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Designing a Model for Improving Human Resource Productivity in the Tax Administration Using a System Dynamics Approach: A Case Study of East Azerbaijan Province

1. Hossein. Ehrami: Department of Management, Ta.c., Islamic Azad University, Tabriz, Iran
2. Mohammad. Pasban*: Department of Management, Ta.c., Islamic Azad University, Tabriz, Iran
3. Mojtaba. Ramazani: Department of Management, Ta.c., Islamic Azad University, Tabriz, Iran

*corresponding author's email: pasban@iau.ac.ir

ABSTRACT

This study aimed to design and simulate a comprehensive model for improving human resource productivity in the East Azerbaijan Province Tax Administration using a system dynamics approach. This applied-developmental study employed an exploratory mixed-methods design and explanatory modeling based on system dynamics. Data were collected through a review of the literature and organizational evidence, questionnaires, and open interviews with experts. Fourteen university academics, senior tax experts, and human resource and productivity specialists were selected through purposive and convenience sampling to contribute to model development. Six experts additionally participated in evaluating the structural validity of the causal-loop and stock-flow models and the validity of mathematical relationships among endogenous variables. System dynamics modeling involved problem structuring, developing dynamic hypotheses, constructing causal-loop and stock-flow diagrams, model validation, simulation, scenario development, and policy evaluation. Simulation of five feasible scenarios showed substantial differences in their predicted effects on human resource productivity. Scenario 4, involving simultaneous improvement of empowerment-related facilities and tax-process automation, produced the greatest increase in productivity, amounting to 240 units. Scenario 3, which enhanced the relative welfare of different employee groups, increased productivity by 109 units. Scenario 2, involving increased recruitment rates across employee categories, resulted in a 50-unit improvement. Scenario 5, increasing in-service training hours within organizational capacity, generated only a 19-unit increase. Under Scenario 1, representing continuation of existing conditions, the human resource productivity index was projected to reach 2,449 units by the end of the simulation period. An integrated strategy combining employee empowerment with technological development and automation appears to provide the strongest leverage for improving human resource productivity in tax administration. Welfare-oriented interventions may offer additional substantial benefits, whereas isolated recruitment or training initiatives are likely to generate comparatively limited improvements.

Keywords: Human Resource Productivity; System Dynamics; Tax Administration; Human Resource Empowerment; Automation; East Azerbaijan Province

Introduction

Human resource productivity is one of the central determinants of organizational effectiveness, particularly in public-sector institutions whose performance depends heavily on the quality, efficiency, adaptability, and

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professional competence of their employees. Unlike purely technical or capital-intensive systems, public organizations frequently operate through complex interactions among human competencies, administrative structures, regulatory requirements, technological infrastructure, organizational culture, and managerial processes. Consequently, improving productivity cannot be reduced to increasing employees' workload or controlling their outputs; rather, it requires a systematic understanding of how human resources are recruited, developed, motivated, supported, deployed, and integrated into organizational processes. Contemporary strategic human resource management therefore places productivity within a wider framework of strategic alignment, ethical management, sustainability, organizational resilience, and continuous capability development (1-3). This perspective is especially important in governmental organizations, where the productivity of human capital affects not only internal performance but also the quality, accessibility, timeliness, and legitimacy of public services.

The concept of human resource productivity is multidimensional and has been approached through different theoretical and measurement traditions. Conventional productivity measurement has often focused on the ratio between organizational inputs and outputs, while more recent approaches recognize that the productivity of knowledge-intensive employees cannot always be adequately represented through simple quantitative output indicators. Reviews of productivity measurement approaches demonstrate considerable diversity in the concepts, indicators, and analytical methods used to assess performance (4). In knowledge-intensive environments, productivity may also depend on the quality of decisions, knowledge application, problem-solving capacity, communication, learning, creativity, and the ability to generate organizational value under changing conditions (5, 6). Accordingly, studies have attempted to construct more comprehensive productivity indicators that incorporate scientific, ethical, behavioral, and organizational dimensions (7, 8). Other measurement-oriented studies have applied decision models, efficiency analysis, and multi-criteria approaches to evaluate knowledge-worker and human resource productivity more accurately (9, 10). These developments indicate that human resource productivity should be viewed as a dynamic organizational outcome rather than as a single static performance ratio.

A growing body of research has therefore focused on identifying the antecedents of human resource productivity. Meta-analytic and organizational studies indicate that productivity emerges from an interconnected set of individual, managerial, structural, motivational, cultural, and environmental factors (11, 12). Empirical work conducted in governmental and quasi-governmental settings has likewise demonstrated the importance of organizational policies, managerial practices, employee attitudes, and workplace conditions in shaping productivity (13, 14). Research conducted in specific organizational settings such as ports, energy companies, hospitals, scientific organizations, and regional innovation systems has further emphasized that productivity determinants are context-dependent and may vary according to institutional missions, occupational structures, technological requirements, and environmental constraints (15-18). Thus, although general principles of human resource management provide an essential foundation, productivity-improvement strategies should be adapted to the particular structure and operating environment of each organization.

One of the most important dimensions of productivity is the quality and capability of human resources themselves. Human resource quality includes professional knowledge, technical competence, adaptive capacity, motivation, resilience, and the capacity to respond effectively to organizational challenges. Recent research has linked the quality of human resources to organizational resilience, suggesting that organizations with stronger human capital are better able to maintain performance under changing and uncertain conditions (19). Knowledge-based dynamic capabilities, including the ability to acquire, integrate, share, and apply knowledge, are likewise important for sustaining the productivity of knowledge workers, while organizational culture can strengthen or constrain these effects (20). Research in higher education has similarly demonstrated the relevance of knowledge-management enablers and knowledge processes to knowledge-worker productivity (21). Even collaborative structures can influence productivity by facilitating knowledge exchange and collective scientific performance (22). These findings collectively support the view that human productivity is generated not merely by the presence of skilled individuals, but by organizational systems that enable those individuals to use, develop, and exchange their capabilities effectively.

Motivation, employee engagement, perceived support, quality of work life, and organizational fairness represent additional mechanisms through which human resources translate their capabilities into productive behavior. Studies of virtual work environments have linked employee engagement and self-efficacy with productivity, highlighting the importance of psychological and motivational conditions even when work is technologically mediated (23). Similarly, contemporary human resource practices increasingly emphasize work flexibility, distributive fairness, and quality of work life as mechanisms that may strengthen employee productivity (24). Sustainable human resource productivity has also been associated with broader combinations of organizational and employee-related conditions rather than isolated interventions (25). At the strategic level, productivity may serve as an important pathway connecting human resource practices to broader organizational performance (26). These relationships are particularly relevant in public organizations, where rigid administrative structures, workload pressures, limited financial incentives, and restricted career opportunities may weaken the connection between employee competence and actual organizational performance.

The digital transformation of organizations has added another major dimension to the productivity debate. Human resource management is increasingly influenced by automation, artificial intelligence, analytics, digital platforms, and data-driven decision-making. Digital human resource practices have been associated with transformative organizational productivity by enabling faster processes, improved coordination, better access to information, and more efficient management of human capital (27). Human resource analytics capability is similarly becoming an important organizational architecture for supporting evidence-based workforce decisions (28). Developments in artificial intelligence have further shifted the role of technology from simple automation toward augmentation, in which technological tools complement employee capabilities and reshape work processes (29). Research on the integration of artificial intelligence into human resource digitalization emphasizes that technological implementation must remain sustainable and organizationally integrated rather than being treated merely as a technical upgrade (30). Likewise, emerging applications of generative artificial intelligence in human resource management demonstrate that digital technologies can affect multiple HR processes and outcomes, although their effectiveness depends on organizational conditions, implementation mechanisms, and human acceptance (31).

Technological development, however, does not automatically translate into productivity improvement. Evidence from smart manufacturing and digitally enabled production environments suggests that technology must be aligned with organizational structures and productivity objectives to create sustained value (32). More advanced approaches, such as human digital twins, illustrate how digital technologies can increasingly be used to simulate, monitor, and optimize labor productivity (33). At the same time, quantitative research on human resource configuration has shown that workforce composition itself has financial and productivity implications, indicating that effective performance depends on the appropriate combination of human and technological resources rather than on the maximization of either one in isolation (34). These developments are highly relevant to tax administrations, where digitalization, automated information processing, taxpayer databases, online services, risk-based auditing, and electronic transactions increasingly reshape the nature of employees' work. In such environments, employee productivity depends not only on staffing levels but also on digital competence, technological infrastructure, quality of information, and the degree to which automation supports rather than obstructs professional performance.

The relationship between workforce quantity and productivity is similarly complex. Expanding staffing may be necessary when service demand increases, but numerical expansion alone does not guarantee greater productivity if recruitment, specialization, training, work allocation, technology, and organizational processes are not coordinated. Productivity challenges identified in labor-intensive sectors demonstrate that performance can be affected by interacting combinations of workforce, managerial, environmental, and operational variables (35, 36). In modern labor markets, changes in employment forms and the emergence of new work arrangements also require human resource management systems to become more adaptive and strategic (37). These developments reinforce the need to evaluate staffing policies in interaction with other productivity drivers rather than assuming a linear relationship between employee numbers and organizational outputs. This issue is especially important in governmental tax systems, where excessive staffing may create hidden inefficiencies, whereas insufficient staffing may increase workload, delay service provision, intensify burnout, and weaken the organization's capacity to administer increasingly complex tax processes.

At a broader institutional level, public-sector productivity is closely connected with governance, organizational scale, coordination, and the capacity of institutions to allocate resources effectively. Research on public-sector productivity has emphasized that governance arrangements and the scale at which administrative activities are organized can influence institutional efficiency (38, 39). Productivity is also relevant to wider processes of economic and regional development because improvements in the effectiveness of organizations can influence the utilization of economic resources and institutional capacities (40, 41). For tax administrations, this relationship is particularly significant. Tax organizations occupy a strategic position in public governance because they are responsible for mobilizing government revenue, interacting directly with taxpayers, enforcing statutory requirements, processing large volumes of financial information, and supporting fiscal capacity. Weak human resource productivity in such organizations can therefore extend beyond internal inefficiency and affect service quality, tax administration capacity, revenue collection, and citizens' perceptions of public institutions.

The complexity of these relationships creates a methodological challenge. Conventional cross-sectional or linear analytical models can identify associations among variables, but they may be insufficient for explaining feedback loops, delayed effects, nonlinear relationships, accumulated consequences, and policy interactions over time. Human resource productivity can contain reinforcing and balancing mechanisms; for example, training may improve competence, improved competence may increase effectiveness, increased effectiveness may reduce work pressure, and reduced work pressure may subsequently influence job satisfaction and productivity. At the same time, automation may initially require investment and training but later reduce workload and improve information quality. Changes in employee welfare may affect motivation, retention, and quality of performance, while staffing policies may simultaneously influence workload and the productivity ratio. Such relationships are inherently dynamic.

System dynamics provides an appropriate framework for examining systems characterized by these forms of complexity. Rather than examining variables independently, system dynamics represents the system through causal relationships, feedback loops, stocks, flows, delays, and simulations of behavior over time. System dynamics models have been used to analyze the effects of interacting organizational and operational factors on labor productivity and to examine how structural changes generate different behavioral trajectories (42). In human resource research, system dynamics has been applied directly to the development of productivity models, demonstrating its usefulness for integrating multiple human, managerial, and organizational components within a unified analytical framework (43). Similarly, modeling of the relationships among job satisfaction, productivity, and service quality demonstrates the capacity of system dynamics to represent reciprocal and time-dependent effects that are difficult to capture using static approaches (44). More broadly, system dynamics has been used in policy and resource modeling to assess alternative interventions under complex conditions and limited resources (45).

The use of a dynamic approach is particularly justified when decision makers must choose among competing productivity-improvement policies. Organizations rarely have sufficient resources to improve all aspects of human resource management simultaneously. Managers may have to choose whether to prioritize recruitment, employee development, welfare, career opportunities, automation, information systems, or managerial interventions. The effects of these policies may differ in magnitude and time horizon. Some strategies may generate rapid but limited improvements, whereas others may require substantial initial investment but produce stronger long-term benefits. Studies concerned with sustainable productivity and contemporary human resource management increasingly emphasize the need to move away from isolated interventions toward integrated configurations of organizational resources and capabilities (1, 2). The increasing availability of digital systems, analytics, and advanced modeling methods further strengthens the possibility of evaluating alternative human resource strategies before full-scale implementation (28, 33).

Despite the expanding literature on human resource productivity, several limitations remain relevant to public tax administration. First, many studies have concentrated on identifying or ranking productivity factors rather than modeling their dynamic interactions (11, 12). Second, context-specific studies have demonstrated that the importance of productivity determinants varies considerably across organizations and sectors (15, 16). Third, research on knowledge workers, digital human resources, automation, and organizational productivity has expanded rapidly, yet these areas are frequently examined separately rather than within an integrated model combining employee development, career management, motivation, welfare, staffing, technology, and organizational processes (6, 9, 29). Finally, although productivity models have been developed in Iranian governmental and service organizations, a context-specific dynamic model capable of simulating alternative human resource productivity policies within a provincial tax administration remains necessary (8, 13, 43).

Accordingly, the present study aimed to design and simulate a system dynamics model for improving human resource productivity in the East Azerbaijan Province Tax Administration and to evaluate the comparative effects of alternative productivity-enhancement scenarios.

Methods and Materials

The present study employed a mixed-methods design and was classified, in terms of purpose, as an applied-developmental study with an explanatory modeling orientation. The research was conducted within the context of the tax administration system of East Azerbaijan Province, Iran, with a specific focus on modeling the mechanisms underlying the improvement of human resource productivity. System dynamics was adopted as the principal methodological framework because human resource productivity in a tax administration represents a complex organizational phenomenon characterized by multiple interconnected variables, feedback mechanisms, time-dependent effects, and reciprocal relationships among managerial, technological, educational, motivational, and organizational factors. The system dynamics procedure followed an iterative process consisting of problem structuring, development of a dynamic hypothesis, formulation and modeling through causal-loop and stock-flow diagrams, model validation, simulation, scenario development, and policy evaluation. The study population comprised the tax administration system and related executive organizations in East Azerbaijan Province, as well as experts possessing specialized knowledge of human resource productivity in the provincial tax administration. Participants were selected through purposive and convenience sampling. Fourteen experts participated in the different stages of data collection, development of the causal relationships, and construction and refinement of the dynamic model. Eligibility for membership in the expert panel required fulfillment of at least three of four predetermined criteria: holding a relevant doctoral degree in management together with at least two publications related to the research field; having at least 15 years of executive experience in tax administration, particularly in human resource management; having sufficient familiarity with productivity and human resource productivity concepts; and willingness to participate in the research interviews. Of the 14 experts, eight were university faculty members and six were senior tax experts working in the province, representing 57.14% and 42.86% of the expert panel, respectively. The participants possessed substantial professional experience, and a considerable proportion had between 21 and 25 years of professional experience. From the original expert group, six specialists actively involved in tax affairs in East Azerbaijan Province participated specifically in examining the structural validity of the causal-loop and stock-flow models, evaluating the mathematical relationships among endogenous variables, and reviewing the relationships incorporated into the quantitative simulation model.

Data were collected from multiple sources to provide the empirical and conceptual information required for developing the system dynamics model. The primary sources included a comprehensive review of the theoretical and empirical literature on human resource productivity, organizational and historical data relating to the East Azerbaijan Tax Administration, expert interviews, and questionnaires used during the model development and validation stages. The literature review was initially used to identify the principal determinants and dimensions of human resource productivity and to establish the conceptual boundaries of the system. On the basis of this synthesis, the major subsystems associated with productivity were identified, including human resource empowerment, training and development, career-path development, productivity-oriented organizational structures and processes, human resource management and productivity-oriented policymaking, behavioral and motivational factors, information technology and digital mechanization, organizational culture, and productivity-oriented leadership and management. The expert interviews were subsequently used to examine the applicability of these factors to the tax administration setting, determine the relationships among the model components, refine the causal-loop structure, and assist in defining quantitative relationships for variables included in the stock-flow model. Because several constructs in the causal model were qualitative and complete longitudinal organizational data were unavailable for all variables, the experts also contributed to the formulation and adjustment of quantitative relationships where direct organizational measurements were insufficient. The initial stock-flow model underwent repeated review and revision to improve its correspondence with the actual conditions of the tax administration system. Historical organizational data were used whenever available, particularly for variables such as the number of employees in different occupational groups, employee in-service training hours, tax-service levels, educational person-hours for different categories of employees and tax auditors, and indices related to available facilities and technological resources. Time-series observations for a number of variables were incorporated into the model as lookup functions because their historical trajectories were nonlinear and could not be represented with adequate accuracy by simple linear regression functions. Future values for selected variables were estimated using time-series-based projections and incorporated into the simulation model. For model validation, a structured questionnaire was used to obtain expert judgments concerning whether the model structure corresponded with organizational regulations, procedures, actual conditions, and human resource decision-making processes; whether the model was suitable for assessing human resource productivity in the provincial tax administration; whether the quantitative outputs adequately represented the historical behavior of the system; and whether the principal concepts and variables had been appropriately included within the model boundary. The questionnaire-based review was conducted with six senior specialists over three successive rounds, with intervals ranging from approximately one week to one month between rounds. The model, its mathematical relationships, and its preliminary graphical and statistical outputs were provided to the experts for review, and their comments were subsequently incorporated into successive revisions.

Data analysis was conducted using the methodological principles of system dynamics and proceeded through a sequence of interrelated qualitative and quantitative modeling stages. Initially, the research problem was structured by defining human resource productivity as the central system variable and identifying the organizational conditions that could increase or reduce its behavior over time. The dynamic hypothesis was then developed by integrating evidence from the literature, organizational information, and expert judgments. Causal-loop diagrams were constructed to represent causal relationships and feedback mechanisms among the identified variables. These diagrams were subsequently transformed into a quantitative stock-flow model in which human resource productivity was treated as a stock influenced by multiple flows and auxiliary variables. Mathematical and logical relationships were specified for the endogenous variables according to the causal structure of the model, available historical data, relevant theoretical evidence, and expert judgments. Where longitudinal data displayed nonlinear patterns, lookup functions were used rather than conventional linear estimation, while statistical time-series projections were employed to obtain plausible future values for selected variables. The simulation covered the historical and projected study period, and a time step of 0.5 year was specified for collecting and calculating model outputs at successive simulation intervals. Following construction of the stock-flow model, validation was performed before using the model for scenario analysis. Structural validity and model-boundary adequacy were evaluated through expert review. Six tax administration specialists assessed the compatibility of the model with actual organizational procedures and decision-making processes, the adequacy of the variables incorporated within the model boundary, and the plausibility of the mathematical and logical relationships. The initial model and associated simulation outputs were reviewed across three successive rounds, with expert recommendations incorporated into each revision. By the third round, the overall structural validity of the model was rated from desirable to highly desirable, with the reported validity index exceeding 74%, and no additional substantive modifications were proposed by the expert panel. Behavioral robustness was further examined through sensitivity analysis and extreme-condition behavioral testing. Exogenous variables were entered both individually and collectively into the sensitivity analyses to determine the extent to which changes in external parameters affected the behavior of major endogenous variables and the stability of the model outputs. Four hundred simulation runs were performed for each sensitivity-analysis cycle, with the noise-seed parameter specified as part of the simulation procedure. After confirming an acceptable level of structural and behavioral validity, policy simulation and scenario analysis were conducted. Five feasible scenarios were formulated and compared over the medium-term simulation horizon to estimate how alternative interventions, including continuation of the existing situation, changes in recruitment, improvements in employee welfare, simultaneous enhancement of empowerment-related facilities and tax-process automation, and expansion of in-service training, would alter the human resource productivity trajectory. The resulting simulated changes in the human resource productivity index were then compared to determine the relative effectiveness and priority of the alternative policy scenarios.

Findings and Results

The findings were developed through successive stages of problem definition, dynamic-hypothesis development, stock-flow modeling, model validation, sensitivity analysis, and simulation of alternative policy scenarios. In defining the problem, human resource productivity was conceptualized as the efficiency and effectiveness with which employees generate organizational output or added value relative to the resources consumed. Within the tax administration system, the principal factors incorporated into the dynamic representation of productivity included employee skills and professional expertise, managerial and employee efficiency and effectiveness, employees' attitudes, motivation and morale, costs associated with the provision of tax services, the level and effectiveness of staff training, and career-path conditions encompassing opportunities for material, professional, and welfare-related advancement. Low human resource productivity was consequently associated with such organizational conditions as wasted working time, inadequate salaries and benefits, excessive staffing accompanied by hidden unemployment or insufficient staffing associated with occupational exhaustion, poor service quality, inappropriate human resource utilization policies, inadequate employee support, and insufficient job satisfaction.

Development of the dynamic hypothesis indicated that human resource productivity in the tax administration was formed through the interaction of several organizational subsystems. Eight major domains were identified: human resource empowerment, education and development; employee career-path planning directed toward productivity; productivity-oriented structures and processes; human resource management and productivity-oriented policymaking; behavioral, motivational, and attitudinal factors related to work and productivity; information technology and digital mechanization; an organizational culture compatible with productivity objectives; and productivity-oriented leadership and management. These domains were incorporated into the causal structure of the model and subsequently translated into the stock-flow representation.

Following formulation of the causal relationships, the qualitative causal-loop structure was converted into a quantitative stock-flow model. Human resource productivity was treated as the principal stock variable whose value changed over time according to interconnected inflows, auxiliary variables, constants, and delayed effects. Because a number of variables identified in the causal model were qualitative and lacked complete longitudinal measurements, only variables for which sufficiently defensible quantitative information could be obtained were incorporated into the final stock-flow model. Quantitative relationships were formulated by integrating available organizational data, previous empirical evidence, causal relationships identified in the dynamic hypothesis, and expert judgments. The initial stock-flow model was subjected to 18 rounds of partial and comprehensive review before its final structure was established.

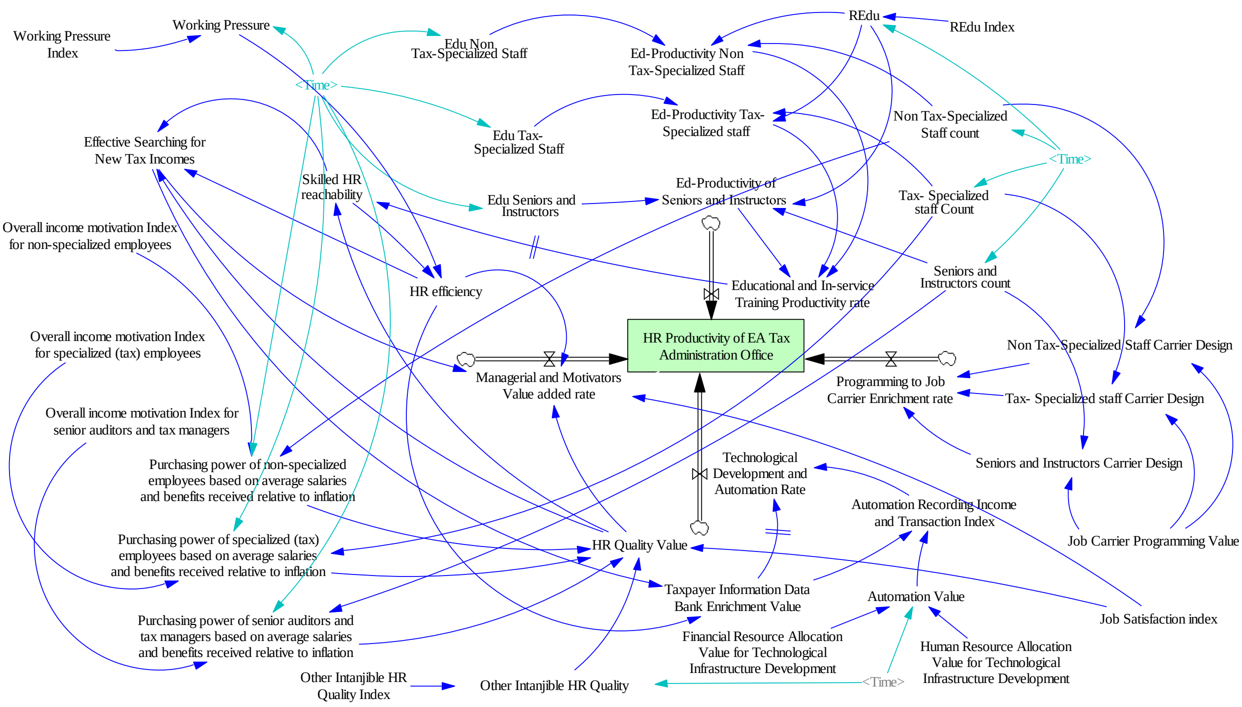

Figure 1. Stock-Flow Diagram of Human Resource Productivity in the East Azerbaijan Province Tax Administration

Longitudinal information concerning employee numbers, in-service training hours, tax-service levels, training person-hours for different occupational groups and tax auditors, expected service levels, and the availability of organizational facilities was incorporated primarily through lookup functions. This approach was used because the observed trajectories of several variables were nonlinear and could not be estimated with acceptable error through conventional linear regression. Where necessary, future values were derived through time-series projections. The main quantitative components of the stock-flow structure are summarized in Table 1.

Table 1. Principal Quantitative Components and Relationships of the Stock-Flow Model

Model component	Operationalization or model relationship
Training hours of non-tax-specialized staff	Entered as a time-based lookup function using observed data from 1390 to 1404 and a projected value for 1414; the model projected approximately 490 person-hours for 1414.
Training hours of senior auditors and managers	Entered through a lookup function using longitudinal observations; the projected value for 1414 was 1,055 person-hours.
Training hours of tax-specialized staff	Entered through a lookup function using historical observations and future projection; the 1414 value was projected at approximately 5,500 person-hours.
Educational productivity of non-tax-specialized staff	Defined principally as training hours divided by the number of non-tax-specialized employees, adjusted through the education-rate parameter and delay structure.
Educational productivity of senior auditors and managers	Calculated as training hours of senior auditors and managers divided by their number, raised according to the education-rate parameter.
Educational productivity of tax-specialized staff	Calculated as training hours of tax-specialized employees divided by the number of tax-specialized employees and adjusted by the education-rate parameter.
Overall educational and in-service training productivity	Defined as a weighted combination of educational productivity for non-specialized staff, tax-specialized staff, and senior auditors/managers, with respective weights of 1, 2, and 3 and division by 6.
Automation recording income and transaction index	Modeled as a joint function of taxpayer-information database enrichment and delayed automation value.
Automation value	Modeled through delayed financial and human resource allocations for technological infrastructure development.
Effective search for new tax revenues	Determined by delayed skilled-human-resource availability, human resource efficiency, and human resource quality.

Human resource productivity of the East Azerbaijan Tax Administration	Modeled as an accumulated stock driven jointly by educational and in-service training productivity, managerial and motivational value added, career-path enrichment programming, and technological development and automation.
Human resource quality value	Determined by the combined purchasing power of non-specialized employees, senior auditors/managers, and tax-specialized employees, modified by intangible human resource quality and job satisfaction.
Managerial and motivational value-added rate	Modeled as a function of human resource quality, human resource efficiency, effective identification of new tax revenues, and job satisfaction.
Career-path enrichment programming	Calculated from career-development values for non-specialized staff, senior auditors/managers, and specialized tax staff, with relatively greater weight assigned to specialized and senior occupational groups.
Purchasing power of employee groups	Calculated separately for non-specialized employees, senior auditors/managers, and specialized tax employees using their income-motivation indices and employee counts.
Skilled human resource availability	Modeled as a delayed function of educational and in-service training productivity combined with human resource quality.
Taxpayer-information database enrichment	Determined by effective search for new tax revenues and human resource efficiency, including a delayed component.
Technological development and automation	Modeled through the interaction of the automation-based income/transaction recording index and enrichment of the taxpayer-information database.
Working pressure	Modeled using service accessibility, expected service gap, expected facility gap, unexpected service demand, recruitment potential, and the ratio of tax experts to other employees.
Simulation period	Initial time = 1390; final time = 1414.
Simulation time step	0.5 year.

The model contained several additional constants and auxiliary parameters. The financial resource allocation value for technological infrastructure development was set to 5, while human resource allocation for technological infrastructure development was expressed through a step function. Career-path programming was assigned a value of 10, the job satisfaction index was initially set at 1, and the intangible human resource quality index was set at 0.5. The income-motivation indices were set at 0.25 for non-specialized employees, 0.50 for senior auditors and tax managers, and 0.25 for specialized tax employees. The education-rate parameter was initially set to 1.

The number of non-tax-specialized employees was modeled through historical data ranging from 54 employees in 1390 to a projected 107 employees in 1414. Senior auditors and managers were projected to reach 190 employees in 1414, while tax-specialized staff were projected to reach 800 employees. The model also included separate career-design functions for each occupational group. Purchasing power was defined separately for non-specialized staff, senior auditors/managers, and specialized tax personnel based on average salaries and benefits relative to inflation. Skilled human resource availability was linked to educational productivity and human resource quality, while enrichment of the taxpayer-information database was linked to the capacity to identify new tax revenues and human resource efficiency. The simulation stored outputs at 0.5-year intervals.

After completion of the stock-flow model and extraction of preliminary simulation outputs, the model was validated before scenario analysis. Validation focused on structural adequacy, boundary adequacy, and behavioral robustness. Structural validation was performed through three successive rounds of expert assessment. Six senior tax experts reviewed whether the model corresponded with organizational rules, procedures, realities, and human resource decision-making processes; whether it was appropriate for assessing human resource productivity in the provincial tax system; whether its mathematical and quantitative outputs reasonably reproduced the previous behavior of the system; and whether the major relevant concepts and variables were located within the endogenous model boundary. Expert recommendations were incorporated after each assessment round. By the third round, structural validity was reported to be desirable to highly desirable, with a validity index exceeding 74%, while boundary adequacy was also evaluated as desirable. No further substantive revision was requested during the third round.

Sensitivity analysis was then conducted by varying exogenous variables individually and collectively. Four hundred simulations were performed in each sensitivity-analysis cycle. The findings showed that educational and in-service training productivity, educational productivity of non-tax-specialized employees, educational productivity of specialized and senior personnel, and employee career enrichment exhibited relatively stable uncertainty patterns over time. The accumulation of parameter uncertainty did not expand substantially for these variables, indicating controlled model behavior. In contrast, uncertainty associated with technological development, automation, the automation-based recording of income and transactions, and managerial and motivational value-added components became more evident over longer simulation horizons, indicating greater sensitivity of these components to changes in exogenous assumptions.

Table 2. Summary of Model Validation and Sensitivity-Analysis Findings

Evaluation domain	Main result	Interpretation
Structural validity	Third-round structural validity index exceeded 74%	Overall structure was judged desirable to highly desirable by the expert panel.
Boundary adequacy	Rated desirable	Major concepts and variables were considered adequately represented within the model boundary.
Expert-review convergence	No substantive new revisions were proposed in the third round	Model refinement was terminated after the third expert-review round.
Number of sensitivity simulations	400 runs per sensitivity-analysis cycle	Exogenous parameters were tested individually and collectively.
Educational productivity	Uncertainty remained comparatively stable over time	Educational components showed controlled sensitivity behavior.
Career-path enrichment	Accumulated uncertainty remained relatively stable	No evidence of unstable or explosive future behavior was identified.
Technology and automation	Uncertainty bands became wider over time	These components were more responsive to exogenous parameter uncertainty.
Overall human resource productivity	Final uncertainty band widened gradually rather than explosively	The total productivity stock remained behaviorally controlled over the simulation horizon.
Human resource productivity range in 1414	Approximately 2,246 to 2,800	This represented the largest observed uncertainty interval at the end of the simulation horizon.

The final sensitivity analysis of the human resource productivity stock showed that the uncertainty bands widened only gradually as the simulation moved further into the future. By 1414, the distance between the approximate upper boundary of 2,800 and the lower boundary of 2,246 reached its maximum. Nevertheless, the widening was mild, indicating that although parameter uncertainty accumulated over time, the overall human resource productivity system remained controlled and did not exhibit chaotic or explosive uncertainty. Therefore, the endogenous outputs used for modeling human resource productivity were considered to have an acceptable and relatively stable level of robustness.

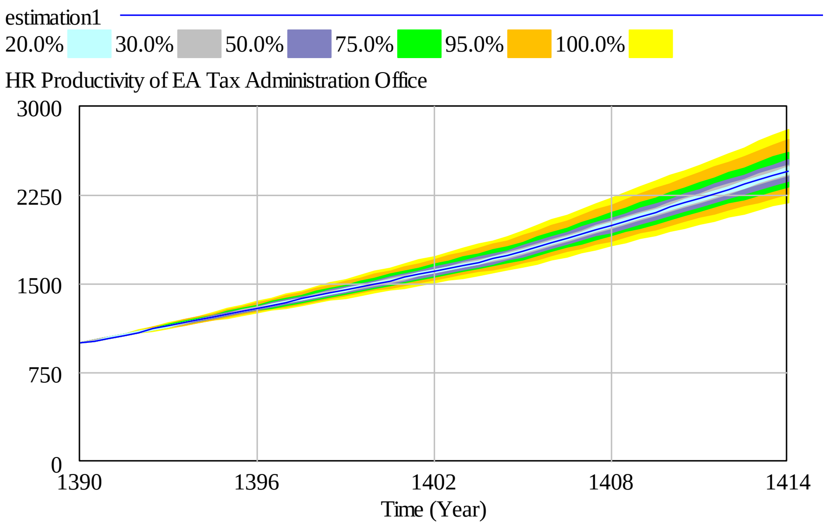

Figure 2. Final Sensitivity Analysis of Changes in the Human Resource Productivity Stock of the East Azerbaijan Province Tax Administration

Following validation, the final model was simulated to compare continuation of the existing organizational conditions with alternative productivity-improvement policies. Five scenarios were formulated using feasible changes in the model parameters and the organizational capacities of the provincial tax administration. The reference scenario represented continuation of the existing conditions, whereas the four intervention scenarios examined increases in recruitment, improvement in employee welfare, simultaneous development of employee empowerment and tax-process automation, and expansion of in-service training. The aggregated effects of these interventions on human resource productivity and other principal system variables were compared over the simulation horizon.

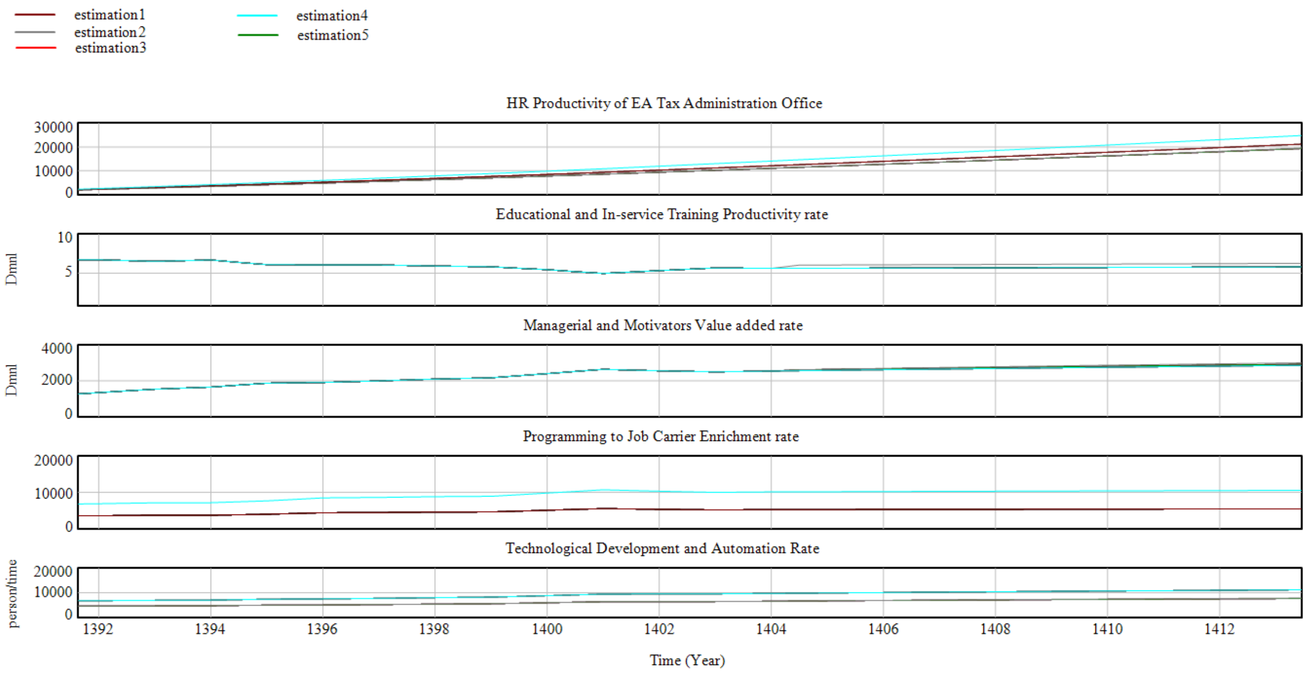

Figure 3. Aggregate Effects of Changes Applied in Different Scenarios on Human Resource Productivity and Other Main Variables

Under the reference scenario, the model was executed using the original parameters and assigned values for the exogenous variables without an additional policy intervention. For the period from 1404 to 1414, educational and in-service training productivity displayed a very mild declining trend. Human resource quality showed a mild, nonlinear increase with fluctuations over time, while human resource effectiveness also exhibited a very modest nonlinear upward trajectory. Despite these component-level changes, overall human resource productivity was projected to rise from 1,000 units in 1390 to 2,449 units in 1414.

In the second scenario, the recruitment rate for active human resources was increased by 20% across occupational categories. Consequently, the projected number of specialized tax employees in 1414 increased from 800 to 960, the number of senior personnel and managers increased from 190 to 228, and the number of non-specialized employees increased from 107 to 128. Despite the increased workforce, the model indicated only a small improvement in overall productivity, partly because expansion in staff numbers could also generate hidden organizational unemployment and reduce some components entering the productivity calculation. Human resource productivity increased from the reference value of 2,449 to 2,499 units, corresponding to a 50-unit improvement. The simulation therefore suggested that major increases in employee numbers would have limited effects on productivity over the short and medium term and that any stronger effect might emerge only over a longer time horizon.

The third scenario modeled improvement in the relative welfare of different employee groups. Under optimistic projections, the purchasing-power indicator for non-specialized tax employees increased from 26.75 to 37.45 units by 1414. The corresponding purchasing-power indicator for senior employees and tax managers increased from 95 to 171 units. The managerial and motivational value-added indicator increased from 2,894 units under the reference scenario to 3,832 units under Scenario 3. These changes were accompanied by an increase in overall human resource productivity from 2,449 to 2,558 units, representing a reported improvement of 109 units. The scenario therefore demonstrated that relative employee welfare exerted a comparatively substantial influence on the productivity stock.

Scenario 4 examined the simultaneous improvement of employee empowerment-related facilities and tax-process automation. Under this scenario, the employee career-path planning indicator increased from 5,477 units in the reference scenario to 6,504 units in 1414. The tax-process automation indicator increased from 2,321 to 2,626 units. Improvements were also observed in human resource effectiveness, the identification of new sources of tax revenue, and enrichment of taxpayer information resources. Overall human resource productivity increased from 2,449 units in the reference scenario to 2,686 units in 1414.

Scenario 5 assessed a 20% expansion in employees' in-service training hours, which represented the maximum feasible increase identified by the expert group under the existing educational infrastructure and availability of qualified instructors. In the target year, the modeled training hours of non-specialized tax employees increased from 402 to 482, those of specialized tax employees increased from 5,279 to 6,335, and those of senior auditors and managers increased from 673 to 808. Before the intervention, educational productivity displayed a marked declining trajectory between 1400 and 1414; after the additional 20% training input was introduced, this deterioration was moderated toward maintenance of the existing condition. At the level of total human resource productivity, however, the improvement remained limited, with the index increasing from the reference value of 2,449 to 2,468 units, corresponding to a 19-unit increase. Although the short-term effect was small, the simulation suggested that additional training could produce more substantial effects on human resource effectiveness and productivity over medium- and long-term horizons.

Table 3. Comparison and Ranking of the Five Human Resource Productivity Scenarios

Priority	Scenario	Main simulated intervention	Reference/initial condition	Simulated condition	Human resource productivity in 1414	Reported change from reference
1	Scenario 4	Simultaneous enhancement of employee empowerment facilities and tax-process automation	Career-path indicator = 5,477; automation indicator = 2,321; HR productivity = 2,449	Career-path indicator = 6,504; automation indicator = 2,626	2,686	+240 units*
2	Scenario 3	Improvement in the relative welfare of different employee groups	Non-specialized purchasing power = 26.75; senior/manager purchasing power = 95; managerial/motivational value = 2,894; HR productivity = 2,449	Non-specialized purchasing power = 37.45; senior/manager purchasing power = 171; managerial/motivational value = 3,832	2,558	+109 units
3	Scenario 2	20% increase in recruitment across employee categories	Specialized = 800; senior/managerial = 190; non-specialized = 107; HR productivity = 2,449	Specialized = 960; senior/managerial = 228; non-specialized = 128	2,499	+50 units
4	Scenario 5	20% increase in in-service training hours	Training hours: non-specialized = 402; specialized = 5,279; senior/managerial = 673; HR productivity = 2,449	Training hours: non-specialized = 482; specialized = 6,335; senior/managerial = 808	2,468	+19 units
5	Scenario 1	Continuation of existing conditions; reference scenario	HR productivity = 1,000 in 1390	Continuation of baseline parameters	2,449	Reference

Overall comparison of the simulated policies showed a clear ordering of their effects on the human resource productivity stock. The simultaneous improvement of empowerment-related facilities and automation in Scenario 4 generated the strongest medium-term change, followed by improvement in relative employee welfare in Scenario 3. Increasing recruitment generated only a modest improvement, while a 20% increase in in-service training produced the smallest immediate change in overall productivity. Continuation of the existing conditions generated a projected productivity level of 2,449 units in 1414 and served as the reference against which the intervention scenarios were evaluated. Thus, among the feasible alternatives examined by the system dynamics model, the combined empowerment-and-automation intervention produced the most favorable simulated trajectory for improving human resource productivity in the East Azerbaijan Province Tax Administration.

Discussion and Conclusion

The present study was conducted to design a system dynamics model for improving human resource productivity in the East Azerbaijan Province Tax Administration and to compare alternative policy scenarios capable of influencing productivity over time. The findings demonstrated that human resource productivity in the tax administration is generated through the interaction of several mutually dependent organizational subsystems rather than through a single isolated factor. The final dynamic model incorporated employee empowerment and development, career-path planning, organizational structures and processes, human resource management and productivity-oriented policies, motivational and attitudinal conditions, information technology and digital mechanization, organizational culture, and productivity-oriented leadership. The model also passed structural and boundary-validity assessments and showed generally controlled behavior under sensitivity analysis. More importantly, simulation of the five policy scenarios revealed clear differences in their projected effects: simultaneous enhancement of employee empowerment facilities and tax-process automation produced the strongest improvement in human resource productivity, improvement in relative employee welfare ranked second, increased recruitment produced only a limited improvement, and expansion of in-service training generated the smallest immediate increase. These findings reinforce the idea that productivity should be understood as a systemic, multidimensional, and dynamically evolving organizational outcome rather than merely as a function of employee numbers or isolated training inputs (4, 11, 12).

The structure of the final model is consistent with previous research showing that human resource productivity is influenced by combinations of individual, structural, managerial, technological, motivational, and contextual conditions. Previous studies in governmental, technological, and service organizations have similarly emphasized that employee productivity cannot be explained solely by personal characteristics or technical competence, because organizational policy, managerial support, working conditions, institutional structures, and available resources jointly shape performance (8, 13, 15). Likewise, studies focused on sustainable human resource productivity have demonstrated that organizational productivity is strengthened when human resource capabilities are aligned with structural and strategic resources (25). The inclusion of eight interacting components in the present system dynamics model therefore reflects the multidimensional nature of productivity documented in the literature. This finding is also supported by work on knowledge-intensive employees, where productivity depends simultaneously on knowledge processes, organizational culture, collaboration, employee capability, and managerial conditions (6, 20, 21).

The model-validation findings further support the methodological suitability of the system dynamics approach. Structural validity was judged desirable to highly desirable after three rounds of expert assessment, and the overall structural-validity index exceeded 74%. Boundary adequacy was also considered satisfactory. Sensitivity analysis indicated that the major endogenous variables remained generally stable under variation in exogenous parameters, although technology- and automation-related variables demonstrated comparatively greater sensitivity over longer time periods. Nevertheless, the final human resource productivity stock showed only gradual widening of uncertainty bands rather than unstable or explosive behavior. These results suggest that the model reproduced system behavior with an acceptable degree of robustness and that the major feedback mechanisms incorporated in the model were sufficiently stable for policy simulation. This methodological outcome corresponds with previous system dynamics research showing that the value of dynamic modeling lies not merely in producing point estimates, but in representing feedback, delay, accumulation, uncertainty, and nonlinear relationships among organizational factors (42-44). Similar applications of system dynamics in resource and policy environments have shown that scenario-based simulation is particularly useful when decision makers need to evaluate interacting policy alternatives under uncertain and changing conditions (45).

The most important substantive finding was related to Scenario 4. Simultaneous improvement of empowerment-related facilities and tax-process automation generated the strongest projected increase in human resource productivity. In this scenario, the employee career-path planning indicator increased substantially, the tax-process automation indicator improved, and favorable changes were also observed in human resource effectiveness, identification of new tax-revenue sources, and enrichment of taxpayer information. Overall human resource productivity rose from the reference value of 2,449 to 2,686 units, reported in the study as an increase of 240 units. This finding indicates that technological improvement produces its strongest productivity effects when it is combined with organizational and human empowerment rather than implemented independently. Digital transformation can reduce repetitive administrative tasks, improve access to information, increase processing speed, enhance monitoring and analysis, and support evidence-based decision-making; however, these advantages can be realized only when employees possess the competence, authority, resources, and organizational support required to use new technologies effectively.

This result strongly corresponds with recent research on digital human resource practices and technology-enabled productivity. Digital human resource practices have been associated with transformative improvements in organizational productivity when technology is integrated into broader human resource systems rather than treated as an isolated technological investment (27). Similarly, the integration of Fourth Industrial Revolution technologies into human resource practices has been shown to influence productivity through organizational mechanisms such as work flexibility, quality of work life, and distributive fairness (24). Studies of automation and artificial intelligence also suggest that contemporary organizations are moving from simple replacement-oriented automation toward augmentation, in which technology increases employees' capabilities and enables them to perform higher-value tasks (29). The sustainable integration of artificial intelligence and digital technologies into human resource systems likewise depends on the alignment between human skills, organizational processes, and technological infrastructure (30, 31). Therefore, the superiority of Scenario 4 can be explained by its simultaneous intervention in both the human and technological subsystems of the organization.

The finding also aligns with research emphasizing the importance of human resource quality and organizational capability. Human resource quality has been associated with stronger organizational resilience, suggesting that capable and well-supported employees are better able to use available resources effectively and respond to changing environmental conditions (19). Similarly, knowledge-based dynamic capabilities contribute to productivity when organizations create conditions that allow employees to acquire, apply, and integrate knowledge (20). Human resource development is fundamentally concerned with improving employees' capabilities while simultaneously creating organizational conditions that allow those capabilities to contribute to strategic objectives (3). Thus, empowerment and automation should not be considered separate productivity programs. Empowerment strengthens employees' ability to exercise judgment, use information, solve problems, and adapt to new systems, while automation increases the informational and technological capacity through which those competencies can be transformed into productive outputs.

Scenario 3, which focused on improving the relative welfare of different groups of employees, produced the second-largest improvement in productivity. The simulated improvement in employee welfare increased the purchasing-power indicators of non-specialized personnel, senior employees, and managers and substantially increased the managerial and motivational value-added indicator. Overall human resource productivity increased from 2,449 to 2,558 units, representing a 109-unit improvement. This result indicates that employee welfare, compensation adequacy, and perceived economic conditions play an important motivational role in productivity. When employees perceive that their compensation and benefits are increasingly inadequate relative to living costs or comparable employment opportunities, motivation, commitment, and willingness to invest discretionary effort may decline. Conversely, improvement in relative welfare can strengthen organizational attachment and motivation even if absolute compensation does not reach an ideal level.

The importance of welfare and motivational conditions is supported by studies emphasizing the role of quality of work life, fairness, employee attitudes, and psychological engagement in productivity. Al-Suwaidi et al. demonstrated that work flexibility, quality of work life, and distributive fairness represent important pathways through which modern human resource practices influence productivity (24). Research on employee engagement and self-efficacy has similarly shown that positive psychological relationships with work are associated with stronger productivity outcomes (23). Individual attitudes also contribute to variations in human resource productivity within organizational environments (14). More broadly, productivity can mediate the relationship between human resource management and strategic organizational performance, illustrating how improvements in employee-level conditions can ultimately influence organizational outcomes (26). The findings of Scenario 3 therefore reinforce the need for tax administrations to consider compensation, welfare, fairness, and employee motivation as productivity variables rather than treating them only as administrative expenditures.

In contrast, Scenario 2 demonstrated that increasing recruitment by 20% across employee categories generated only a modest increase in human resource productivity. Although the projected numbers of specialized staff, senior managers, and non-specialized personnel increased, overall productivity improved by only 50 units. The model suggested that expansion in employee numbers could even create hidden unemployment or reduce certain productivity components if recruitment exceeded the organization's effective capacity to allocate and utilize additional personnel. This finding is important because public organizations often respond to increasing workload by emphasizing additional recruitment. However, a larger workforce does not automatically produce greater productivity when organizational processes, job design, specialization, technology, and managerial capacity remain unchanged.

Previous research supports this interpretation by demonstrating that productivity depends on the configuration and effective utilization of human resources rather than simply on workforce size. Quantitative analysis of human resource configuration suggests that the financial and productivity effects of staffing depend on how employees are distributed and integrated within organizational processes (34). Studies identifying critical labor-productivity determinants also show that labor outcomes are influenced by interacting managerial, technological, operational, and environmental factors rather than numerical staffing levels alone (35, 36). Similarly, human resource productivity strategies require an appropriate fit among individual capabilities, organizational requirements, and development policies (18). The limited effect of Scenario 2 therefore suggests that recruitment may be necessary to compensate for workforce shortages, but it should not be regarded as an independent productivity strategy. Recruitment is more likely to create productivity gains when new employees possess the appropriate competencies and are integrated into redesigned processes, technological systems, and clearly defined career structures.

Scenario 5 produced the smallest immediate improvement in total human resource productivity. A 20% increase in in-service training hours increased the training exposure of non-specialized employees, specialized tax employees, and senior auditors and managers; nevertheless, total human resource productivity increased by only 19 units relative to the reference scenario. The simulation indicated that greater training helped moderate the declining trend in educational productivity, but its effect on total productivity over the modeled period remained limited. This result should not be interpreted as evidence that training is unimportant. Instead, it suggests that increasing training quantity alone may be insufficient when training content, transfer of learning, job relevance, technological application, organizational support, and career opportunities are not simultaneously changed.

This interpretation is consistent with the broader human resource development literature. Effective human resource development requires more than exposure to training because learning must ultimately enhance relevant competencies and be transferable to organizational performance (3). Sustainable human resource management similarly emphasizes the integration of development practices with organizational strategy rather than isolated interventions (2). Evidence from knowledge-intensive environments shows that productivity depends on how knowledge is transformed into practice through organizational processes and capabilities (9, 21). Furthermore, research on human resource productivity indicators highlights the importance of combining scientific, professional, ethical, and organizational factors rather than relying on any single developmental input (7). Therefore, the modest immediate effect of Scenario 5 may reflect the limited leverage of merely increasing training hours without simultaneously changing job design, empowerment, technological capacity, incentives, or mechanisms for applying newly acquired knowledge.

The reference scenario also provides an important insight. Under continuation of existing conditions, overall productivity was projected to increase from 1,000 units at the beginning of the modeled period to 2,449 units at the end, although some components, particularly educational productivity, showed weak or declining trends. This means that the existing organizational system could continue producing gradual productivity improvement, but such improvement would be substantially lower than that generated through strategically coordinated intervention. The difference between the reference scenario and Scenario 4 particularly demonstrates the importance of deliberate policy intervention. This conclusion corresponds with strategic human resource management perspectives emphasizing that organizational excellence results from purposeful alignment of human resource practices with emerging strategic and technological conditions (1). It also reflects the broader view that productivity is not merely an outcome of resource availability but of the manner in which organizational resources are configured and governed (38, 39).

Overall, the findings demonstrate that improving human resource productivity in tax administration requires an integrated policy architecture rather than fragmented interventions. Technological development is most productive when accompanied by employee empowerment; welfare policies influence motivation and therefore productivity; recruitment has limited value when disconnected from organizational capacity; and training produces stronger effects when embedded within a broader system of career development, knowledge application, technology, and managerial support. This systemic interpretation corresponds with previous research demonstrating the multidimensional nature of human resource productivity and supports the application of system dynamics for studying organizational outcomes characterized by feedback, delayed effects, and nonlinear interactions (42-44). Consequently, the principal contribution of the present study lies not only in identifying relevant productivity factors, but also in demonstrating how alternative combinations of these factors may generate substantially different organizational outcomes over time.

The present study has several limitations that should be considered when interpreting its findings. First, the model was developed for the East Azerbaijan Province Tax Administration and therefore reflects the organizational structure, available resources, workforce composition, administrative procedures, and contextual conditions of that setting; consequently, direct generalization to other provincial or national tax administrations should be undertaken cautiously. Second, complete longitudinal organizational information was not available for all variables identified in the causal-loop model, particularly for qualitative constructs such as organizational culture, psychological empowerment, job attitudes, and certain managerial characteristics. As a result, some variables could not be incorporated into the quantitative stock-flow structure, while others required lookup functions, expert judgments, constants, or projected values. Third, the number of experts involved in developing and validating the model was relatively limited. Fourth, scenario outcomes represent simulated trajectories based on assumptions and estimated relationships rather than outcomes observed after actual implementation of the proposed policies. Finally, some uncertainty remained in technology- and automation-related components of the model over longer simulation horizons, although overall sensitivity analysis indicated controlled behavior.

Future studies should replicate the model in tax administrations from other provinces and compare the resulting causal structures and policy priorities to determine which relationships are context-specific and which are relatively stable across organizational settings. Larger expert panels incorporating tax managers, frontline employees, human resource specialists, information technology personnel, policymakers, and external productivity experts could strengthen model development and validation. Future researchers should also collect longitudinal primary data for motivational, psychological, cultural, leadership, and empowerment variables so that a larger proportion of the conceptual causal-loop model can be quantified directly. Additional scenarios could examine combinations of compensation reform, flexible work arrangements, performance-based incentives, digital competency development, artificial intelligence adoption, job redesign, succession planning, and employee retention. Empirical follow-up studies could implement the highest-ranked scenarios and compare observed productivity changes with the model's predictions. Future research may also integrate system dynamics with structural equation modeling, machine learning, optimization methods, or agent-based modeling to improve parameter estimation and evaluate heterogeneous employee responses to policy interventions.

Tax administration managers should prioritize coordinated investments in employee empowerment and technological automation rather than implementing these initiatives independently. Digitalization programs should be accompanied by appropriate delegation of authority, access to information, revised workflows, technical support, career-development opportunities, and competency development so that employees can use technological systems effectively. Employee welfare and compensation should also be monitored relative to inflation, labor-market conditions, workload, and occupational responsibility because deterioration in relative welfare may weaken motivation and productivity. Recruitment should be based on verified workload and competency gaps rather than numerical expansion alone, with particular attention to specialized tax, legal, accounting, analytical, and digital skills. In-service training should shift from an emphasis on training hours toward competency-based programs linked to actual job requirements, new tax technologies, measurable performance outcomes, and mechanisms for transferring learning to the workplace. Finally, managers should use scenario-based planning and periodically update the system dynamics model with new organizational data so that productivity policies can be evaluated before large-scale implementation and adjusted as workforce, technological, and environmental conditions change.

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Authors’ Contributions

All authors equally contributed to this study.

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The authors of this article declared no conflict of interest.

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All ethical principles were adheried in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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