Static and dynamic approaches in industrial metrology in the framework of measuring enterprise productivity

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Abstract. Workforce productivity measurement is a key metric at the evaluation of the operational efficiency for any industrial enterprise. The relevance of measuring the operational efficiency horizon - static or dynamic approaches in industrial metrology - is due to the need to ensure long-term sustainable development. Accelerating workflow and innovation is redefining performance measurements by offering new sources of productivity gains. The reduction in personnel becomes economically due to the reduction in downtime. Such innovations are especially effective when considering static performance metrics. At the same time, a dynamic approach that does not provide for staff reduction, but aimed at reducing the labor costs of each individual employee, no less positively affects productivity metrology, while laying a more stable, long-term trend for maintaining and increasing the achieved indicators.

1. Introduction
Operational efficiency, as an area of analysis of production activities, and the processes associated with it, isolates and dissect productivity gains, both in terms of practices and technologies, and in relation to people. From a metrological point of view, the measurement of productivity is a simple derivative of revenue to the average number of employees for a certain period of time, or the volume of output per unit of time to the number of employees. At the same time, if we consider only static physical quantities, then a simple downsizing of staff should lead to an increase in productivity, which, of course, is not quite true in reality. A different picture in relation to the change in the measured value is observed with a different approach, when performance indicators are considered cumulatively and in dynamics [1, 2], taking into account the possibility of productivity growth while maintaining or even increasing the existing number of employees due to the digital transformation of the business [3].

The analysis of digital initiatives of the largest Russian companies carried out in the study indicates that they are looking for sources of productivity growth in the field of digital technologies. The investigated cases show that the implemented innovative technologies are primarily focused on a shorter cash-to-cash cycle, that is, on the speed of the process of capital passing through the stages of production and circulation and the mobility of capital in economic circulation. Capital turnover as an element of enterprise efficiency allows not only avoiding the trap of "squeezing" capital, but also reducing payments for the use of attracted funds.

Measuring and comparing the operating and financial indicators of companies - the flagships of industrial innovation in Russia before the implementation of the largest digital projects and after their
implementation - shows that innovative changes can free up an additional resource for increasing productivity in the absence of any other sources of growth.

The main implemented projects of digitalization of Russian manufacturing companies are in the field of improving the efficiency of equipment and predicting sudden failures of critical equipment based on the use of Big Data technologies and machine learning. A person makes decisions based on previous experience, aggregated data from previous anomalies. The machine is able to take into account in detail a much larger data array, conducting clustering and building associative links more broadly. As a result, a decrease in equipment productivity losses during unscheduled repairs is achieving, leveling the disruptive effect of wear.

We studied the possible effects of digitalization in the following areas:

- **Qualitative:**
  - Maintaining a uniform planning process;
  - Modeling and analytics "what - if";
  - Single “window to the future” as a visualization of the integrated planning process.

- **Quantitative - direct and indirect, such as:**
  - Changes directly affecting financial performance:
    - Growth in production;
    - Shorter cash-to-cash cycle;
    - Reducing the cost of shipped products.
  - Changes indirectly affecting financial performance:
    - Reducing the probability of forecast errors;
    - Increase in labor productivity;
    - Reducing the number of personnel.

Since all these changes lead to the optimization of resources, stocks, purchases, and in general, they reduce the pressure on capital and the deficit of investment financing by including alternative sources of development, the rate of accumulation may not be constant during the transition to a long-term stable state. Moreover, if capital intensity (that is, capital per employee) increases due to an increase in labor productivity, the number of employees decrease for the same reason, part of the necessary investments replaced by a decrease in equipment productivity losses during unplanned repairs, then the financial situation of the enterprise improves. Investment or capital increase per employee is that part of production that is not consuming, minus the capital depreciation rate. Consequently, investments become the same as savings, specifically free cash flow [4].

2. **Static measurements**

If we assume that the turnover of all invested productive capital remains constant, then the proportion of total investment that simply maintains the stock of total capital usually increases as the total stock increases. Income growth and net new investment must also pick up to accelerate fixed capital growth. Simply put, the more capital grows, the more capital it takes to grow, and the more markets need to expand. However, in conditions of a shrinking resource base, lack of investment growth and geopolitical risks, it seems difficult to increase production by expanding funding sources. Diminishing returns implies that at some point the amount of new capital produced is no longer sufficient to offset the amount of existing capital lost due to wear and tear [5]. Here measurements of productivity dynamics begin to play a key role only through the development of the factor of innovation and digital technologies. The standard neoclassical model shows that the economy in long-terms period is converging towards its stable equilibrium, and constant growth might been obtained by methods of the technological progress
Accordingly, investments are losing their critical importance for the reproduction of capital, giving way to such new sources of growth as technological improvements and innovations.

An industry report presented by McKinsey experts, who conducted and in July 2018 released a study entitled “Innovation in Russia - an inexhaustible source of growth”, notes that since 2008, there has been a trend in Russia towards a decrease in investment in fixed assets and “it is increased productivity through innovation can become a growth driver in Russia” [7]. McKinsey experts bring together a set of innovation-related tools under the Industry 4.0 name and include big data analytics, machine learning, industrial vision, the industrial Internet of things, virtual augmented reality, 3D modeling, and more.

An example to illustrate measurements with a static approach is a modernization project at NLMK for predicting the failure of a blast furnace tuyere. The lance is the most important element of the furnace design. Before the implementation of the project, the replacement of tuyeres was carried out upon the occurrence of burnouts and upon reaching the standards of durability. In the first case, this led to the need for a long-term shutdown of the entire furnace, in the second - to the planned replacement of capable tuyeres that could still serve. The cost of the lance is high, so it is important to let it finish for the entire period. Replacement is economical to carry out half a step before the critical state. SAP and NLMK have created a solution that predicts burnout and destruction of tuyeres and reports the optimal replacement time [8].

To build a project model, we used the SAP Predictive Analytics solution. It allows you to create and train predictive models in a semi-automatic mode. As a result, the model issues recommendations for replacing the tuyeres 20 days in advance. The solution increases the productivity of the blast furnace by 20%. The measurement data is illustrating at the table 1.

| Equipment operation mode | Increase in equipment productivity by 20% |
|--------------------------|------------------------------------------|
| Loading production equipment | Reduce equipment downtime by 90% |
| Forecasting | Improving forecast accuracy up to 85% |
| Direct savings in working capital | 1% of the current investment level |
| Labor productivity | Labor productivity growth per employee - 4% |
| Accumulation rate | Free cash flow growth by 60% |

According to NLMK and SAP estimates, direct savings on replacement tuyeres exceed 60 million rubles per year. But much more important is the influence of the project effect on the productivity of the furnace itself. If the savings themselves amount to about 0.8% of the total investment of the entire Group, where the plant is only part of the assets, then the multiplier effect from reducing repair costs and downtime allows increasing productivity by 2-10%, which leads to an increase in steel output and growth in free cash flow (table 2).

| Employees, '000 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|-----------------|------|------|------|------|------|------|------|------|
| Labour productivity, t of steel per pers | 406 | 420 | 437 | 463 | 482 | 502 | 503 | 448 |

a Source: NLMK Group corporate website (https://nlmk.com/ru/ir/financial-results/)

Projects of similar efficiency carry out in:

- the chemical industry: predicting the optimal parameters of equipment operation for the operator of a drum granulator-dryer to maximize the yield of finished products;
- the oil and gas sector: developing a model that allows you to find and place anomalies in the data, to identify changes signal patterns even when there are no known characteristics of the anomalies themselves.
3. Dynamic measurements

In the case of dynamic performance measurements, an enterprise investing in future development and revenues focuses on an integrated approach to personnel training and development [9], as well as lean production systems. This vector of development presupposes an increase in sales and income not by reducing the cost of equipment or personnel, but by improving the quality of the product and sales with the help of more highly motivated and competent employees than those of competitors.

As part of the implementation of the integrated management system (IMS), four certificates received. ISO 9001: 2008 (quality management system), ISO 14001: 2004 (environmental management system) and OHSAS 18001: 2007 (occupational health protection) obtained for the corporate center and 26 sites of the company, and the ISO 50001 certificate (energy management system) for the corporate center and 9 sites.

Speaking about the effects of a single certification for the company, the company's management emphasized that the IMS allowed to structure work in all departments in accordance with uniform requirements, which contributes to the successful implementation of opportunities to achieve strategic goals and initiatives. Thus, personnel and the problem of their management becomes a fundamental pillar of the system of strategic planning and the creation of commercial value in general. The certification programs mainly focused on the issues of the current work of personnel (reduction of document circulation, reduction of the distraction of personnel from production activities for external audits, the incidence of injuries at work, etc.).

The global nature of reengineering is associated with a complex transformation of business processes and, in general, the operating model of their functioning, which ultimately leads to increased involvement in work at all levels of the company. Small departments from different units should not perform some part of the functionality of one large process in isolation from each other. In accordance with this logic, three main end-to-end processes have formed in the SIBUR project office: purchases (“from request to settlements”, p2p - Procure to Pay), settlements (“from closing a deal to receiving payment”, o2c - Order to Cash), reporting (“From the first record to the final document, r2r - Record to Report). The reduction of identical transactions to a single business process allows you to eliminate “interdepartmental” communication barriers, eliminate duplication and unnecessary control at each stage. As a result,

- the period for holding tenders was gradually reduced in the company from 109 days to 50;
- the introduction of a “single window” system coordinating the internal audit, reduced the number of visits by auditors to each production site from five to once a year, and the number of visits of evaluating functions from 109 to 41. These allowed the holding's enterprises to reduce their labor costs for internal audit processes for 1,000 person-days per year;
- the introduction of customs cards with the concomitant refinement of SIBUR's information accounting systems based on ORACLE, and subsequently SAP, made it possible to reduce labor costs and increase the transparency of the use of customs payments, cutting the time for creating a customs payment by half;
- the refinement of the “preliminary admission” functionality allowed new employees to start work in full immediately, unlike the previous experience, when the approval of the release of a new employee took about two weeks, he, accordingly, did not have access to systems and infrastructure and had to make do with diaries and a pen until completion of the negotiation procedures.

If we consider the above data in a comprehensive manner, then for us the growth of costs is not so much important as their impact on changes in labor productivity (table 3). SIBUR headcount in four years of the reengineering program from 2015 to 2018 remained almost unchanged, but revenue per employee increased by almost 60% over 5 years and remained unchanged even with a significant reduction in staff in 2019.
Table 3. Key operating indicators of SIBUR Holding for the period 2014-2019\(^a\).

|                | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|----------------|------|------|------|------|------|------|
| Employees, '000| 25.9 | 27.1 | 27.7 | 27.3 | 27.3 | 22.9 |
| Labour productivity, RUB million per pers | 12.3 | 14.0 | 14.9 | 16.6 | 20.9 | 20.8 |

\(^a\) Source: compiled by the author based on materials from SIBUR presentations for investors (http://investors.sibur.com).

4. Conclusion

Space-time values in the measurement of productivity allow us to talk about the efficiency of productivity growth due to innovative sources in the following configuration:

- increasing in the productivity of the enterprise by improving the operating mode and loading of production equipment, subject to a parallel reduction in staff;
- keeping the number of staff at the current level while introducing innovative models of integrated management.

If we analyze the activities of companies, in our case we cite the practice of Russian manufacturers, then there is a tendency of gradual transformation from the struggle for productivity by reducing costs and introducing innovations to the transition to progressive growth in productivity as a guarantee of competitive advantages provided by creative, well-trained employees. This configuration is much more difficult to replicate than a simple investment in capital improvements, but it lays the foundation for long-term productivity growth.

The acceleration of the technological process, the use of artificial intelligence methods make their additions to the regularities of measurements. With a static consideration, technological productivity allows to increase production. However, the potential for artificial mechanical growth may be finite. Dynamic calculations show that sustainable economic development seems to be more promising in terms of competitive advantages. It achieves with help of the relationship between employee satisfaction, labor force flexibility and productivity of not only mechanistic, but also managerial type.

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