European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
http://eelet.org.uk

# Assessing Key Success Elements for the Economic Sustainability of the Robotics Industry

**Dr. Sawankumar Naik**
Assistant Professor, Mechanical Engineering Dept.,

Mukesh Patel School of Technology Management & Engineering, SVKM's NMIMS University

**Dr. Girish Bagale**
Associate Professor, Pravin Dalal School of Entrepreneurship & Family Business Maangement

SVKM's NMIMS University

Girish.Bagale@nmims.edu

**Abstract**
Robotics frequently entails the provisioning of resources in order to maximize long-term sustainability. When analyzing investments and funding, economic theories and models assist in assessing the dynamics of the remedy market, environmental impacts, and policy impacts. The numerous costs and challenges are identified in the current study. By classifying the 12 encountered elements into causes and effects to detect the causal interrelationships, the study is successful in providing guidelines for development of a model.

**Keywords:** Economic factors, Robotics, MCDM

## Introduction:

With applications in everything from industry and healthcare to agriculture and space exploration, robotics has advanced substantially. The robotics industry is global, with components and expertise sourced from around the world. For better implementation, decision making in various contexts becomes essential. It encompasses a range of criteria regarding the development, deployment, and management of robotic systems. However, when a new system is being implemented, economic analysis becomes of paramount significance due to its direct and far-reaching impact on various aspects of a manufacturing operation, a company's bottom line, and the broader economy.

## Literature Review:

To identify the economic factors were investigated from the published literature. The initial cost of acquiring (CA) robotic systems, including hard- ware, software, and installation expenses (Savin, 2016). Operational and Maintenance costs (OMC) include ongoing expenses related to running and maintaining robotic systems, such as energy consumption, maintenance, spare parts and labor costs (Warszawski, 1985). Total cost of ownership (TCO) implies the holistic cost of owning and operating a robotic system over its entire lifespan, including depreciation and disposal costs (Landscheidt & Kans 2016).. Return on Investments (ROI) for a robotics project is calculated by considering factors like increased productivity, reduced labor costs, and improved product quality (Ulewicz & Mazur 2019).. Evaluating the benefits of robotics adoption, such as increased efficiency or quality, against the associated costs makes Cost Benefit Analysis (CBA) an essential economic factor (Hu et al., 2020). Robotics decisions are influenced by Market Dynamics (MD) - factors related to market conditions, such as demand fluctuations, price competitiveness, and supply chain disruptions (Daim & Faili 2019) . Balancing Resource allocation (RA) impacts redundancy and safety against perils of the project crucially. (Fechter et. al., 2018). Costs of Integration (CI) are associated with efforts required to integrate robotic systems into existing processes or systems (Bataev & Aleksandrova 2020). Advanced robotics systems can involve various types of failures. At such times minimizing the Costs of Downtime (CD) becomes a priority (Chang et. al., 2012).. Customization of the solutions is a major challenge for this integration. The expenses incurred to comply with industry-specific regulations and safety standards are referred as the Costs of Regulatory Compliance (CRC) (Holder, C.,et al.,2016). Assessing the economic viability of ramping up or down robotic activities to match shifting demand or business demands is part of the Costs of Scalability (CS) process (Hamann & Reina 2021).. The management of hazards connected to robotics projects, such as unforeseen expenses, market volatility, and technological obsolescence, is addressed in accounting of Risks and Uncertainty (RU) factor (Liu et al., 2019).. In the context of robotics, economic criteria are interdependent, meaning that changes or decisions related to one criterion can impact other economic criteria. Some criteria may be at odds with one another. CA may be positively correlated with an increase in OMC because investing in more expensive hardware may lead to higher maintenance costs. Conversely, an increase in ROI is negatively correlated with CA because higher acquisition costs may impact the time it takes to achieve a positive ROI.

**Methodology:**

Classification of factors into cause and effect to identify their relationships can be done by structural modelling based on survey of relevant experts. Experts in the field of robotics who specialize in the economic criteria of robotics often come from various backgrounds, including robotics engineering, economics, and business. These professionals have familiarity and knowhow in comprehending the economic characteristics of robotics likr cost analysis, return on investment (ROI), market dynamics, and resource allocation. The design, development, and use of robotic systems are deeply understood by engineers and researchers (Raheel et al., 2023). Economists with expertise in industrial or technology economics can offer significant perspectives on the financial consequences of the implementation of robotics. (Drews et al., 2017). They analyze the cost-effectiveness, market dynamics, and broader economic impact of robotics. Professionals in the field of business consulting, particularly those specializing in technology and automation, help organizations make informed decisions about incorporating robotics into their operations. They often conduct cost-benefit analyses and develop robotics strategies (Nissen & Seifert 2018). Academics in universities and research institutions may focus on the eco- nomic aspects of robotics through interdisciplinary research (Pimsakul et al., 2021). They publish studies and papers that contribute to the understanding of economic criteria in robotics. Experts in policy analysis and regulatory affairs examine the economic implications of robotics regulations, incentives, and government policies. They assess the impact of policy decisions on the adoption and deployment of robotics. (Leenes et al. 2017). Professionals in finance and investment analyze the financial viability of robotics companies and technologies (Zolas et al. 2021). They provide insights into investment opportunities in the robotics industry. Market analysts and research firms specialize in assessing market trends, demand, and competition in the robotics sector. They help businesses make strategic decisions related to robotics adoption and market positioning. Organizations and associations dedicated to robotics and automation often have experts or committees focused on economic factors within the industry. They provide industry-specific insights and resources. Professionals working in government agencies or regulatory bodies may specialize in the economic aspects of regulating robotics and automation technologies. They help shape policies that balance economic interests with safety and ethics. Consulting firms with a focus on robotics and automation offer a range of services, including economic assessments, feasibility studies, and cost-benefit analyses for organizations considering robotics adoption.

Economic factors are fundamental in managing the costs associated with developing, acquiring, operating, and maintaining robotic systems. Organizations need to allocate budgets effectively to ensure that their robotics projects remain financially viable.

Robust economic analyses, encircling issues such as initial costs, operational and maintenance expenses, return on investments, market dynamics, resource allocation, and risk assessment, are pivotal in influencing the success and endurance of robotics enterprises. For the purpose of this study, emails were sent to selective experts from various fields. Out of 73 questionnaires sent to various experts from above mentioned domains, 46 responses were received. The respondents were required to rank effect of criteria on one another on a scale of 0 (No influence) to 4 (High influence). The sample of the responses received is shown in Table 1. Out of 46, there were 7 responses incomplete responses. 39 fully complete responses were received which were suitable for analysis. As illustrated in Table 2, direct relationship matrix (R) is created by averaging the responses. The values are truncated for depiction To create the normalized relationship matrix (N) in Table 3, divide each matrix element by the largest sum of the R matrix's rows and columns.

TABLE 1

| | CA | TCO | OMC | ROI | MD | CBA | RU | CI | CD | CRC | CS | RA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CA | 0 | 0 | 1 | 0 | 3 | 0 | 2 | 1 | 1 | 3 | 2 | 3 |
| TCO | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 1 | 2 | 2 | 2 | 3 |
| OMC | 3 | 2 | 0 | 3 | 2 | 3 | 3 | 3 | 0 | 3 | 1 | 1 |
| ROI | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 2 | 2 | 3 | 1 | 0 |
| MD | 1 | 0 | 2 | 0 | 0 | 3 | 1 | 2 | 0 | 1 | 3 | 3 |
| CBA | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 3 | 0 |
| RU | 2 | 0 | 1 | 1 | 0 | 2 | 0 | 3 | 2 | 3 | 0 | 2 |
| CI | 2 | 2 | 2 | 1 | 2 | 0 | 2 | 0 | 1 | 3 | 1 | 1 |
| CD | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 0 | 3 | 0 | 1 |
| CRC | 2 | 2 | 3 | 0 | 1 | 2 | 0 | 3 | 2 | 0 | 3 | 1 |
| CS | 1 | 3 | 1 | 1 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 3 |
| RA | 2 | 0 | 3 | 2 | 1 | 3 | 1 | 1 | 3 | 0 | 2 | 0 |

TABLE 2

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
http://eelet.org.uk

| | CA | TCO | OMC | ROI | MD | CBA | RU | CI | CD | CRC | CS | RA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CA | 0. | 1.96` | 1.40 | 1.68 | 1.343 | 1.71 | 1.75 | 1.37 | 1.5 | 1.09 | 1.53 | 1.31 |
| TCO | 1.40 | 0 | 1.65 | 1.71 | 1.59 | 1.5 | 1.65 | 1.46 | 2.03 | 1.5 | 1.62 | 1.75 |
| OMC | 1.62 | 1.43 | 0 | 1.68 | 1.40 | 1.34 | 1.28 | 1.59 | 1.56 | 1.53 | 1.78 | 1.21 |
| ROI | 1.56 | 1.15 | 1.56 | 0 | 1.62 | 1.31 | 1.40 | 1 | 1.68 | 1.75 | 1.71 | 1.28 |
| MD | 1.81 | 1.43 | 1.37 | 1.03 | 0 | 1.31 | 1.65 | 1.40 | 1.53 | 1.53 | 1.59 | 1.75 |
| CBA | 1.34 | 1.12 | 1.68 | 1.56 | 1.15 | 0 | 1.71 | 1.37 | 1.40 | 1.59 | 1.34 | 1.34 |
| RU | 1.34 | 1.37 | 1.43 | 1.43 | 1.12 | 1.68 | 0 | 1.62 | 1.28 | 1.65 | 1.31 | 1.65 |
| CI | 1.56 | 1.34 | 1.40 | 1.06 | 1.96 | 1.59 | 1.21 | 0 | 1 | 1.40 | 1.65 | 1.43 |
| CD | 1.75 | 1.46 | 1.18 | 1.78 | 1.43 | 1.75 | 1.28 | 1.43 | 0 | 1.5 | 1.37 | 1.5 |
| CRC | 1.62 | 1.56 | 1.53 | 1.59 | 1.03 | 1.53 | 1.56 | 1.34 | 1.40 | 0 | 1.81 | 1.46 |
| CS | 1.34 | 1.46 | 1.62 | 1.28 | 1.46 | 1.46 | 1.71 | 1.28 | 1.56 | 1.62 | 0 | 1.53 |
| RA | 1.40 | 1.65 | 1.40 | 1.43 | 1.43 | 1.84 | 1.65 | 1.68 | 1.43 | 1.40 | 1.37 | 0 |

The Total Relationship Matrix (T) = N x (I-N)-1 is shown in Table 4. The normalized matrix helps standardize scales of the direct relationship matrix while the matrix T accounts for all underlying interdependencies. The threshold value calculated from the average of the elements of the matrix T is 0.918. The values greater than the threshold value are highlighted.

TABLE 3

| | CA | TCO | OMC | ROI | MD | CBA | RU | CI | CD | CRC | CS | RA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CA | 0 | .11 | .079 | .094 | .075 | .096 | .097 | .077 | .084 | .061 | .086 | .073 |
| TCO | .079 | 0 | .092 | .096 | .089 | .084 | .092 | .082 | .113 | .084 | .091 | .098 |
| OMC | .091 | .08 | 0 | .094 | .079 | .075 | .072 | .089 | .087 | .086 | .099 | .068 |
| ROI | .087 | .065 | .087 | 0 | .091 | .073 | .079 | .056 | .094 | .098 | .096 | .072 |
| MD | .101 | .08 | .077 | .058 | 0 | .073 | .092 | .079 | .086 | .086 | .089 | .098 |
| CBA | .75 | .063 | .094 | .087 | .065 | 0 | .096 | .077 | .079 | .089 | .075 | .075 |
| RU | .075 | .077 | .08 | .08 | .063 | .094 | 0 | .091 | .072 | .092 | .073 | .092 |
| CI | .087 | .075 | .079 | .059 | .110 | .089 | .068 | 0 | .056 | .079 | .092 | .08 |
| CD | .098 | .082 | .066 | .099 | .08 | .098 | .072 | .08 | 0 | .084 | .077 | .084 |
| CRC | .091 | .087 | .086 | .089 | .058 | .086 | .087 | .075 | .079 | 0 | .101 | .082 |
| CS | .075 | .082 | .091 | .072 | .082 | .082 | .096 | .072 | .087 | .091 | 0 | .089 |
| RA | .079 | .092 | .079 | .086 | .08 | .013 | .092 | .094 | .08 | .079 | .077 | 0 |

TABLE 4

| | CA | TCO | OMC | ROI | MD | CBA | RU | CI | CD | CRC | CS | RA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CA | 0.87 | **0.94** | **0.93** | **0.94** | 0.88 | **0.98** | **0.97** | 0.89 | **0.94** | **0.93** | **0.97** | **0.92** |
| TCO | **1.00** | 0.89 | **0.99** | **1** | **0.95** | **1.03** | **1.02** | **0.95** | **1.02** | **1.00** | **1.03** | **1.00** |
| OMC | **0.94** | 0.90 | 0.84 | **0.93** | 0.88 | **0.95** | **0.94** | 0.89 | **0.93** | **0.94** | **0.97** | 0.90 |
| ROI | **0.93** | 0.87 | 0.90 | 0.83 | 0.87 | **0.93** | **0.93** | 0.84 | 0.91 | **0.92** | **0.95** | 0.89 |
| MD | **0.96** | 0.90 | 0.91 | 0.90 | 0.80 | **0.95** | **0.95** | 0.88 | **0.93** | **0.93** | **0.96** | **0.93** |
| CBA | 0.89 | 0.85 | 0.89 | 0.88 | 0.83 | 0.83 | **0.92** | 0.84 | 0.88 | 0.90 | 0.91 | 0.87 |
| RU | 0.90 | 0.87 | 0.89 | 0.89 | 0.84 | **0.94** | 0.84 | 0.87 | 0.88 | 0.91 | **0.92** | 0.90 |
| CI | 0.90 | 0.86 | 0.87 | 0.86 | 0.87 | **0.92** | 0.89 | 0.77 | 0.86 | 0.89 | **0.93** | 0.88 |

European Economic Letters
ISSN 2323-5233
Vol 13, Issue 5 (2023)
http://eelet.org.uk

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CD | **0.95**2 | 0.90 | 0.90 | **0.94** | 0.88 | **0.87** | **0.94** | 0.88 | 0.84 | **0.93** | **0.95** | **0.92** |
| CRC | **0.94** | 0.91 | **0.92** | **0.93** | 0.86 | **0.96** | **0.95** | 0.88 | **0.92** | 0.86 | **0.97** | **0.92** |
| CS | **0.93** | 0.90 | **0.92** | 0.91 | 0.88 | **0.85** | **0.96** | 0.87 | **0.93** | **0.94** | 0.88 | **0.92** |
| RA | **0.96** | **0.93** | **0.93** | **0.94** | 0.89 | **0.99** | **0.97** | 0.91 | **0.94** | **0.95** | **0.97** | 0.86 |

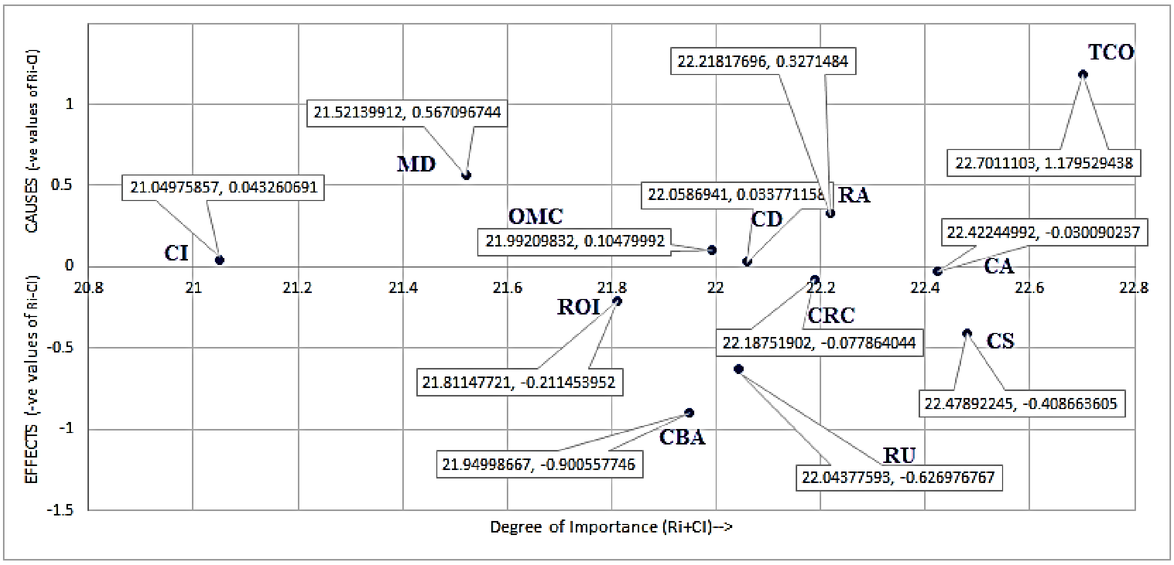
**Results:**

Table 5 helps interpret the results of the analysis. The sum of each row is calculated (Ri) and each column (Ci) calculated. The higher the value of Ri+Ci the more the importance of the factor. The factors are ranked as per the degree of importance. The factors having a positive value for Ri-Ci are classified as Causes while those having negative value are classified as Effects.

TABLE 5

| | Ri | Ci | Ri + Ci | Rank by Deg. Of Imp. | Ri - Ci | Classi-fication |
|---|---|---|---|---|---|---|
| **CA** | 11.196 | 11.226 | 22.422 | 3 | -0.030 | Effect |
| **TCO** | 11.940 | 10.760 | 22.701 | 1 | 1.180 | Cause |
| **OMC** | 11.048 | 10.943 | 21.992 | 8 | 0.105 | Cause |
| **ROI** | 10.800 | 11.011 | 21.811 | 10 | -0.211 | Effect |
| **MD** | 11.044 | 10.477 | 21.521 | 11 | 0.567 | Cause |
| **CBA** | 10.524 | 11.425 | 21.950 | 9 | -0.901 | Effect |
| **RU** | 10.708 | 11.335 | 22.044 | 7 | -0.627 | Effect |
| **CI** | 10.546 | 10.503 | 21.050 | 12 | 0.043 | Cause |
| **CD** | 11.046 | 11.012 | 22.059 | 6 | 0.034 | Cause |
| **CRC** | 11.054 | 11.132 | 22.188 | 5 | -0.078 | Effect |
| **CS** | 11.035 | 11.443 | 22.479 | 2 | -0.409 | Effect |
| **RA** | 11.272 | 10.945 | 22.218 | 4 | 0.327 | Cause |

The cause and effect diagram derived is depicted in Figure 1 below:




**Discussion:**

The highlighted values in Table 4 total relationship matrix greater than the threshold value that a causal relationship exists from the row to the column. A higher CA might lead to lower OC if it means investing in more reliable and efficient robotic systems, reducing maintenance and operational costs. The CA directly impacts ROI; a higher CA may require a longer time to realize a positive ROI, potentially affecting the project's attractiveness. CA contributes significantly to TCO, as it represents the initial investment in the robotic system. Lower OC can contribute to a quicker and more favorable ROI, making the project financially more appealing. OC is a component of TCO, and reducing OC contributes to lower overall TCO. Operational costs are considered in CBA, as they factor into the cost side of the analysis. RA decisions allocate financial resources to CA and OC, impacting the capacity to invest in robotics and meet operational expenses. Ensuring compliance with regulations may require additional expenditures, contributing to OC. Regulatory compliance is closely related to risk management, as non-compliance can lead to financial penalties and reputational risks. Decisions related to scalability can impact CA by requiring additional investments and OC by influencing resource allocation.

**Conclusion:**

The economics of robotics implementation are recognized, along with their influencing aspects. While six of the factors are categorized as effects, the other half are causes. The cost of integration is regarded as having the least importance while the total cost of ownership is given priority. The outcomes emphasise the significant influence that these components have on each other, bringing forth their interdependencies and the necessity of taking a comprehensive approach when making decisions about robotics integration.

**References:**

1. Bataev, A. V. and Aleksandrova, A. (2020). Digitalization of the world economy: Performance evaluation of introducing cyber-physical sys- tems. *2020 9th International Conference on Industrial Technology and Management (ICITM)*, pages 265–269. https://doi.org/10.1109/icitm48982.2020.9080378
2. Chang, Q., Xiao, G., and Biller, S. (2012). The Costs of Downtime Inci- dents in Serial Multistage Manufacturing Systems. *Journal of Manufac- turing Science and Engineering*, 134:21016–21017 https://doi.org/10.1115/1.4005789.
3. Daim T. U. and Faili, Z. (2019). *Industry 4.0 Value Roadmap: Integrating Technology and Market Dynamics for Strategy, Innovation and Operations*. Springer Nature. https://doi.org/10.1007/978-3-030-30066-1_8
4. Drews, S., Den, V., and Bergh, J. C. (2017). Scientists' views on eco- nomic growth versus the environment: a questionnaire survey among economists and non-economists. *Global Environmental Change*, 46:88– 103. https://doi.org/10.1016/j.gloenvcha.2017.08.007
5. Fechter, M., Seeber, C., and Chen, S. (2018). Integrated process planning and resource allocation for collaborative robot workplace design. *Pro- cedia CIRP*, 72:39–44. https://doi.org/10.1016/j.procir.2018.03.179
6. Hamann, H. and Reina, A. (2021). Scalability in computing and robotics. IEEE Transactions on Computers, 71(6):1453–1465. https://doi.org/10.1109/tc.2021.3089044
7. Holder, C., Khurana, V., Harrison, F., and Jacobs, L. (2016). Robotics and law: Key legal and regulatory implications of the robotics age (Part I of II). Computer law & security review, 32(3), 383-402 https://doi.org/10.1016/j.clsr.2016.03.001
8. Hu, R., Iturralde, K., Linner, T., Zhao, C., Pan, W., Pracucci, A., and Bock,T. (2020). A simple framework for the cost-benefit analysis of single- task construction robots based on a case study of a cable-driven facade installation robot. *Buildings*, 11(1). https://doi.org/10.3390/buildings11010008
9. Landscheidt, S. and Kans, M. (2016). Method for assessing the total cost of ownership of industrial robots. *Procedia Cirp*, 57:746– 751. https://doi.org/10.1016/j.procir.2016.11.129
10. Leenes, R., Palmerini, E., Koops, B. J., Bertolini, A., Salvini, P., and Lu- civero, F. (2017). Regulatory challenges of robotics: some guidelines for addressing legal and ethical issues. *Law, Innovation and Technol- ogy*, 9(1):1–44. https://doi.org/10.1080/17579961.2017.1304921
11. Liu, C., Rouse, W. B., and Belanger, D. (2019). Understanding risks and opportunities of autonomous vehicle technology adoption through systems dynamic scenario modeling-The American insurance industry. *IEEE Systems Journal*, 14(1):1365–1374. https://doi.org/10.1109/jsyst.2019.2913647
12. Nissen, V. and Seifert, H. (2018). Evaluating the virtualization potential of consulting services. *Digital Transformation of the Consulting Industry: Extending the Traditional Delivery Model*, pages 191–205. https://doi.org/10.1007/978-3-319-70491-3_8
13. Pimsakul, S., Samaranayake, P., and Laosirihongthong, T. (2021). Prioritizing enabling factors of IoT adoption for sustainability in supply chain management. *Sustainability*, 13(22):12890–12890. https://doi.org/10.3390/su132212890
14. Raheel, F., Mehmood, H., and Kadri, M. B. (2023). Top-Down Design Approach for the Customization and Development of Multi-rotors Using ROS. In *Unmanned Aerial Vehicles Applications: Challenges and Trends*, pages 43–83. Springer International Publishing. https://doi.org/10.1007/978-3-031-32037-8_2
15. Savin, I. A. (2016). Determination of the effectiveness of the use of robotic systems in mechanical engineering. *European journal of natural history*, (3):94–97. https://s.world-science.ru/pdf/2016/3/19.pdf

16. Ulewicz, R. and Mazur, M. (2019). Economic aspects of robotization of production processes by example of a car semi-trailers manufacturer. Manufacturing Technology, 19(6):1054–1059. https://doi.org/10.21062/ujep/417.2019/a/1213-2489/mt/19/6/1054
17. Warszawski, A. (1985). Economic implications of robotics in building. Building and Environment, 20(2):73–81. https://doi.org/10.1016/0360-1323(85)90001-0
18. Zolas, N., Kroff, Z., Brynjolfsson, E., Mcelheran, K., Beede, D. N., Buffin- gton, C., Dinlersoz, . ., and E (2021a). Advanced technologies adoption and use by us firms: Evidence from the annual business survey (No. w28290). National Bureau of Economic Research. https://doi.org/10.3386/w28290