?	☐		
2. How many robots were PURCHASED for this plant in 2016?	☐		

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Figure 5a. Survey Content Draft for Round 3 of Cognitive Testing

INDUSTRIAL ROBOTIC EQUIPMENT

Industrial robotic equipment (or industrial robots) are automatically controlled, reprogrammable, and multipurpose machines used in industrial automated operations.

Industrial robots may be mobile, incorporated into stand-alone stations, or integrated into a production line.

An industrial robot may be part of a robotic cell (or work cell) or part of a rail system.

In semiconductor manufacturing, an industrial robot may be part of a track system.

Industrial robots are commonly used in operations such as welding, material handling, machine tending, dispensing, cleanroom, and pick and place.

Figure 5b. Survey Content Draft for Round 3 of Cognitive Testing

INDUSTRIAL ROBOTIC EQUIPMENT

Check "Yes" if any of the following types of industrial robotic equipment is used at this establishment.

If some other type of industrial robotic equipment is used at this establishment, provide the type of industrial robotic equipment used in the write-in box next to "Other".

Exclude:

- Automated guided vehicles (AGVs)
- Driverless forklifts
- Automatic storage and retrieval systems
- CNC machining equipment

	YES	NO
Dispensing robots	☐	☐
Flat Panel Display (FPD) transfer robots	☐	☐
Machine tending robots	☐	☐
Material handling robots	☐	☐
Packing/repacking robots	☐	☐
Painting robots	☐	☐
Palletizing robots	☐	☐
Pick and place robots	☐	☐
Wafer handling robots	☐	☐
Welding robots	☐	☐

Other robotic equipment, specify _____

Figure 5c. Survey Content Draft for Round 3 of Cognitive Testing

CAPITAL EXPENDITURES FOR INDUSTRIAL ROBOTIC EQUIPMENT AND NUMBER OF INDUSTRIAL ROBOTS

In (1), report capital expenditures in 2017 for new and used industrial robotic equipment for this plant. Include other one-time costs, including software and installation.

In (2) and (3), report the number of industrial robots used at this plant and purchased for this plant in 2017.

For robots purchased as part of a work cell, track system, or other integrated robotic equipment, it may not be possible to report the expenditures on only the robots. In this case, report the expenditures on the integrated robotic equipment.

Exclude:

- Automated guided vehicles (AGVs)
- Driverless forklifts
- Automatic storage and retrieval systems
- CNC machining equipment

Estimates are acceptable.

Report capital expenditures in dollars.

	Check if none	2017
1. Capital expenditures in 2017 for new and used industrial robotic equipment, including software, installation, and other one-time costs	☐	
	Check if none	2017
2. Number of industrial robots USED at this plant in 2017	☐	
	Check if none	2017
3. Number of industrial robots PURCHASED for this plant in 2017	☐	

Figure 6a. Final Proposed Content

INDUSTRIAL ROBOTIC EQUIPMENT

Industrial robotic equipment (or industrial robots) are automatically controlled, reprogrammable, and multipurpose machines used in industrial automated operations.

Industrial robots may be mobile, incorporated into stand-alone stations, or integrated into a production line.

An industrial robot may be part of a robotic cell (or work cell) or incorporated into another piece of equipment.

Industrial robots are commonly used in operations such as welding, material handling, machine tending, dispensing, cleanroom, and pick and place.

Figure 6b. Final Proposed Content

CAPITAL EXPENDITURES FOR INDUSTRIAL ROBOTIC EQUIPMENT AND NUMBER OF INDUSTRIAL ROBOTS

In (1), report capital expenditures in 2018 for new and used industrial robotic equipment for this plant. Include other one-time costs, including software and installation.

In (2) and (3), report the number of industrial robots in operation at this plant and purchased for this plant in 2018.

For robots purchased as part of a work cell or other integrated robotic equipment, it may not be possible to report the expenditures on only the robots. In this case, report the expenditures on the integrated robotic equipment.

Examples of operations industrial robotic equipment can perform may include:

- Palletizing
- Pick and place
- Machine tending
- Material handling
- Dispensing
- Welding
- Packing/repacking

Exclude:

- Automated guided vehicles (AGVs)
- Driverless forklifts
- Automatic storage and retrieval systems
- CNC machining equipment

Report capital expenditures in thousands of dollars. Estimates are acceptable.

	Check if none	2018
1. Capital expenditures in 2018 for new and used industrial robotic equipment, including software, installation, and other one-time costs	☐	

Figure 6c. Final Proposed Content

Report the number of robots. Estimates are acceptable.

	Check if none	2018
2. Number of industrial robots IN OPERATION at this plant in 2018	☐	

If you are unable to provide the number of industrial robots IN OPERATION in 2018, please explain.

	Check if none	2018
3. Number of industrial robots PURCHASED for this plant in 2018	☐	

If you are unable to provide the number of industrial robots PURCHASED in 2018, please explain.
