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Using Astin's I-E-O model to explain the supervisor's role in doctoral outcomes at a highly selective Russian university

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ABSTRACT

Previous studies have demonstrated that supervisors play a crucial role in doctoral student academic progress. Various supervisory characteristics have been identified as significant factors in student outcomes. However, these findings are often inconsistent and not grounded in strong theoretical frameworks. This study aims to explain the role of supervisors in shaping doctoral student outcomes in the Russian context, where students typically work with only one supervisor and rely heavily on them for both academic and personal support. Using Astin's Input–Environment–Output (I-E-O) model, we propose a framework that connects supervisory characteristics with doctoral completion through the concept of supervisor involvement. We apply this framework using quasi-longitudinal data from a highly selective Russian university (n = 610). The results help us better understand how supervisor involvement functions in a system with limited support structures and offer useful insights for improving supervision where students strongly depend on a single supervisor.

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Supervisor involvement; conceptual model validation; supervision; doctoral completion; Russian doctoral programmes

Introduction

Numerous studies have demonstrated that supervisory characteristics correlate with doctoral student outcomes, such as intentions to leave the programme, student satisfaction, time-to-degree, research productivity, career aspirations, well-being, and skill development (Jaksztat, Neugebauer, and Brandt 2021; Seagram, Gould, and Pyke 1998). Among significant supervisory characteristics are collaboration with supervisors, academic and personal support from them, supervisors' research interests and research activity, regular meetings, and timely feedback (Bair and Haworth 2004; Jaksztat, Neugebauer, and Brandt 2021; McCray and Joseph-Richard 2020; Seagram, Gould, and Pyke 1998; Skopek, Triventi, and Blossfeld 2022). In contrast, the loss or change of a supervisor

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can pose challenges for students and require additional support from other sources (Wisker and Robinson 2013). However, findings on supervision and its effects on student outcomes often differ across studies. Some studies have revealed mixed results about correlations between supervisory characteristics and doctoral student outcomes. For instance, while some studies suggest that more experienced and senior supervisors build stronger working relationships with students, resulting in improved student progress (Ives and Rowley 2005), others indicate that less experienced supervisors may contribute to increased student productivity (Corsini, Pezzoni, and Visentin 2022). Moreover, the limited number of supervisory indicators examined in each study prevents meaningful comparisons across them, restricts the ability to capture the broader picture, or to explain why specific supervisory traits might enhance or hinder student outcomes. Finally, some efforts to implement best practices based on these findings have led to unintended negative results due to unique institutional and national contexts (Gohar and Qouta 2021). The lack of systematization of these results and theoretical frameworks in these works also limits the advancement of effective supervision policies.

Thus, despite the significant role of supervision in doctoral student training and the extensive attention it has gathered from researchers and practitioners, our knowledge about the underlying supervisory factors influencing doctoral student outcomes is still fragmented, especially if we try to apply them to develop effective supervision in specific educational contexts. Therefore, our study aims to explain the supervisor's role in student outcomes within the Russian context of doctoral training. The Russian case offers a clear example of a system characterised by a high level of student dependence on the supervisor, who is often the primary, and sometimes the sole, source of communication and support, as each student is assigned only one supervisor (Taylor, Kiley, and Holley 2020). Declining completion rates, which dropped to a historic low of 11% in 2023 (Federal State Statistics Service 2025), along with ongoing discussions about the quality of supervision, make this study particularly timely and necessary.

The study aims to examine the role of supervisory factors in student completion in a Russian university by employing the Astin's input-environment-output (I-E-O) model (Astin 1993) and introducing the concept of supervisor involvement. Taking into account the lack of theoretical frameworks that systematize the supervisory factors and explain the mechanisms of their effect on doctoral outcomes, we propose that applying the assumptions of the I-E-O model can help deepen our understanding of the connection between student and supervisor characteristics, the process of supervision, and doctoral student outcomes in the Russian context, to implement them for enhancing the quality of supervision.

Conceptualisation of supervisor role in doctoral outcomes in the Russian context

Since most doctoral studies consider associations between characteristics of supervision and doctoral student outcomes as input and output ends of a black box, without considering the mediating mechanisms that explain how particular characteristics of supervisors and their activities result in certain student achievements (Ehrenberg et al. 2007), we employ Astin's logic of argumentation in proposing the concept of student involvement as an indicator of the process, which can help to explain the mechanisms by which

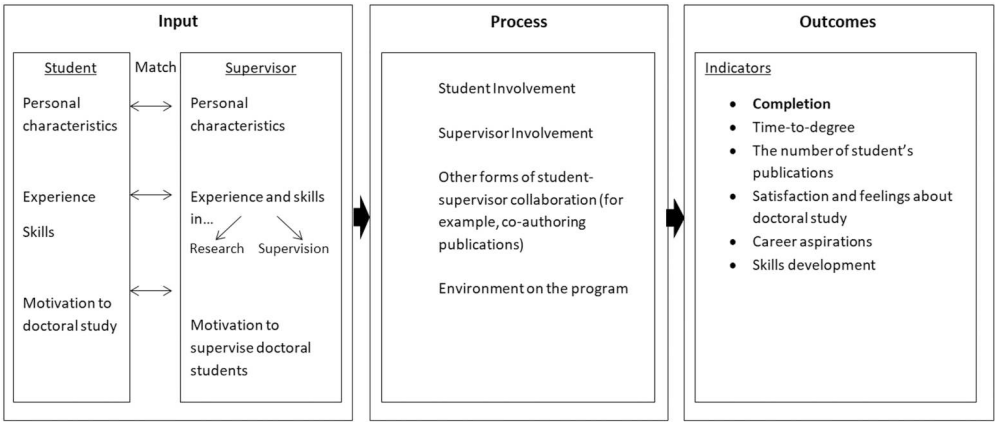

Figure 1. I-E-O model of factors affecting doctoral outcomes.

input characteristics of students and the educational environment result in certain outputs (Astin 1984), in order to conceptualise the role of the supervisor in Russian doctoral education.

According to Astin, traditional pedagogical theories tend to consider undergraduate study as a 'black box,' where on the input end are the various university policies and interventions, and on the output end are different outcome measures such as completion rate or standardised test results (Astin 1984). He suggests opening this 'black box' by using the College Impact Model, which includes three basic elements: (1) *Input*, which includes student entry characteristics; (2) *Environment*, covering student experience and involvement as well as its 'environmental' determinants; and (3) *Output*, relating to different academic outcomes (Astin 1993). Output is affected by both input and environmental characteristics.

Following Astin (1993), and being informed by the results of previous studies on factors affecting doctoral outcomes, we identify three basic elements of the model that maps the effect of supervision on doctoral outcomes (see Figure 1): (1) Input: student and supervisor characteristics and the match between them; (2) Environment or process indicators: indicators including student and supervisor involvement in activities related to dissertation research, collaboration in other professional areas, and characteristics of the programme; (3) Output: student outcomes that can be measured by a wide range of indicators. We argue that the role of supervisors, as a primary source of training and support for doctoral students in Russia, can be revealed through the supervisor's input and involvement characteristics and their correlations with each other, as well as with the characteristics of students and the programme.

Input indicators

According to the results of previous studies (Anttila, Pyhältö, and Tikkanen 2024), for progress in doctoral study, input characteristics should encompass attributes from both groups: students and supervisors. Student input characteristics that have been shown to be significant for doctoral outcomes include the following: previous academic

achievement (Mendoza-Sanchez et al. 2022), graduating from the same university (Bekova 2021), prior research experience (Zhuchkova and Bekova 2023a), student motivation to pursue their degree (Sauermann and Cohen 2010; Sverdlik et al. 2018), and different socio-demographic characteristics (race, gender, age, family characteristics, etc.) (Helin et al. 2023; Herzig 2004; Vassil and Solvak 2012). These student input characteristics can affect student involvement in conducting dissertation research (input's effect on the process), the quality of their work, and their outcomes (input's effect on output).

Supervisory input characteristics include (1) demographic characteristics, such as supervisor gender, which is a significant predictor of doctoral student outcomes according to the results of empirical research (Bu et al. 2022); (2) supervisor proficiency in research (Zhao, Golde, and McCormick 2007), and (3) teaching (Bastalich 2017; Cotterall 2011). Studies have shown that students often benefit from supervisors who show higher research productivity, possess robust fundraising abilities (Corsini, Pezzoni, and Visentin 2022), develop diverse skills relevant to supervision (Manathunga 2005), demonstrate an inspirational leadership style (Levecque et al. 2017), and foster student writing abilities (Leijen, Lepp, and Remmik 2015). However, studies have revealed inconsistent results regarding the effects of supervisors' academic experience. Some studies indicate that more experienced and senior supervisors establish better working relationships with students, leading to better student progress (Ives and Rowley 2005). These supervisors frequently engage in regular meetings with students, closely monitor their advancement, and provide tailored guidance based on each student specific requirements (Brew and Peseta 2004). Conversely, some studies suggest that less experienced supervisors might correlate with increased student productivity (Corsini, Pezzoni, and Visentin 2022).

Finally, previous research has demonstrated that not only do the input characteristics of supervisors and students contribute to doctoral outcomes, but their match can also affect output variables (Gube et al. 2017). Studies have shown that student satisfaction is higher when students and supervisors share similar interests (Seeber and Horta 2021) and have aligned views on resources and challenges (Pyhältö, Vekkaila, and Keskinen 2012). Although optimal matching between doctoral students and supervisors can positively impact doctoral outcomes, implementing such practices is challenging for several reasons. First, the actual degree of compatibility between a supervisor and a supervisee often becomes clear only after they have started working together and gained some experience (Cardilini, Risely, and Richardson 2022). Second, many countries face structural limitations in facilitating such matching due to regulatory constraints on doctoral admissions or a shortage of qualified supervisors (Taylor, Kiley, and Holley 2020).

For instance, in Russia, universities differ in how they define the minimum requirements for supervising doctoral students, further complicating the consistent implementation of matching practices. Some universities allow only Doctor of Science[1] to supervise, assuming that only professors with this highest degree can effectively advise doctoral students. As a result, these institutions face a serious shortage of staff for this role, since the number of Doctor of Science is three times lower than that of Candidates of Science (PhDs) (Gohberg, Ditkovsky, and Evnevich 2020). This skews the supervisor-supervisee ratio and leads to increased supervisor workload, subsequently contributing to a lower quality of supervision. Other Russian universities permit Candidates of Science to supervise doctoral students if they demonstrate high research productivity and have

enough scientific publications related to the dissertation topic (Taylor, Kiley, and Holley 2020). As a result, supervisors' academic degrees and research productivity serve as important input characteristics within the Russian educational context. Therefore, in this study, we examine student and supervisory characteristics separately, without attempting to combine them or identify optimal matches.

According to Astin's I-E-O model, we propose that supervisory input characteristics can affect: (1) the amount of time and effort that the supervisor invests in working with doctoral students (input's effect on the process), and (2) the quality and productivity of that work (input's effect on output).

Process indicators

One of the key characteristics of the process component in the model is involvement. Astin introduces the concept of student involvement to capture what students do at university and how educational programmes influence these activities (Astin 1984). He proposed that 'the amount of student learning and personal development associated with any educational programme is directly proportional to the quality and quantity of student involvement in that programme,' and that 'the effectiveness of any educational policy or practice is directly related to the capacity of that policy or practice to increase student involvement' (Astin 1984, 519). These postulates highlight the crucial role of the programme environment in shaping student involvement and outcomes. Astin defines student involvement by emphasising its behavioural component, describing it as 'the amount of physical and psychological energy that a student devotes to the academic experience' (Astin 1984, 518). Studies of undergraduate students have shown that higher levels of student involvement are associated with better grades, higher completion rates, gains in generic skills, and greater satisfaction with the learning experience (Kuh 2009; Kuh et al. 2008; Pascarella, Seifert, and Blaich 2010). We argue that, in the context of doctoral education, important process indicators include not only student involvement, but also supervisor involvement and other forms of student – supervisor collaboration that extend beyond the formal supervision process.

Doctoral student involvement

The number of studies on doctoral student involvement remains relatively low, and although most of these studies are based on Astin's approach, there is no widely accepted or consistently used definition of the concept. Some researchers define academic involvement in terms of faculty mentorship and the significance of the intellectual community (Anderson, Cutright, and Anderson 2013). In this context, student involvement reflects engagement with mentors and the broader intellectual environment, rather than student independent academic activities. Other researchers define doctoral student involvement more broadly, as participation in academic, research, teaching, social, institutional, and professional life, including interactions with peers and faculty (Cárdenas, Ting, and Wilson 2010).

We argue that student involvement should be defined based on students' own activities rather than on the actions of their supervisors or academic community. Although researchers have examined various student characteristics related to outcomes, such as

motivation, skills, experience, psychological traits, and well-being (Sverdlik et al. 2018), little attention has been paid to the actual effort students invest in obtaining their degrees and engaging in related academic activities. Previous research has shown that, in addition to coursework and dissertation research, which are directly tied to degree completion, academic activities play a crucial role in the professional development of future doctoral graduates. These activities include professional development, participation in conferences, collaboration with researchers and faculty within the department, engagement in departmental life, co-authoring publications, and working on research projects as part of a team (George and Newhouse 2024; Gopaul 2011; Kuzhabekova and Temerbayeva 2018; McAlpine and Asghar 2010; McAlpine, Jazvac-Martek, and Hopwood 2009; Weidman 2010; Weidman and Stein 2003). Thus, drawing on Astin's definition of involvement (1984) and the approach of Cárdenas, Ting, and Wilson (2010) to categorising aspects of student life, we define doctoral student involvement as the amount of time and effort a student devotes to curricular work, dissertation research, professional socialisation, and the development of academic and professional skills through participation in a range of academic, research, teaching, social, institutional, and professional activities.

Supervisor involvement

The term *supervisor involvement* in doctoral studies typically refers to the supervisor's actions and engagement in various activities, such as literature searches, the writing process, and general supervision (Everitt 2023; Pole et al. 1997). Several attempts have been made to apply the concept of supervisor involvement within the framework of self-determination theory, which emphasises three fundamental human needs: competence, autonomy, and relatedness (Deci and Ryan 2004). In these studies, supervisor involvement is recognised as a key element of supervisory support, addressing the student's need for relatedness (De Clercq et al. 2021). The definition of supervisor involvement in these studies often encompasses the emotional aspects of the supervisor – student relationship. Devos et al. (2015, 453) define supervisor involvement as 'the quality of the relationship' with the supervisor and their ability to provide 'warmth and empathy to the doctoral student.' Wollast et al. (2023, 3) describe the concept as 'reassuring students when needed and showing respect and concern for the student not only as a researcher but also as an individual.' Van der Linden et al. (2018) operationalise supervisor involvement using items from the need-support scale, which includes aspects such as 'Behaves warmly toward me when we discuss my research,' 'Shows that he/she respects me and values me,' 'Is available when needed,' and 'Behaves inappropriately toward me,' among others.

While the application of self-determination theory to supervisor involvement provides a robust framework for understanding the dynamics between supervisors and doctoral students, it also has limitations. One of these is the emphasis on emotional and relational aspects, which may overshadow other critical dimensions of supervision, such as the supervisor's expertise. The reliance on subjective measures such as warmth, empathy, and reassurance can create challenges in assessing supervisor involvement, as these perceptions may be influenced by personal biases and cultural differences. Additionally, the conceptual overlap with related constructs like supervisor support and ethical behaviour

can result in a lack of clarity and precision in defining and measuring supervisor involvement. This ambiguity makes it difficult to isolate its specific impact on doctoral student outcomes and to develop targeted interventions for improving supervision quality.

Based on Astin's I-E-O model, we consider supervisor involvement to be a crucial environmental characteristic influencing doctoral student outcomes. We define it as the amount of time, effort, and energy that a supervisor dedicates to activities related to dissertation research and the development of doctoral students' academic and professional skills.

Other forms of student-supervisor collaboration

In conceptualising supervisor involvement, we focus on activities through which supervisors support students in their dissertation research, professional development, and socialisation, within the boundaries set by doctoral programme requirements and norms. However, student – supervisor relationships can also involve teamwork, collaborative projects, and co-authoring publications, which may extend beyond the scope of the dissertation or formal programme completion. Prior research has shown their positive impact on doctoral outcomes (Kamler 2008; Larivière 2012; Lee and Kamler 2008; Wang et al. 2024). For instance, doctoral students can develop academic writing skills through co-authorship with their supervisors (Anderson and Okuda 2019), which can enhance their prospects for a successful academic career (Horta and Santos 2016).

In Russian higher education institutions, doctoral students may be invited by their supervisors to join research projects. They can participate in such projects on a volunteer basis or be employed as research assistants or laboratory assistants, typically for a relatively low salary. The dissertations of these doctoral students may align with the topic of the supervisor's research project, or they may address a different subject. However, the practice of student – supervisor co-authorship can significantly affect degree completion in Russia, as doctoral students are required to publish at least two to three articles (depending on their specialty) in academic journals included in the list recommended by the Higher Attestation Committee, or approved at the institutional level, before they are eligible to submit their dissertation for defense.

Other environment/process characteristics

Institutional and other contextual characteristics that have been shown to significantly impact student outcomes include field of study (Golde 2005; Vassil and Solvak 2012), mode of study (Castelló et al. 2017), financial aid (Spronken-Smith, Cameron, and Quigg 2018), and departmental climate (Maloshonok and Bekova 2025). However, because these factors vary considerably across institutions and countries, and because their relationships with student outcomes may change direction depending on context, these indicators are more appropriately treated as control variables.

Output indicators

Researchers consider various output indicators of doctoral studies, including completion and doctoral degree attainment, intentions to leave the programme, student satisfaction,

time to degree, research productivity, career commitment, well-being, and skills development (Cisco 2020; Lindahl, Colliander, and Danell 2021; Lindsay 2015; Van Rooij, Fokkens-Bruinsma, and Jansen 2021). Some of these indicators are primarily used to assess the quality of doctoral programmes, such as satisfaction or well-being, while others, like completion rate and skills development, are regarded as key measures of programme efficiency. Specific doctoral output indicators can vary depending on national and institutional contexts. In some countries, particularly those that follow the apprenticeship model of doctoral training, student publications and degree completion are considered the most important output indicators. In contrast, countries with more structured doctoral programmes may place greater emphasis on the development of skills, which are highly valued in both academic and non-academic labour markets (Bao, Kehm, and Ma 2018; Gilbert et al. 2004; Nerad 2010; Park 2005). Some output indicators may be part of formal degree requirements, as they are mandatory for obtaining the degree in a given national context, while others may be viewed as additional indicators of programme performance. For example, publishing during doctoral study is widely considered good practice. However, in some countries, it is a formal requirement to publish a certain number of articles before degree conferral, whereas in others, it is encouraged but not mandatory.

The Russian doctorate is primarily aimed at preparing researchers and faculty for academia. As a result, the research productivity of doctoral students and the successful defense of the dissertation are considered the main student outcomes in Russian doctoral education. Russian doctoral training places a strong emphasis on efficiency. The primary indicator of a university's performance is the proportion of students who defend their theses within the standard period of study plus one year. Doctoral programmes are heavily state-funded, and this metric directly determines the amount of state funding allocated to doctoral programmes for the following year (Zhuchkova and Bekova 2023b). In some universities, supervisors receive a bonus for each successful thesis defense by their student. Therefore, in this study, we use degree attainment as the primary indicator of student outcomes in the Russian context.

To obtain a doctoral degree in Russia, a doctoral student must publish two to three articles in scientific journals, prepare the text and extended abstract of the dissertation, and successfully complete the following stages: (1) pre-defence, (2) acceptance of the dissertation by a dissertation council for defence, and (3) public defence of the dissertation. At the pre-defence stage, two reviewers examine the dissertation text and extended abstract, preparing written reports with comments, recommendations, and a decision on whether the doctoral student can proceed to the next stage. In the second stage, the dissertation is considered by three members of the dissertation council. Finally, during the defence stage, at least two reviewers present review reports on the dissertation research. Usually, the reviewers involved in these three stages are different researchers with recognised expertise and publications on the dissertation topic. In some cases, it can be difficult to find reviewers with the appropriate research background. Supervisors often rely on their professional networks to identify suitable reviewers and to secure their agreement to participate at the pre-defence and defence stages. Additionally, the dissertation may require a preliminary, unofficial review by external experts to confirm that it is ready for pre-defence. As a result, in the final year of doctoral study, supervisors in Russia are involved not only in advising, reviewing, and editing student texts, but also in helping

students prepare for the pre-defence and defence stages, and in identifying reviewers with relevant expertise. Therefore, locating appropriate reviewers is a critical supervisory responsibility in the successful completion of doctoral programmes.

Methods and data

Data

The study is based on a quasi-longitudinal dataset that combines five waves of annual web-based surveys of doctoral students conducted at one highly selective Russian university, along with data on their graduation outcomes collected from administrative records and publicly available websites as of the end of 2021. The university is a top research-intensive institution located in Moscow. It offers 22 doctoral programmes across a wide range of disciplines, including science, economics, management, social sciences, law, education, humanities, engineering, mathematics, computer science, art, and media. Between 2014 and the end of 2023, the number of doctoral students enrolled in the university's programmes increased from 712 to 1,352. The university permits both Candidates of Science and Doctors of Science to serve as supervisors. To become a supervisor, a candidate must be approved by the Department Committee, which evaluates the applicant's publication record, research grants, and expertise in the relevant field of study.

A standardised questionnaire was consistently employed throughout the survey years. Each May, all students received an email invitation and were given the opportunity to complete the questionnaire. We merged five datasets, collected in 2012 and each year from 2015 to 2018, into a single dataset comprising 948 doctoral students. Following the compilation of the dataset, a data-cleaning procedure was carried out. First, we retained only one record per student, even if a student had responded more than once across the survey years. We selected the record with the fewest missing responses. In cases where multiple responses from the same student were equally complete, we retained the one corresponding to a later stage of the student's doctoral studies to reflect academic progression. Second, participants for whom information about the supervisor or the doctoral programme could not be identified (155 participants) were excluded from the analysis. Finally, a missing value analysis was conducted using SPSS 20.0. The results showed that one variable, measuring out-of-campus employment, had 15 percent missing data (117 respondents). However, previous research demonstrated that this variable significantly contributed to explaining graduation outcomes (Bekova 2021). Therefore, we retained this variable in the analysis. All other variables used in the analysis had between 0 and 8 percent missing data. Pairwise deletion was applied to handle missing values. The final dataset used for analysis consists of 610 doctoral students. Descriptive statistics for the sample are presented in Table A in the Supplementary Materials.

This data was combined with information on supervisors' characteristics and confirmed graduation outcomes obtained from university records. To verify these data, we extracted information from the official university website about thesis defence and conducted internet searches to identify students who may have defended their theses at other institutions. Most supervisors (53 percent) whose students were included in the dataset supervise only one doctoral student. Twenty-five percent supervise two students participating in the current study, and 22 percent supervise three or more students.

Before the start of the survey, participants signed an informed consent form, which permitted the use of their survey responses for multiple research purposes, including secondary data analysis. The use of the collected data for secondary analysis was approved by the Institutional Review Board of the Higher School of Economics.

Measurement

Supervisor involvement

1) Quantitative aspect of supervisor involvement: The frequency of meetings with students was used as an indicator. Students were asked how often they met with their supervisors regarding their thesis work over the past three months. Response options ranged from 'less than once a month' to 'several times per week.' For further analysis, this variable was recoded into a dichotomous measure: a value of 1 indicated meetings at least once a week, while a value of 0 indicated meetings two to three times per month or less frequently.
2) Qualitative aspect of supervisor involvement: This was measured through different supervisor activities related to supervision. The question was formulated as follows: '*What does your academic supervisor do as part of your interaction regarding your doctoral training?*' Students were asked to select all applicable responses from the following list of activities:
   - Recommends literature on the thesis topic
   - Advises on data analysis methods
   - Comments on results
   - Organises interaction with experts
   - Provides information about relevant research events
   - Helps in finding reviewers
   - Edits the text of articles
   - Edits the text of the dissertation

This list of activities was developed based on the findings of previous empirical studies on supervisor practices in the Russian doctoral system (Zhuchkova et al. 2023).

Student – supervisor collaborations not directly related to the doctoral dissertation were measured by counting the number of joint publications authored by doctoral students and their supervisors. This data was obtained from the university's administrative records.

Student outcomes

To assess doctoral outcomes, we used degree attainment as the primary metric. This information was obtained from university administrative records and publicly accessible websites as of the end of 2021.

Input characteristics

As control variables, we included a set of student, supervisor, and programme characteristics that have been shown to be significant in previous studies.

Student characteristics include the following indicators:

1. Gender
2. Inbreeding status, which indicates whether students obtained their bachelor's or master's degree at the same university where they are currently pursuing their doctoral studies. These students are likely to be more familiar with internal procedures, academic expectations, and faculty members, including potential supervisors. Previous studies have shown that inbred doctoral students are more likely to defend their theses (Bekova 2021), and that inbred early career researchers may be more productive (Slepykh 2025).
3. Employment status, distinguishing between on-campus and off-campus employment
4. Plans to work in academia after graduation

Both employment status and academic career plans have been shown to be significant factors in doctoral completion (Bekova 2021).

The following supervisor-level variables were included in the analysis:

1. Gender of the supervisor (male or female).
2. Academic degree, indicating whether the supervisor holds a Doctor of Science (a higher doctoral degree) or a Candidate of Science.
3. Recognition as a 'Best Instructor', a title awarded based on student voting. This designation is interpreted as an indicator of pedagogical skill, openness and willingness to communicate, the ability to build positive relationships with students, and the capacity to motivate them in their learning. While we acknowledge that this variable may overlap with broader concepts of instructional quality, we use it as a student-informed signal of communication and teaching style factors that may influence the nature of supervisory relationships.
4. Share of supervised students who defended their theses, used as a proxy for supervisory proficiency. However, we recognise that this variable may also reflect supervisor selection practices and unobserved characteristics.
5. Number of international publications, used as a proxy for research productivity and academic engagement in global scholarly networks. Unfortunately, data on national publications were not available.

All supervisor-level variables were obtained from the university's administrative records.

The program-level variables included the following: (1) Mode of study, distinguishing between full-time and part-time enrolment; (2) Field of study; (3) Year of enrolment, which is particularly important as it distinguishes between students who enrolled before 2014 and those who enrolled between 2014 and 2016. This latter group began their studies during a period of legislative reform that introduced stricter requirements for research productivity and educational activity among doctoral candidates.

Data analysis

The analysis of the data was conducted in three steps. First, descriptive analysis was performed to examine the frequency distributions of student responses and the statistical associations between input variables and supervisor activities. To test the significance

of observed differences, we employed chi-square tests. Second, we conducted a binary logistic regression analysis to examine the relationships between input variables, variables measuring supervisor involvement, and degree attainment as the dependent variable. Finally, we employed structural equation modelling to test the proposed relationships between input, process, and output variables, in line with the model developed based on Astin's Input–Environment–Output (I-E-O) framework.

Limitations

Despite its contributions, this study has several limitations that should be acknowledged. First, the data were collected from a single university in one country, which raises concerns about the generalizability of the findings. However, the use of institutional data allowed us to access non-anonymous records and combine them with administrative information on thesis defenses, thereby enhancing the accuracy and depth of our analysis within this specific context. The Russian doctoral education system, with its highly hierarchical supervisory structures and centralised dissertation defence process, presents a unique yet illustrative case of the challenges in doctoral supervision. Rather than aiming for broad generalizability, this study seeks to provide insight into how supervisor-related factors operate within a particular institutional and cultural setting. To evaluate the broader applicability of this model as a theoretical framework, future research should test it in other national and institutional contexts, potentially adapting it to reflect local norms and educational structures.

Second, our analysis relied on secondary data, which limited the range of available variables and constrained the depth of analysis. Most notably, we had limited information on student characteristics, particularly regarding student involvement and the process by which students are matched with supervisors. The dataset did not include information on the age of doctoral students or supervisors, or on their previous work experience outside academia. These factors may have a significant influence on the supervision process. Future studies could incorporate survey or interview data to better capture the relational and psychological dimensions of doctoral education. In addition, we relied on self-reported survey data. As with all self-reported measures, there is a risk of various biases that may affect the reliability of certain student-reported indicators, especially those related to perceptions of supervision quality or the doctoral experience.

Third, although the administrative data allowed for the inclusion of novel indicators such as 'Best Instructor' and 'prior student success rate,' these proxies may be interpreted in multiple ways. For example, the 'Best Instructor' variable could reflect teaching ability, popularity, or interpersonal approachability. Similarly, the 'prior student success' indicator may reflect supervisor competence, selectivity in choosing students, or accumulated institutional capital. We acknowledge that these variables may capture different underlying constructs, and we therefore interpret them with caution. Ideally, such indicators should be triangulated with qualitative data or supervisor self-reports in future research.

Next, our study encountered substantial missing data across several variables. We retained all variables related to supervisory characteristics, as these are central to the research and have been shown to be significant predictors of student outcomes. This

decision reduced the final sample size but enabled a more comprehensive analysis of supervision and a broader coverage of the conceptual model.

Finally, due to the observational design of the study and the reliance on administrative and secondary data, causal relationships cannot be definitively established.

Results

Results of descriptive analysis and logistic regression modelling

The most frequent activities performed by Russian supervisors include commenting on the results of research (83.6%), recommending literature on the thesis topic (77.5%), advising about data analysis methods (56.6%), providing information about relevant research events (54.4%), and editing the text of the dissertation (51.1%) (see Table B in Supplementary Materials). The types of supervisory activities vary significantly across fields of study (see Table B1 in the Supplementary Materials). Supervisors in mathematics, science, and engineering disciplines most frequently engage in commenting on research results, organising interactions with experts, and providing information about relevant research events. Supervisors in engineering fields are also more frequently involved in finding reviewers for their doctoral students and sharing information about research-related events. By contrast, supervisors in doctoral programmes in the social sciences are generally less involved in nearly all types of supervisory activities compared to their counterparts in other disciplines.

The prevalence of supervisory activities also correlates with both student and supervisor input characteristics (see Table B in the Supplementary Materials). Male students more frequently receive comments on the results of their research from supervisors. This pattern may be partially explained by gender imbalances across fields of study. As noted earlier, supervisors are more likely to comment on results in mathematics, science, and engineering programmes, which are predominantly male-dominated disciplines. Doctoral students who enrolled in 2014 or later reported receiving more support from supervisors in organising interactions with experts and in editing article manuscripts. Female supervisors are more frequently involved in editing the texts of articles and dissertations. Additionally, supervisors who have received the Best Instructor award are more likely to recommend literature to their students.

The frequency of student – supervisor meetings also varies across disciplines and input characteristics (see Tables C and C1 in the Supplementary Materials). Students enrolled in mathematics, science, and engineering programmes, as well as those admitted in 2014 or later, tend to meet with their supervisors more frequently. In addition, supervisors who have received the Best Instructor award are significantly more likely to have frequent meetings with their students. These findings indicate meaningful associations between the input characteristics of both students and supervisors and the variables used to measure supervisor involvement.

In the next step of the analysis, we ran five logistic regression models, using degree attainment as the dependent variable, and regressing it on student input characteristics, co-authoring, supervisor input characteristics, and supervisor involvement (see Table D in Supplementary Materials). Model 1 included only student input characteristics as independent variables and explained 14.5% of the variance in degree attainment

(Nagelkerke R^2). The odds ratios (ORs) indicate that inbred students (OR = 1.46, $p < 0.05$), students planning to work in academia (OR = 2.30, $p < 0.001$), those enrolled before 2014 (OR = 2.49, $p < 0.001$), and those working on-campus (OR = 1.97, $p < 0.01$) had significantly higher odds of obtaining a degree. In contrast, engineering students had lower odds (OR = 0.35, $p < 0.05$). Model 2 added co-authoring to the variables in Model 1 and explained 16.9% of the variance. Student-supervisor co-authoring significantly increased the odds of obtaining a degree (OR = 1.22, $p < 0.01$), and the effect of inbreeding was no longer statistically significant once this variable was included.

Model 3 included the variables from Model 2 along with supervisor input characteristics and explained 30.2% of the variance in the dependent variable (Nagelkerke R^2). The odds of students obtaining a degree increased when the supervisor was female (OR = 1.62, $p < 0.05$), had a higher number of international publications (OR = 1.02, $p < 0.05$), or had a higher proportion of former students who obtained PhDs (OR = 69.87, $p < 0.001$). In contrast, having a supervisor with a Doctor of Science degree was associated with lower odds of degree completion (OR = 0.64, $p < 0.05$).

Model 4 included the variables from Model 2 along with supervisor involvement indicators. It explained 23.0% of the variance which is higher than Model 2 but lower than Model 3. Among the supervisor involvement variables, only assistance in finding reviewers was significantly associated with degree attainment (B = 0.12, $p < 0.01$); other supervisory activities did not show a significant relationship with doctoral completion.

Model 5, which includes all sets of variables (student and supervisor input characteristics, co-authoring, and supervisor involvement) provided the best fit for explaining the variance in doctoral degree attainment (Nagelkerke $R^2 = 0.354$). When supervisor involvement variables were included, on-campus employment no longer contributed significantly to the explained variance.

According to the logistic regression results, supervisor input characteristics are stronger predictors of doctoral completion than supervisory activities. However, we believe this may reflect more complex interrelationships among supervisor input characteristics, supervisory activities, and student outcomes, which require deeper investigation. Therefore, in the next stage of analysis, we apply structural equation modelling (SEM), which enables us to examine these complex relationships in a manner consistent with the proposed conceptual Input–Environment–Output (I-E-O) framework.

SEM analysis

Structural equation modelling (SEM) was employed to test the proposed conceptual model using R. According to the conceptual model developed for the Russian context, we argue that supervisor involvement can be affected by supervisor input characteristics. The model also proposes that doctoral completion (output) depends on both student and supervisor input characteristics and two process variables: (1) supervisor involvement and (2) student – supervisor collaborations not directly related to the doctoral dissertation, such as co-authoring publications.

To test these links, we specified three competing structural models. The first model includes one latent variable measuring supervisor involvement, using a set of eight indicators representing supervisor activities and one indicator measuring the frequency of meeting with a supervisor at least once per week. In the second model, we assumed

that the nine indicators described above represent not one but three distinct latent variables of supervisor involvement: (1) *research consulting* (three items: recommending literature on the thesis topic, advising on data analysis methods, and commenting on results); (2) *academic socialisation* (four items: organising interaction with experts, providing information about relevant research events, helping to find reviewers, and meeting students at least once per week); and (3) *editing* (two items: editing article texts and dissertation texts). In this model, we suppose that the three dimensions of supervisor involvement directly affect doctoral outcomes.

Finally, in the third model, we hypothesise that the three dimensions of supervisor involvement constitute one factor – supervisor involvement – which ultimately affects doctoral student completion. This model assumes the importance of combining all three supervisory roles (consultant, mentor, and editor) for doctoral student outcomes and emphasises that supervisor involvement in each activity may depend on different supervisor characteristics. All three models use the same set of indicators in the analysis but differ in how they explain the association between supervisor involvement and degree attainment.

The three models were evaluated using the following fit indices: Chi-square, Comparative Fit Index (CFI), Tucker – Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Given the sample size exceeds 200, CFI, TLI, RMSEA, and SRMR are considered the most appropriate measures of model fit (Chen 2007). According to Browne and Cudeck (1992) and Hu and Bentler (1999), acceptable model fit is indicated by CFI and TLI values ≥ 0.90, RMSEA < 0.06, and SRMR < 0.08.

Although all three models showed acceptable RMSEA and SRMR values and significant factor loadings aligned with the proposed constructs, only Model 3 met the CFI and TLI thresholds of 0.90 or higher. Based on this comparison, Model 3 demonstrates the best overall fit (see Table 1). Therefore, we present the results using the structural coefficients estimated for Model 3 (see Figure 2).

Results of SEM

Structural Model 3 indicates that supervisor involvement in Russia comprises three dimensions: research consulting, academic socialisation, and editing. These dimensions collectively form a single, integrated factor of supervisor involvement, though they contribute to it with varying weights. Based on the factor loadings estimated for Model 3 (see Figure 3 and Table E in Supplementary Materials), academic socialisation and editing activities load more strongly onto the overall factor than research consulting.

Research consulting is positively associated with supervisors' teaching proficiency measured by receipt of a Best Instructor award (B = 0.05, $p < 0.05$) and with supervisory

Table 1. Comparison of three models.

Model	Chi-square	df	CFI	TLI	RMSEA	SRMR
Model 1 (one latent variable)	397.826	182	0.761	0.717	0.044	0.041
Model 2 (three latent variables)	359.274	162	0.781	0.710	0.045	0.049
Model 3 (four latent variables)	221.949	161	0.932	0.910	0.025	0.032

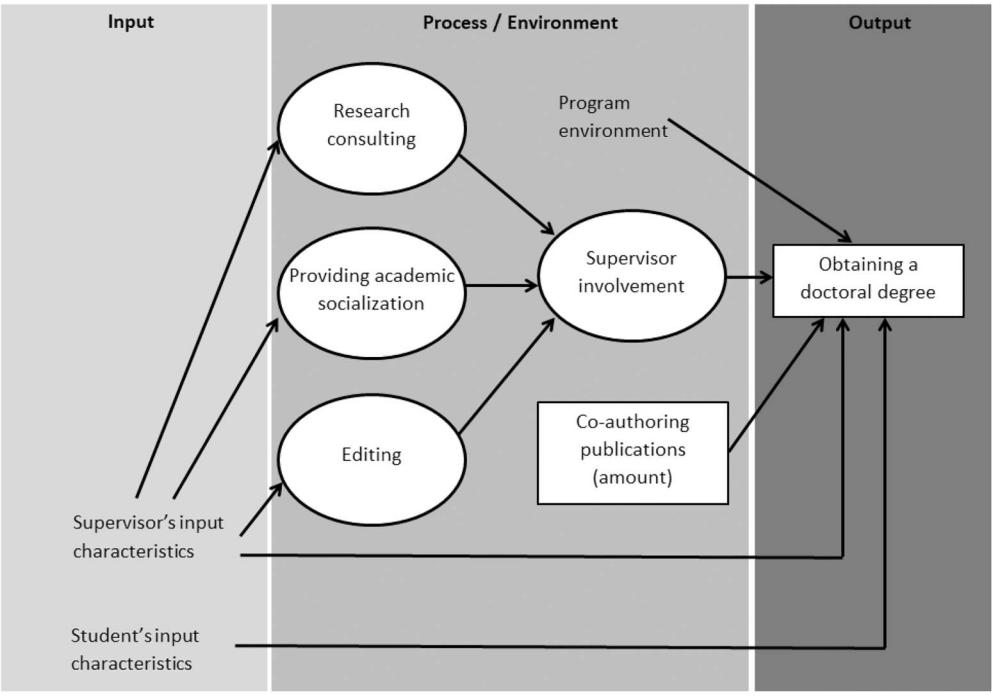

Figure 2. Specified Model 3 of relationships between input, process and output variables.

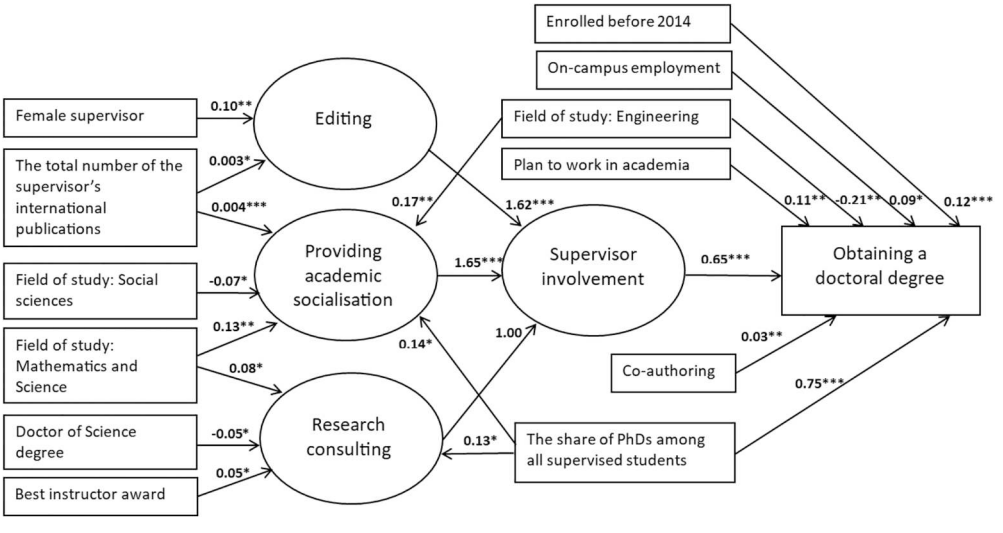

Figure 3. Statistically significant associations in the specified Model 3.

effectiveness, as indicated by the share of supervised doctoral students who obtained a degree (B = 0.13, $p < 0.05$). Conversely, this dimension is negatively associated with holding a Doctor of Science degree (B = –0.05, $p < 0.05$) and shows no significant relationships with other supervisor characteristics (see Table 2 and Figure 3).

Table 2. Structural coefficients for Model 3: three dimensions of supervisor involvement as dependent variables.

	Research consulting	Providing academic socialisation	Editing
Doctor of Science degree	−0.05* (0.02)	−0.04 (0.03)	−0.03 (0.03)
Best instructor award	0.05* (0.02)	0.02 (0.03)	−0.003 (0.03)
Female supervisor	0.04 (0.02)	0.05 (0.03)	0.10** (0.04)
Field of study (ref. – Humanities)			
Mathematics and Science	0.08* (0.04)	0.13** (0.05)	−0.03 (0.06)
Engineering	0.05 (0.05)	0.17** (0.06)	−0.01 (0.07)
Social sciences	0.01 (0.03)	−0.07* (0.03)	−0.02 (0.04)
Education	−0.01 (0.06)	−0.02 (0.08)	−0.18 (0.10)
The total number of the supervisor's international publications	0.001 (0.001)	0.004*** (0.001)	0.003* (0.001)
The share of PhDs among supervised students	0.13* (0.06)	0.14* (0.07)	−0.001 (0.09)

Note. * – $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$

The second dimension of supervisor involvement, providing academic socialisation, varies significantly across fields of study. This form of involvement is more prevalent in mathematics and science (B = 0.13, $p < 0.01$) and in engineering (B = 0.17, $p < 0.01$), while it is less common in doctoral programmes in the social sciences (B = –0.07, $p < 0.05$). Involvement in academic socialisation is also positively associated with the number of publications in international journals by the supervisor (B = 0.004, $p < 0.001$) and the proportion of supervised students who obtained a degree (B = 0.14, $p < 0.05$). These findings suggest that this form of involvement is closely related to both the research productivity and the supervisory effectiveness of the supervisor. Involvement in editing activities is positively associated with the number of international publications by the supervisor (B = 0.003, $p < 0.001$). In addition, female supervisors are more likely to engage in this type of activity (B = 0.10, $p < 0.01$).

Obtaining a doctoral degree is positively associated with both types of process indicators examined in this study. These include supervisor involvement (B = 0.65, $p < 0.01$) and the number of publications co-authored with the supervisor (B = 0.03, $p < 0.01$), which serves as an indicator of student – supervisor collaboration not directly related to the dissertation (see Table 3). As expected, degree attainment is also positively associated with student input characteristics such as on-campus employment (B = 0.09, $p < 0.05$) and plans to work in academia after graduation (B = 0.11, $p < 0.01$). Additionally, completion is linked to the proportion of PhD graduates among all students supervised by the advisor (B = 0.75, $p < 0.001$) and enrolment before 2014 (B = 0.12, $p < 0.01$).

Overall, the results of the SEM analysis are largely consistent with the correlations identified through logistic regression. However, a few notable differences emerged. First, while the logistic regression indicated that having a supervisor with a Doctor of Science degree significantly reduced the odds of a student obtaining a doctoral degree, the SEM analysis did not reveal a significant direct effect of this variable on degree completion. Instead, it showed that the Doctor of Science degree negatively influences supervisors' engagement in research consulting activities. This suggests that SEM captures an indirect pathway through which the Doctor of Science degree affects doctoral outcomes, a relationship that appeared as a direct effect in the logistic regression.

Second, in logistic regression Model 5, on-campus employment was not significantly associated with degree attainment when supervisor input characteristics and supervisor

Table 3. Structural coefficients for Model 3: degree obtained as the dependent variable.

	B (SE)
On-campus employment	0.09* (0.04)
Female student	−0.03 (0.04)
Full-time mode	0.02 (0.05)
Inbred students	0.07 (0.04)
Supervisor Involvement	0.65** (0.20)
Co-authoring	0.03** (0.01)
Field of study (ref. – Humanities)	
Mathematics and Science	−0.04 (0.06)
Engineering	−0.21** (0.07)
Social sciences	−0.07 (0.04)
Education	0.12 (0.11)
Plan to work in academia	0.11** (0.04)
The total number of the supervisor's international publications	0.003 (0.001)
The share of PhDs among all supervised students	0.75*** (0.10)
Enrolled before 2014	0.12** (0.04)
Full-time employment out of university	0.04 (0.04)

Note. * – $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$

involvement were included in the model. In contrast, the SEM model showed that on-campus employment remained significantly associated with obtaining a doctoral degree. The difference can be attributed to how the two models are specified. In the SEM model, supervisor involvement is included as a latent variable that mediates the relationship between input indicators and degree attainment. This structure aligns more closely with the theoretical assumptions of the study and, as a result, may produce more valid conclusions.

Finally, in the logistic regression analysis, only one supervisor activity was significantly associated with degree attainment. In contrast, the SEM analysis showed that all supervisor activities contributed meaningfully to three distinct dimensions: research consulting, academic socialisation, and editing. These dimensions formed a higher-order factor, supervisor involvement, which was strongly associated with obtaining a doctoral degree.

Due to the substantial differences in model specifications, these results should not be directly compared. However, we suggest that the difference can be explained by the way supervisor activities are treated in each model. In logistic regression, these activities are considered as independent variables. In SEM, the specification accounts for the interrelationships among activities, which better reflects the complex and multifaceted nature of doctoral supervision. Because the SEM analysis aligns more closely with the theoretical framework of the I-E-O model by capturing the relationships between input, process, and output variables, we consider its results the primary findings of this research.

Discussion

This study contributes to the understanding of how various supervisory characteristics influence doctoral outcomes by developing a conceptual model of supervisor involvement and demonstrating its application within a specific Russian university context. The proposed conceptual model, tested using quasi-longitudinal data, showed an acceptable fit, supporting its applicability. This reinforces our argument that the I-E-O model, when adapted to doctoral education and incorporating supervisor involvement, provides a valuable framework for explaining how supervisory characteristics impact doctoral students

and their outcomes. It also highlights the model's potential as a theoretical foundation for future research. Previous efforts to develop conceptual frameworks in this area (e.g. Halse and Malfroy 2009; Lee 2008) have largely emphasised the nature of supervisory work rather than its direct effects on student outcomes. This study identifies three core supervisory activities that constitute the key dimensions of supervisor involvement: research consulting, academic socialisation, and editing. Although these activities reflect characteristics of Russian doctoral programmes toward training academic and research staff, they align with findings from international studies on doctoral supervision (Franke and Arvidsson 2011; Gruzdev, Terentev, and Dzhafarova 2020; Zhao, Golde, and McCormick 2007) and correspond to Boehe's (2016) two foundational dimensions of supervision: process and product. Our study found that supervisor involvement significantly influences the likelihood of a student earning a doctoral degree, with academic socialisation and editing exerting slightly stronger effects. These findings align with international research emphasizing the central role of socialisation in shaping doctoral student experiences and outcomes (Gardner 2010; Rigler Jr et al. 2017), as well as the critical role of supervisors in facilitating this socialisation (Schneijderberg 2021) and supporting student academic writing (Cafferella and Barnett 2000; Curtin, Malley, and Stewart 2016).

Supervisory practices that constitute supervisor involvement vary notably by field and supervisor characteristics. For instance, supervisors in STEM disciplines show higher involvement in directing students to research events, which can be explained by the importance of conference publications in these fields. Meanwhile, the relatively low involvement reported by students in the social sciences may reflect different disciplinary cultures, where autonomy or informal mentorship is more common (McAlpine and Norton 2006). Gender differences also occurred: female supervisors tend to be more involved in text editing, which may be shaped by societal and institutional expectations, relational mentoring styles, and a commitment to a feminist ethics of care in academic supervision (Gilbert et al. 2024; Sambrook 2024).

Interestingly, supervisors with 'Best Instructor' awards not only meet more frequently with students but also demonstrate higher engagement across multiple support dimensions, suggesting that institutional recognition in teaching may signal a broader commitment to student development. In general, students tend to benefit more from supervisors who demonstrate strength in both research and teaching. And it is the *quality* of the supervisor's work, rather than seniority alone, that plays a crucial role. For example, supervisors who advise a larger number of doctoral students or who are actively involved in international research tend to be more involved. This, in turn, increases the likelihood that their students will complete their doctorate. As previously shown, faculty quality is a key factor of both short- and long-term PhD student outcomes (Waldinger 2010).

In the Russian context, risks to faculty quality are shaped by several factors. First, there is a shortage of supervisors. There are 99.9 thousand researchers with a degree in Russia; 75% of them have a PhD (75.1 thousand), and only 25% have a Doctor of Science degree (24.8 thousand) (Gohberg, Ditkovsky, and Evnevich 2020). This skews the supervisor-supervisee ratio and leads to an increased workload for supervisors. Second, the supervisor's work is greatly underestimated in terms of the time and effort it requires and is consequently underfinanced. Supervision is typically included in academic staff contracts, amounting to 50 academic hours annually per doctoral student, which is much less than the actual time needed for effective supervision (Taylor, Kiley, and Holley 2020). The absence of explicit supervision

guidelines and a lack of training support, combined with high workloads and insufficient financial compensation, limits supervisor involvement. Finally, recent social and economic disruptions have made the situation even worse. The onset of the COVID-19 pandemic in 2020, the Russian-Ukrainian conflict beginning in 2022, and the resulting geopolitical tensions have limited opportunities for doctoral students to participate in international research and academic exchange. These developments, along with a significant outflow of Russian academics, have further complicated the situation. The loss of experienced faculty reduces the number of available supervisors, disrupts research, and limits mentoring capacity. This affects not only the quality of doctoral training but also student motivation and well-being (Chankseliani and Belkina 2024).

Our model assumes that a higher level of supervisor involvement leads to higher doctoral outcomes. So, to boost student chances of defending their theses, enhancing supervisor involvement is crucial. However, some researchers argue that excessive supervisor involvement may lead to negative consequences for doctoral students, such as over-influencing, preventing them from becoming independent researchers and hindering their agency, autonomy, originality, creativity, and critical thinking (Benmore 2016; Lindsay 2015). It is, therefore, essential to find a balance between providing adequate support and fostering student initiative. One way to reach this balance is to treat doctoral students as colleagues rather than students. Developing professional collaborations with students, such as co-authorship of papers, cannot only enhance their skills as authors and contribute to their overall expertise (Florence and Yore 2004; Kamler 2008) but also increase their chances to defend their thesis, as we showed in this study.

Further studies are needed to test the provided conceptual model of supervisor involvement in different national and institutional contexts and to deeply investigate factors affecting supervisor involvement. Moreover, future research may provide further theoretical and methodological elaboration of the supervisor involvement concept and other concepts of the I-E-O model, such as student involvement, by identifying the factor structure and dimensions of these concepts and the development of valid instruments to measure them.

Note

1. There is a two-degree system in Russia with a Candidate of Science (PhD) awarding after graduating from the PhD program and a Doctor of Science that required several years of independent research work resulting in significant contribution compared to the Candidate of Science (Taylor, Kiley, and Holley 2020).

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