Artificial Intelligence – Myth or Measurable?

A systematic framework to determine AI-induced productivity gains

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Abstract—**Many companies using Analytical and Generative Artificial Intelligence (AI) are proclaiming productivity gains, but there is still no structured approach how to calculate the real values. This article shows a set of dimensions to classify use cases with regard to savings in time/ cost or rises in quality and suggests a way of calculating results based on the relationship between productivity and profitability. To estimate the costs, a Total-Cost-of-Ownership (TCO) approach for AI systems is introduced, covering the whole system lifecycle. Comparing both structures, estimations of AI benefits can be calculated more efficiently. A set of AI projects from different branches is used to demonstrate the appropriateness of the framework.**

Keywords-artificial intelligence; productivity; profitability; cost of ownership.

I. INTRODUCTION

Productivity gains resulting from analytical Artificial Intelligence (AI), such as in medical diagnosis or fraud detection, have been discussed for several years now. AI can solve complex problems that would otherwise need much more time, resources or would be intractable due to the sheer volume of data involved. Since the introduction of Open AI's Large Language Model (LLM) GPT3.5 to the general public in November 2022 and the emergence of many competing models, the number of news articles and publications that postulate even higher expectations concerning the use of Generative AI (GenAI) in the form of LLMs has multiplied.

For example, a McKinsey study conducted in 2023 [1] proclaimed an estimated world-wide productivity gain induced by GenAI of 2.6 to 4.4 billion dollars and a rise in working productivity of 0.1% to 0.6% per year. According to this study, branches benefitting the most from GenAI will be finance, high-tech, media and bioscience. 75% of this potential can be found in the field of customer service, sales and distribution, software development and research & development. The study evaluated 850 different jobs and 2.100 different job tasks. The study also distinguished between three clusters of task types: Physical work (foreseeable or unforeseeable) with productivity gains of 70% rsp. 34% (slightly more than using analytic AI only), data collection (79%, 65% by analytical AI only) and data management (92%, 75% by analytical AI only) and decision making and collaboration (management, stakeholder communication and interaction, knowledge application) with an increase of 50-55% in productivity – almost three times as much as with analytical AI only. That the amount of productivity gains seems correlated with the level of education comes as a surprise – employees with lower qualifications saw less possibilities to raise their productivity.

There are further national and international studies that aim to quantify the economic effects of AI and its impact on functions and job profiles. In 2024, a study conducted by ifo among German companies [2] revealed that almost 84% of them expected productivity gains for the national economy within five years, estimating an average increase of 12%. But 70% of all managers predicted productivity gains of averagely 8% for their own company, thereby estimating lower values for their company than nationwide.

Hammermann et al. [3] report that 45% of all employees in the 815 companies included in their study, who have used AI in their daily work between 2022 and 2024, claim productivity gains in their own job. On the other hand, 15% of the employees using AI stated the opposite.

Demary et al. [4] arrive at a moderate assessment: their study conducted for the Institute of the German Economy (IW) estimates a rise of the gross domestic product by 0.9% that can be derived from AI-usage between 2025 and 2030, so it does not act as a strong growth driver. For the decade starting in 2030, an increase of 1.2% is predicted. Demary et al. see AI as complementary to human work. They also raise the question whether rises in productivity can be accomplished by AI alone or only if AI is flanked by other digitalization technologies like robotics, software, internet access etc.

The saving of processing time is often cited as a reason for productivity gains. Looking at these ambitious expectations, AI seems to be a must-have for companies to stay competitive. However, AI solutions and their integration in a company's way of working often come with considerable costs and sometimes ethical implications. Before making decisions on investment, organizations must be able to assess the expected productivity gains and construct a fact-based calculation to make sure that AI-investments will be amortized and do not cause any uncontrollable risks, especially with regard to reductions in the workforce as a consequence of productivity gains. It seems insufficient to just ask employees about their general personal impression of the extent to which productivity has increased when using (generative) AI, especially when it is unclear whether this can be attributed to the use of AI alone. The research question is: what kind of values can be measured and in which dimensions?

This article compares measurement dimensions and reference values for different use cases and develops a systematic framework for calculating realistic economic effects of AI usage. Instead of calculating each new AI business case from scratch, it might be helpful to have standard categories, benchmarks and a set of indicators that can be measured.

To provide a solid foundation, the concepts of productivity and profitability are clarified and differentiated in Section II. Section III shows the dimensions for measuring AI-induced productivity and profitability gains related to time, cost and quality. In Section IV, some examples and case study projects are presented to illustrate which productivity gains have already been proven and how they have been calculated. Section V describes a Total Cost of Ownership (TCO)-based approach to calculate investments needed to plan, train, implement and run an AI system. Section VI sums up both sides of the equation: cost structure versus profitability to sketch a framework showing how to develop benchmarks in the future. Finally, Section VII draws a conclusion and offers suggestions for future work.

II. Productivity and Profitability

Due to Thommen et al. [5], productivity is defined as the quantitative relationship ratio between output and input of the production process (1):

$$Productivity = \frac{Work\ Outcome}{Input\ Quantitiy\ of\ production\ factors} \quad (1)$$

Since it is impossible to measure productivity for a whole enterprise at once, partial productivities are calculated related to work hours, machine running times or area sizes. For example, an accountant could execute 20 bookings per hour, a punching machine could produce 1.000 parts per hour, or a toy shop could achieve a turnover of 1.000 € per square meter. If the usage of AI is somehow beneficial to the company, these partial productivities can be expected to rise.

This effect can be direct or indirect: An increase in productivity per area means better utilization of limited resources and thus a direct increase in sales. Conceivable areas of application include stationary retail or agricultural production. Conversely more output from a machine or worker per unit of time means - assuming investment or labor costs remain the same (considered here as fixed costs) - that less machine running time or labor is now required for the same result, indirectly reducing costs.

Productivity is an output-oriented concept measured in physical units like pieces or amounts. Since productivity figures can usually also be expressed in monetary units, the concept of profitability (or economic viability) can be used as a substitute for productivity in the planned framework.

Profitability can be defined in different ways. The following equation assumes a direct relationship to productivity via (2):

$$Profitability = \frac{Productivity \times Revenue\ per\ Unit - Total\ Expenditures}{Revenue} * 100\% \quad (2)$$

Alternatively, the concepts of the net profit ratio (after deduction of all taxes) (3)

$$\text{Net Profit Ratio (\%)} = \frac{Net\ Income}{Revenue} \quad (3)$$

or the gross margin ratio (after deduction of all direct costs) (4)

$$\text{Gross Margin Ratio (\%)} = \frac{Gross\ Profit}{Net\ Revenue} \quad (4)$$

can be used.

The central question is: to what extent can the use of AI reliably contribute to the productivity gains predicted by recent studies, and which investments in AI technologies are necessary to leverage this potential? Although there are currently many studies that attempt to quantify the expectations of AI use in this regard, it is difficult to verify whether these expectations will actually materialize. There is a lack of clear assignability and classification of measurement methods. The following section will therefore examine which dimensions and characteristics are suitable for operationalization.

III. Dimensions for Measuring AI-Induced Productivity and Profitability Gains

AI can be classified into different fields based on its purpose, underlying methodologies, and applications. For our framework, we will distinguish between Analytical AI, Generative AI, and Reactive AI.

- Analytical AI focuses on data-driven decision-making, pattern recognition, and predictive analytics. It processes structured and unstructured data, extracts insights, and assists in optimization and forecasting without autonomously generating new creative content. It can be used in the fields of medical diagnosis, fraud detection, predictive maintenance or algorithmic trading as well as for natural language recognition, sentiment analysis, etc.
- Generative AI is designed to create new, synthetic content, such as text, images, music, or videos, by learning patterns from existing data. It uses advanced models like Generative Adversarial Networks (GANs) that allow the creation of videos and Transformer-based architectures like GPT4.x and other Large Language Models for natural language generation.
- Reactive AI operates based on real-time inputs and predefined rules, without memory or learning from past experiences at runtime. It was mainly used for fast-response, rule-based systems like chess-playing systems like “Deep Blue”, or older AI-powered, but rule-based chatbots.

Today, especially the methods in Analytical and Generative AI can be used to leverage potentials for productivity - and therefore - profitability gains. There are three dimensions to be improved: time, cost and quality. Table 1 shows the relation between these dimensions and whether Analytical (A) or Generative (G) AI is used. It lists examples for measures that can be used to calculate AI-related profitability increases.

TABLE I. MEASURING DIMENSIONS FOR AI PRODUCTIVITY

Dimen-sion	Context/Scenarios	AI class
Time	Planning time Project planning, Product planning, Logistic optimization (e.g., airports, freight forwarders, harbors, railways)	A+G
	Design time Product design, Service design, Individualization of consumer goods, Developing protein structures for pharmaceutical or chemical applications (e.g., AlphaFold), Developing recipes	A+G
	Production time of physical goods (time needed to produce one piece or unit)	A
	Production time of immaterial artefacts Creation of text, audio, video, e.g., in journalism, marketing, consulting, arts, Creation of program code	G
	Testing time Creation of test cases (e.g., software testing), Automatic test execution and evaluation	A+G
	Delivery time Demand forecasting, Route optimization	A
	Support time Analyze service requests by natural language recognition, Speech-to-Text, Answer customer requests, Analyze customer feedback	G
Cost	Material usage: production factors like raw materials, supplies and energy	A
	Waste, Offcut: raw materials	A
	Required space: inventory optimization	A
Quality	Quality inspection Automatic anomaly detection in production processes, Medical diagnosis (e.g., skin cancer, tumor detection in X-Rays or MRTs, Proofreading, Stylistic improvement of texts, Translation	A+G

With regard to GenAI, it needs to be pointed out that time and cost might tend in a different direction than quality, i.e., gains in the first two dimensions might cause reductions in the third. Consider this example: It is often stated that GenAI helps save a lot of time in producing text and illustrations. Employees working with text, such as journalists or marketers, can produce results in a shorter time or reduce the effort necessary to check translations or edit articles. And this means that one person can create a larger amount of output (i.e., text or graphic elements) in a given time, therefore getting more things done for the same salary. But in this case, productivity gains are more difficult to estimate, since the quality or originality of results is also important for the artefacts. Just speeding things up might lead to counterproductive effects in the long run.

IV. CASE STUDY EXAMPLES FOR SUCCESSFULLY MEASURING PRODUCTIVITY GAINS

The two following tables show some examples for case studies in the fields of Analytical and Generative AI that documented concrete absolute or relative values for productivity gains. In most cases, percentages or absolute values for savings were mentioned, but none of them listed any data on the cost side as described in Section IV. Table 2 lists projects using mainly analytical AI.

TABLE II. CASE STUDIES USING ANALYTICAL AI TO INCREASE PROFITABILITY OR SAVE COSTS.

Company and branch	What was measured?	Scope	Relative or absolute change in productivity / reported savings
Salling Group, Energy consulting [6]	Cost: Energy consumption in supermarket buildings via smart meters or data from energy providers	AI system analyses weather data and energy consumption and optimizes usage of device during closing hours	700 supermarkets were evaluated, savings in the millions are reported
Municipality of Holstebro, Denmark [7]	Cost: Energy consumption in community buildings	AI system analyses weather data and energy consumption and optimizes usage of device during closing hours	Savings: 1 million DKK = ca. 146.000 $
SWMS Systemtechnik Ingenieur-gesellschaft mbH [8]	Cost: Automated production of composite materials using a printing robot arm: usage of 3D printing materials	Reduction of printing errors through AI-supported monitoring: image-based object recognition and segmentation.	Material savings of 1/3 (estimated), Savings in energy for robot and cooling of printed artefacts
Orthopedical insoles [9]	Cost: Material usage in 3D printing instead of insole construction using blanks	AI system calculates ideal form to realize material saving	Material savings: >70% in plastic materials, up to 60% in energy
FRAPORT AG, Aviation [10]	Time: staff are assigned to ground handling based on qualification and availability	AI system IDA simulates and optimizes staff planning	(no data yet, project in beta-status)

Table 3 shows some examples of projects using GenAI. Productivity gains here often mean that standard tasks can be automated, so that the employee gets more time for more difficult tasks.

TABLE III. CASE STUDIES USING GENERATIVE AI TO INCREASE PROFITABILITY OR QUALITY OR SAVE COSTS.

Company & Branch	Scope	What was measured?	Change in productivity / reported savings
heise (IT magazine publisher, online portal provider) [11], [12]	System heiseIO (based on LLM and a process-oriented approach with predefined prompts)	a) Time: Annotation time of 14.000 pictures in a CMS b) Time: Production time of a newsletter	a) 5-15min human-based annotation time saved per picture, total cost of 300 € Daily “Botti” newsletter can be produced 12 minutes faster, saving a total of 1,5 person days per moth
Fieldcode GmbH [13]	System Fieldcode (based on LLM) planning of field service assignments	Time: Ticket diagnosis: analysis of field service requests to solve service problems remotely instead of sending a service technician, optimize “first fix rate” Cost: avoid unnecessary order of spare parts avoid unnecessary travel cost, fuel etc.	Up to 50% of spare parts could be saved, Rise of First fix rate (no exact number given)
Klarna [14]	System Kiki (based on LLM) used for internal knowledge management	Time, Quality: The system answers up to 2.000 questions of employees per day and is used by 85% of all staff	Contracts can be generated in 10 minutes instead of 1 hour Chatbot performs 2,3 million chats with customers (equals work of 700 employees) Estimated profit increase: 40 million $
Boston Consulting Group [15]	General usage of AI	Time, Quality	12% more tasks accomplished, 25% savings in time 40% increase in quality

The two tables show that the case studies can easily be categorized in terms of the dimensions mentioned in Section III. Table 4 shows an overview of all case studies mapped to these dimensions.

TABLE IV. ASSIGNMENT OF CASE STUDIES TO MEASURING DIMENSIONS AND AI CLASS

Case Study	Dimension	AI class
Salling Group	Cost	A
Municipality of Holstebro	Cost	A
SWMS Systemtechnik Ingenieur-gesellschaft mbH	Cost	A
Orthopedical insoles	Cost	A
Fraport	Time	A
Heise	Time	G
Fieldcode GmbH	Time, Cost	G
Klarna	Time, Quality	G
Consulting	Time, Quality	G

The next section discusses how different AI-system investments can be made comparable using a lifecycle

V. COST OF AI-USAGE: A TOTAL COST OF OWNERSHIP-APPROACH FOR AI-SYSTEMS

Before productivity gains can be realized, AI-based systems need to be developed, trained and fine-tuned. To get an overall picture of the total cost of ownership (TCO) of an AI system, the following cost components need to be considered. They can be organized along the life cycle of an AI system, using a TCO-like approach with lifecycle phases and corresponding tasks as follows.

A. System Design and Development

All AI systems need to be modelled and trained. This can either be done using supervised or unsupervised learning, reinforced and/or deep learning. Developing these systems requires a large amount of storage and compute resources like GPUs or other AI-chips. Training data needs to be collected or artificially generated, and the data needs to be cleaned and consolidated. Interfaces to control and monitor the settings are needed and the system may have to be integrated into existing processes. This results in a significant fix-cost block before installing the final system. In the case of prefabricated AI models, this cost block will be covered by later subscription fees.

The cost determinants in this phase are especially the programming time, data engineering time (calculated via salary), on-premises hardware or cloud cost for CPU/GPU time, and energy cost.

B. Customizing

Especially in the case of GenAI, the resulting models need to be finetuned to perform specific tasks or to improve their performance in a particular domain. Guard rails need to be developed to ensure responsible and ethical AI use.

The cost determinants are salary (programmers and domain experts), acquisition of domain-specific data sets, and computing resources.

C. Integration into Controlling

Key Performance Indicators (KPIs) and performance metrics need to be developed in order to monitor the system and to assess its performance. This is a prerequisite to ensure that the AI system meets the desired outcomes

The main cost determinant is the time required to choose and to agree upon KPIs and appropriate metrics with AI engineers, domain experts and executives being involved.

D. Deployment and Documentation

The AI system needs to be deployed within the existing infrastructure, which involves technical setup, integration with systems and platforms already in use, and testing. Documentation facilitates maintenance, troubleshooting and further development.

The cost determinant is the time spent by the technical team.

E. User training

Users need to be initially trained in how to use the AI systems (e.g., required by the EU AI act). The training ensures employees understand AI opportunities, risks, and legal compliance requirements. The curriculum also depends on what tasks the employees are assigned to, e.g., whether they work in the IT department, in a dedicated AI team, human resources etc.

The cost determinants are salary, course fees, course material, travelling and accommodation costs.

F. Operation

Each request to the running system causes a certain amount of costs for inferencing, i.e., producing a solution or an answer. These costs are often covered using subscription fees like user licenses for LLMs on a monthly or per-token basis. For critical systems, human workers need to be kept in the loop to meet ethical requirements.

The cost determinants are subscription fees (fix costs on monthly/annual basis), token consumption (variable cost), salary.

G. User Training Cycle

After certain intervals, these training courses need to be repeated to keep users up-to-date and refresh their knowledge.

The cost determinants are salary, course fees, course material costs, travel and accommodation costs.

H. Risk Management

Installing AI systems in certain processes might also require additional insurance, e.g., to protect against potential damage caused by AI system failures, or monitoring frameworks to assess and mitigate associated risks.

The cost determinants are salary and insurance premiums.

I. Certification for Compliance

Certifications might be required regarding compliance with legal and regulatory standards, which can vary by industry and region (e.g., the AI Act by the European Union). They must be renewed in prescribed intervals. Renewal processes typically involve reassessment and auditing of systems to confirm that they still meet the necessary requirements.

The cost determinants are certification fees on an annual or long-term basis and salaries for the internal and external experts involved in the certification.

This structure can be used to calculate a concrete AI project, resulting in the estimated total costs of the system. It can further be used to calculate the time needed to amortize.

VI. The Integrated Framework for Comparing Costs and Productivity/Profitability Gains

To be able to reliably quantify productivity and profitability gains, the two concepts explained in Sections III and V must now be combined as illustrated in Figure 1. The sum of all profitability increases can be calculated by measuring the difference (Δ) between time, material cost or quality level and multiplying it with the proper computing unit like salary/hour or price/unit. Predicting the benefit of a rise in quality is more difficult to calculate. In a medical environment for example, it could be measured by the follow-up costs of the treatment of a patient who was not correctly diagnosed but would have been using AI-techniques – or by future purchases of a customer who is more satisfied than before.

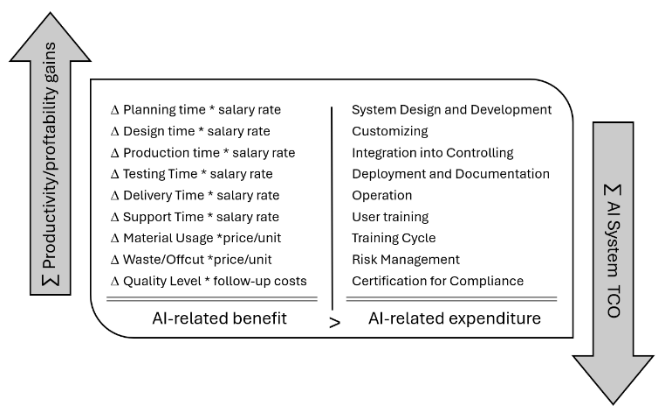

Figure 1. Comparing the benefits of productivity/profitability gains and AI system costs

To calculate a value for an AI-system TCO, more data is needed, for example resulting from past projects and continuous controlling. Companies might search for benchmarks and share experiences. As AI system components become more standardized and included in “software off the shelf”, this will become much easier to accomplish.

Finally, the two sums or at least their order of magnitude can be compared arriving at a first judgment whether the

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benefits outweigh the costs and if so, by what amount. This can prevent companies from running blindly into AI projects that will not be paying off because too many aspects remain unnoticed before the start.

VII. Conclusion and Future Work

Although many companies claim remarkable benefits of AI usage concerning productivity, it is still difficult to find exact numerical proof or compare use cases across branches. Each use case is evaluated on its own, and often only savings, but no cost dimensions are reported. In addition, AI systems are rarely looked at from a TCO-based angle with regard to the whole lifecycle.

Therefore, in this article a framework for measuring and evaluating productivity and profitability gains induced by using analytical or generative AI systems was developed. A volume structure was developed for the beneficial effects, considering time, cost and quality. In addition, AI system cost is structured alongside a TCO approach. Finally, both sides are compared to gain a clearer view on quantitative aspects, which has to be enriched with qualitative aspects like human-AI-cooperation or ethical implications. Integrating these perspectives, the framework can help foster a cautious judgement whether the proclaimed benefits stand on real ground.

Future work should include the following:

- A systematic literature review should be conducted focusing on collecting and categorizing case studies in different industries to gather as much real data as possible. Categorization should include branches, company size, geographical region, type of AI used and governance limitations in force.
- A database with benchmark data should be compiled using the results of the literature review. Data donations from interested companies should be integrated.
- A questionnaire for measuring the single components of the framework should be developed, resulting in a form where companies can enter their specific data to get a first estimation of benefits and cost.
- Institutions like chambers of commerce, industry associations and practical research institutions like universities of applied sciences can help with gathering this data and transferring it into practice.

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