Boosting BOCW Enrollment Through A Contract Design Approach

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In this research, we examine the profound significance of the Building and Other Construction Workers (BOCW) scheme in India, which plays a pivotal role in addressing the multifaceted challenges posed by the labor market, particularly with regard to construction workers. With the construction sector in India experiencing rapid growth and a substantial labor force engaged in it, the BOCW scheme is designed to offer crucial social security and welfare benefits to this vulnerable workforce. Nevertheless, the participation rate of workers in India's scheme remains low primarily due to their lack of awareness about the program and the unfamiliarity with the application process. To tackle this multifaceted issue effectively, we have introduced an innovative contract design approach aimed at facilitating the registration of workers into the scheme. Specifically, we craft a long-term contract between a contractor and a construction worker to illustrate the advantages of the Building and Other Construction Workers (BOCW) scheme for both parties. Within the framework of this long-term contract, the worker improves his productivity and the contractor increases her profit. Our statistical analysis reveals that the facilitation of BOCW registration for workers through the long-term contract not only addresses the immediate concerns of workers but also contributes significantly to the overall development of the construction sector in India through increasing the social surplus in this sector. Importantly, our findings have implications beyond India, shedding light on potential applications in other developing countries grappling with similar labor market challenges.

1 Introduction and Contribution

In the noisy construction sites of India, where the sound of hammers and cement mixers fills the air, a pressing issue remains hidden beneath the dust and debris. It is a story of missed opportunities, untapped potential, and the aspirations of millions left unfulfilled. Imagine a scheme designed to improve the lives of India's construction workers, but in reality, it is languishing, overlooked, and underutilized. This is the issue of the Building and Other Construction Workers (BOCW) scheme: a tale of promise waiting to be unlocked[1]. The BOCW scheme provides a wide range of welfare provisions, including medical aid, maternity support, education funding, and pension benefits. However, despite its potential and substantial budget allocations, the scheme suffers from chronic under-enrolment. Since the implementation of the Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act in 2005, the boards have collected 1,17,507.22 crore as cess from the employers and utilized only 67,669.92 crore with the workers.[2].

Field investigations underscore this gap: 80% of construction workers in the Delhi NCR region were unaware of the BOCW cards existence. Barriers include limited awareness, the burdensome requirement of a 90-day employment certificate, and minimal incentives for contractors to support worker registration.

Our field-based analysis confirms these issues. Among surveyed workers, only 30% were registered with the BOCW scheme. Of the 70% who were not, 77.6% cited lack of awareness as the primary reason, while 21.1% pointed to administrative difficulties. Less than 2% reported barriers related to ID cards or fees. These findings reaffirm the urgent need for an actionable solution that addresses both awareness and participation bottlenecks.

This paper proposes a novel solution rooted in dynamic contract theory. We design a two-period incentivizing contract between contractors and workers, intended to embed BOCW registration into the employment relationship. This model not only ensures workers gain access to welfare benefits, but also leads to improvements in productivity benefiting both parties. Grounded in the principles of dynamic mechanism design, the contract creates a feedback loop where workers improved well-being translates into better output and, consequently, higher contractor profitability.

We look at the importance of the BOCW scheme not only in the context of labor welfare but also in terms of economic efficiency and overall social development. Our designed optimal contract offers a long-term solution to the huge challenge at hand.

Indeed, the BOCW scheme uniformly allocates financial aid to all registered workers. By combining the uniform benefits of the BOCW scheme with performance-based incentives from contractors, the proposed contract design seeks to enhance overall worker well-being and project outcomes. This approach is supported by empirical studies and historical data from similar welfare programs, demonstrating the effectiveness of integrated incentive structures[3,4]. Focusing on our approach, we design a two-period long-term contract that forms a partnership between contractors and construction workers. The contract structure is a menu of contracts in which each worker is matched to a specific contract based on his level of productivity. The main feature of our long- term contract lies in its ability to measure the transformation in a worker's productivity level following the incentivizing contract along with financial aid.

The outline of our paper is as follows: In Section 2, we delve into a comprehensive review of the relevant literature that aligns with our papers focus, encompassing six distinct domains: the labor market, cash transfer programs, economic shocks, government initiatives within the construction sector, limitations of existing interventions and game theoretic basis of the model. Moving to Section 3, we embark on the theoretical design of an optimal two-period contract to govern the relationship between workers and contractors. Section 4 is dedicated to the examination and discussion of the numerical analysis results stemming from our proposed contract. In Section 5, elaborates on the practicality of the designed contract in real-world applications. Section 6 outlines future research directions based on the study's findings. Finally, Section 7 concludes the paper with a summary of key insights and a discussion of its limitations.

2 Literature Review

In order to address the underutilization of the Building and Other Construction Workers (BOCW) scheme in India and design an incentivizing contract between workers and contractors, it is essential to explore relevant literature, theories, and empirical findings. In this literature review, we aim to summarize and analyze previous related works, identify areas of controversy and contested claims, and show how our research paper contributes to and builds upon existing work. This literature review is structured around six interrelated thematic areas: labor markets in developing countries, financial aid cash transfer programs, the impact of economic shocks (focusing on COVID 19) on construction industries, government schemes in the construction sector of India, limitations of existing interventions with the need for an incentive-based approach and Game-theoretic approaches of the model.

2.1 Labor Markets in Developing Countries

Labor markets in developing countries are a critical area of study, particularly concerning poverty reduction and workforce utilization. G. S. Fields introduced a policy evaluation framework that emphasizes the importance of labor in poverty reduction[5]. However, it falls short in providing practical solutions. Our research extends Fields framework by proposing a dynamic incentivizing contract within India's Building and Other Construction Workers (BOCW) scheme, aiming to enhance labor welfare and utilization rates, bridging the gap between theory and tangible solutions. This innovative approach aligns with the ideas of A. J. G. Brown, & J. Koettl who explored Active Labor Market Programs (ALMPs), emphasizing incentive mechanisms and policy design in labor market interventions[6]. By incorporating a similar incentive mechanism, our work contributes to enhancing labor market efficiency and utilization rates. W. F. Maloney highlights informality as a key labor market issue.[7]. Building on this, our research proposes a targeted solution to bridge the formal - informal divide in India's construction sector. Furthermore, S. Verick discusses the challenges of India's labor market, including low female labor participation and informality[8]. Our model, by offering customized contracts based on productivity, supports a more inclusive approach aligned with demographic realities.

2.2 Cash Transfer Programs

Cash transfer programs are crucial tools in reducing poverty and are widely used to alleviate poverty and improve welfare outcomes. S. Baird and coworkers emphasized their positive impact on employment[9]. More recently, X. Wang highlighted that in response to COVID-19 , cash transfers played a critical role in supporting informal workers across Asia[10], underscoring the importance in crisis resilience and labor inclusion. J. Haushofer and J. Shapiro highlighted the benefits on psychological outcomes[11], while E. Duflo focused on gender dynamics[12]. Although these programs are effective, a notable gap remains in sector-specific application and practical implementation strategies. Our study addresses this by embedding cash transfers (via BOCW financial aid) within a contractor - worker incentive system, making the program more accessible and inclusive, particularly for women and vulnerable workers.

2.3 Impact of Economic Shocks on Construction Industries

Economic shocks, such as the COVID-19 pandemic, have amplified the vulnerabilities of the construction sector in developing countries. R. Prasad and S. Bhat examined the pandemics immediate impact[13], Walmsley and coworkers provided a macro-level perspective[14]. and P. Kumari & K. Kumar delved into labor welfare amid crises[15]. While these studies contribute valuable insights, they tend to focus either on macroeconomic trends or broad policy responses. What remains underexplored is the role of micro-level interventions-targeted, ground-level mechanisms that directly support vulnerable workers during times of economic distress.

Unlike top-down aid disbursements, our bottom-up contract structure builds resilience from within the labor relationship. By embedding BOCW scheme benefits such as insurance, healthcare, and unemployment protection into the contract framework, workers are more likely to access and retain welfare entitlements.

In turn, this reduces their financial vulnerability during periods of economic uncertainty and enhances their capacity to recover from shocks. At the same time, contractors benefit from increased worker stability, improved morale, and enhanced productivity, even in turbulent times.

2.4 Government Schemes and Construction Workers in India (BOCW Schemes)

Government schemes, like India's BOCW scheme [1], aim to support construction workers. Existing research identifies challenges and shortcomings but lacks concrete solutions. P. Goswami sheds light on the challenges faced by migrant construction workers in India and operational hurdles encountered by the Building and other Construction Worker's Welfare Board (BOCWWB) [16]. While emphasizing the importance of support for these vulnerable workers, it falls short in offering concrete improvement strategies. In contrast, our research proposes a solution to streamline registration and enhance worker access to benefits, bridging the gap left by Goswami [16]. S. Kumar delves into the impact of government welfare schemes, including the BOCWWB, on Indian construction workers, assessing their effectiveness but calling for more targeted interventions. [17].

Our study complements S. Kumar's findings by proposing a targeted approach to maximize the utilization of the BOCWWB, potentially addressing his identified shortcomings. Similarly, R. Sharma explores labor market dynamics in the construction sector, highlighting challenges and the informal nature of employment [18]. Our research adds practicality by suggesting an incentivizing contract to boost registration and benefit utilization among these workers, aligning with the above issues identified. J. Patel evaluates government schemes efficiency in supporting informal workers, including the BOCWWB, but also seeks targeted improvements [19]. Our study contributes by presenting the incentivizing contract as a specific mechanism to enhance scheme utilization, building upon J. Patel's analysis.

2.5 Limitations of Existing Interventions and Need for an Incentive-Based Approach

While various interventions such as awareness campaigns and registration simplification have been proposed to increase BOCW utilization, we argue that these are limited in scope.

Awareness campaigns require ongoing funding and continuous reinforcement [20,21] and simplification alone does not necessarily incentivize contractors to assist workers in registering [22]. Our approach addresses this gap by aligning contractor and worker interests, creating a self-sustaining incentive structure. In contrast to passive interventions like awareness campaigns, our proposed model builds in a behavioral mechanism that adds practical, economic, and systemic value to the contract design. This turns the welfare entitlement into real productivity gains and profitability, and aligns the interests of all three parties: workers, contractors, and the government.

2.6 Game-Theoretic Basis of the Model

Game-theoretic approaches, particularly principal-agent models, have long been used to analyze incentive structures in labor markets [23]. These models capture the strategic interaction between a principal (contractor) and an agent (a worker), especially under asymmetric information, where one party holds more information than the other. In the context of labor contracts, these models have been applied to design incentive-compatible contracts that motivate agents to exert optimal effort while meeting participation constraints [24].

Dynamic extensions of these models allow for intertemporal incentives, where outcomes and decisions in one period influence behavior in future periods [25]. Our research builds on this literature by applying a two-period dynamic contract structure to the Indian construction sector, with a focus on improving utilization of welfare schemes like the BOCW through targeted performance incentives. Dynamic Incentivizing Contract design proposed in this paper is a classic application of game theory particularly in mechanism design and dynamic contracting under asymmetric information. It includes all key ingredients of a game-theoretic approach like strategic interaction, asymmetric information, payoff optimization, and incentive compatibility over time.

By reviewing literature across the domains, we demonstrate the necessity and relevance of our proposed solution, which bridges the gap between policy design and practical, sustainable implementation for India's construction workforce.

3 Dynamic Incentivizing Contract

To overcome under-utilization of Building and Other Construction Workers (BOCW), we design a monthly contract between a contractor (she) and a worker (he). The method we use to design the contract is based on a game theoretical approach; we consider a game between the contractor and the worker. In this game, the contractor aims to maximize her profit while persuading the worker to sign the contract and make him satisfied by giving him a payment better than his outside option.

3.1 Objective of the Contract:

The contractor aims to maximize her profit while ensuring the worker is motivated to accept and fulfil the contract. This is achieved by offering payments that are more attractive than the worker's alternative option (which is earning nothing). We consider two periods in our contract. The first period is the initial period of the employment, and the second period is the next month. The reason that we considered an "initial period" and a following period is to show the impact of incentivizing the worker in the first period on his performance in the following period. By structuring the contract over two periods, the impact of initial incentives on subsequent performance can be observed. Due to the higher bargaining power of the contractor in the construction section in India, we consider her as the contract designer.[26]. The contractor assists or simplifies the registration process (e.g., via documentation, digital tools, or awareness efforts), thus removing barriers like lack of awareness or procedural difficulties.

By designing a contract that spans two periods, the contractor positions BOCW enrolment as part of a sustained employment relationship, rather than a one-time compliance task. This aligns worker incentives with formal registration, making it a rational and rewarding choice.

Table 1 Notation

Symbol	Definition
θ_t	Worker's productivity during period t; represents how much output the worker can produce in that time frame.
$\equiv$	Logical equivalence or definition symbol; indicates that a term is defined to be exactly equal to another.
U_t^w	Worker's utility in period t; the benefit or satisfaction derived by the worker during that period.
p_t	Payment received by the worker from the contractor in period t.
q_t	Work output produced by the worker in period t, measured in square feet of construction completed.
C_t^p	Worker's performance cost in period t; includes effort, fatigue, or other costs associated with producing output.
e_1	Value of the BOCW scheme benefit.
U_0^w	The worker's outside option if they choose not to accept the contract; assumed to be a salary of zero in this context.

3.2 Key Variables and Parameters used in the Model

Worker Productivity Level (θ_t):
In our model, worker productivity is represented as a scalar value θ_t, which denotes the worker's efficiency level at time period t. It is defined as the square footage of construction output completed, adjusted for quality standards. While the model treats θ_t as a continuous variable observable to the worker, it evolves dynamically across periods based on prior performance and external support.

This approach aligns with existing literature on productivity modeling in informal sectors where formal performance metrics are unavailable. The evolution of productivity over time is captured by the equation:

$$\theta_(t+1) = a * \theta_t + e_1 + \beta$$

Here:

- a reflects the retention rate of productivity from the previous period;
- e_1 is the normalized value of financial aid (e.g., access to welfare benefits, healthcare, insurance);
- β accounts for other exogenous improvements in productivity (e.g., on-the-job learning or experience).

BOCW financial aid value (e_1):
In practice, the BOCW scheme offers uniform financial support to all registered workers, regardless of their productivity level. Our model treats this financial aid as a fixed per-worker benefit e_1 , assumed to be equally accessible to all workers upon registration. The innovation in our contract design lies in creating an incentive mechanism that encourages contractors to assist in worker registration thereby enabling workers to receive these benefits, which then enhance their productivity. In the theoretical model, we do not assume any differentiated or performance-based allocation of BOCW funds. Rather, the allocation is modelled as binary and uniform: once a worker is registered, they receive the full set of benefits. This simplification helps isolate the impact of registration and participation incentives without requiring assumptions about varying aid levels.

In our proposed contract model, it's not just the BOCW benefit itself that adds value - its the contractor's active effort in facilitating worker registration and potentially helping with follow-up claims and benefit access that makes the model truly impactful. In our model, by designing incentives for contractors to perform this support role, the contract directly addresses a real-world bottleneck in scheme implementation.

This approach is supported by empirical studies and historical data from similar welfare programs demonstrating the effectiveness of integrated incentive structures[3,4].

Productivity Retention Rate *(a)*:
The productivity retention rate represents the percentage of a worker's productivity in Period 1 (θ_1) that continues or carries over into Period 2 (θ_2). If a worker was very productive in the first month, a higher a means they are likely to remain productive in the second month. If a is close to 1 (or 100%), it

means most of the worker's past productivity carries forward. If a is low (e.g., 0.3 or 30%), it means only a small part of the previous productivity persists, and other factors (like training or aid) become more important.

Some of a worker's ability carries over (e.g., experience, skill, confidence), but part of it may fade due to fatigue, job change, or other uncertainties. By adjusting a, the model can simulate different realities: High a: stable, skilled workforce with learning effects. Low a: volatile or inconsistent productivity, possibly due to informal or unstable work conditions.

3.3 How the contract works

Period 1:
At the beginning of period 1, the worker realizes his productivity, θ_1. The contractor has already designed a menu of contracts for each productivity level θ_t theres a corresponding contract: $((p_t(\theta_t)q_t(\theta_t)))$ meaning, if the productivity is then the worker should produce the output $q_t(\theta_t)$ and the worker will receive the payment $p_t(\theta_t)$. The worker chooses the contract matching his productivity level. Then he delivers the output $q_t(\theta_t)$ and receives the payment $p_t(\theta_t)$ in period 1. **Period 2:**
At the beginning of the second period of the contract, the worker observes their new productivity level θ_2, which is now influenced by both internal (past performance) and external (BOCW aid and other factors) components:

$$\theta_2 = a \cdot \theta_1 + e_1 + \beta \tag{1}$$

- $a * \theta_1$: To show the validity of our results, we consider a general coefficient of a [0%, 100%] to represent the worker's productivity levels continuity from period 1 to period 2. Indeed, the coefficient a represents the percentage of worker's productivity in period 1 that endures to period 2. Since the percentage is between 0% and 100%, the way we have considered coefficient of a ε [0%, 100%] is without loss of generality.

  we have expanded our numerical analysis to include a broader range of Worker Productivity (a = 0.05,0.5,0.95) to capture low, medium, and high levels of continuity. These values are representative of different potential worker, detailed numerical results and graphs are provided in Appendix A

- e_1: since BOCW enhances the overall well-being of workers, including their physical and mental health, we consider that e_1 improves the worker's productivity level.

- β: We also consider another variable, β, to represent other factors on productivity. Also, the assumption of linearity is without loss of generality.

After observing his second period productivity, θ_2 the worker selects his contract from a menu of contracts designed for all workers with productivity levels in $\theta_2 = [\theta, \theta]$ by the contractor. The worker delivers the output level of $q_2(\theta_2)$ and receives the payment $p_2(\theta_2)$.

3.4 Utilities

In the context of this contract design model, utility refers to the net benefit or satisfaction derived by the respective parties, the worker and the contractor in each period of the contract. The utility functions capture the trade-off between the benefits received (payment or value from output) and the costs incurred (effort or payment made) within the contract.

Worker's Utility in Period t
The worker's utility in period t refers to the net benefit or satisfaction the worker derives after performing the assigned tasks. It is calculated as the difference between the payment received from the contractor and the effort or performance cost incurred in producing the output. The worker's utility (or satisfaction) in period t is

$$U_t^w = p_t(\theta^t) - C_t^p(\theta^t) = p_t(\theta^t) - (1-\theta_t) \cdot q_t(\theta^t) \tag{2}$$

where $\theta^1 = \theta_1,\ \theta^2 = (\theta_1, \theta_2)$

- $p_t(\theta^t)$: The payment the worker receives from the contractor based on his productivity level θ^t.
- $C_t^p(\theta^t)$: The cost or effort the worker incurs to perform his tasks, which depends on his productivity.
- $(1-\theta_t) \cdot q_t(\theta^t)$: A specific way to express the performance cost, indicating that less productive workers (θ_t) experience higher costs for the same output $q_t(\theta^t)$.

The formula assumes that as a worker's productivity increases, the effort required for a given output decrease, leading to higher utility.

Assumptions about Performance Cost:

- Increases with Output: The more work the worker does, the higher the total effort or cost.
- Decreases with Productivity: More productive workers find it easier (less costly) to produce the same amount of work compared to less productive ones.

These assumptions are trivial: doing more work requires more effort, but being better at the job makes each unit of work easier.

Also, although we have considered a linear performance cost function, we claim that our insights remain the same as long as our performance function satisfies the two above-mentioned trivial assumptions. (refer Appendix A)

Indeed, we assume that the cost of performance is less for workers with high productivity levels than for those with low productivity levels.

Contractor's Utility in Period t:
The contractors utility in period t, captures the net benefit derived from the worker's output. It is defined as the value or profit generated from the output produced by the worker, minus the payment made to the worker. The contractors utility in period t is

$$U_t^c = \alpha \cdot v(q_t(\theta^t)) - p_t(\theta^t) \tag{3}$$

- $v\left(q_t\left(\theta^t\right)\right)$: The value or benefit the contractor derives from the worker's output.
- a : A factor that adjusts this value, possibly representing market conditions or the contractor's efficiency in utilizing the worker's output. Numerical analysis performed to validate the robustness in Appendix A
- $p_t\left(\theta^t\right)$: The payment made to the worker.

where we assume v(·) is a concave function. To show the reliability of results, we consider any $\alpha > 0$.

Assumption of Concavity in v(·) :
The concavity of function v(·) is a trivial result of the well-known Law of Diminishing Marginal Utility. This law states that as the quantity of a good or service consumed increases, the additional satisfaction or utility derived from each additional unit decreases. In the context of the contractor's utility, it suggests that while increasing the worker's output leads to higher overall value, each additional unit of output contributes less to the total value than the previous one.

The decreasing marginal utility results in considering a concave, increasing utility function for the contractor. Without loss of generality, we have considered $\sqrt{q_t}$ for our concave function. The square root function is concave and increasing, meaning it captures the diminishing marginal returns characteristic.

By incorporating this concave function into the contractor's utility model, we can more accurately represent scenarios where each additional unit of worker output yields progressively smaller increases in value to the contractor, reflecting realistic economic behaviours and aiding in the design of effective contracts. We show that this insight is the same if we consider other concave, increasing functions with details in Appendix A

So, the contractor's utility is the adjusted value gained from the worker's output minus the payment given to the worker. The goal for the contractor is to maximize this utility, balancing the value obtained from the worker's efforts against the costs of employing him.

In summary, both the worker and the contractor aim to maximize their respective utilities. The worker seeks to get the most benefit from his work after accounting for effort, while the contractor aims to gain the highest value from the worker's output after paying for it. Understanding these dynamics is crucial for designing contracts that align incentives and promote mutually beneficial outcomes.

3.5 The Optimal Contract Design

The contractor wants to maximize her total benefit over two periods. This total benefit is the sum of her benefits in the first and second periods. To obtain the optimal dynamic contract, we first specify the problem of the contract designer (the contractor) as maximization of her life-time utility:

$$\max_{p_1,q_1,p_2,q_2}\left[U_1^c + U_2^c\right] \equiv \max_{p_1,q_1,p_2,q_2}\left[\alpha \times v\left(q_1\left(\theta_1\right)\right) - p_1\left(\theta_1\right) + \alpha \times v\left(q_2\left(\theta_1,\theta_2\right) - p_2\left(\theta_1,\theta_2\right)\right]$$

- a: A positive factor representing external conditions or the efficiency with which the contractor benefits from the worker's output.
- v(.): A concave function representing the value or satisfaction the contractor gets from the worker's output

Worker's Participation Constraint (WPC):
This maximization problem is subject to persuading the worker to accept the contract. We capture this by introducing a constraint named "Worker's Participation Constraint", (WPC):

$$U_1^w + U_2^w \geq 2 \times U_0^w \equiv p_1\left(1-\theta_1\right)\cdot q_1 + p_2 - \left(1-\theta_2\right)\cdot q_2 \geq 2 * U_0^w$$

where U_0^w is the worker's outside option. For the worker to agree to the contract, the combined utility(satisfaction) he gains over both periods should be at least as much as his outside option. As there are no unemployment benefits available to the workers who do not apply for BOCW, we assume that the worker's alternative option has a value of zero.

In essence, the optimal contract is one that aligns the contractor's desire for maximum benefit with the worker's need for fair compensation, ensuring both parties are satisfied over the duration of the contract.

Solution
The contractor aims to maximize her total benefit over two periods by deciding on the optimal amounts of work (outputs) she expects from the worker in each period, denoted as q_1 and q_2. Simplifying the Problem:

Instead of directly determining both the payments (p_1, p_2) and the outputs (q_1, q_2), the contractor simplifies her decision-making by focusing solely on the outputs. we first reduce the number of our decision variables from p_1, q_1, p_2, q_2 to q_1, q_2 . This is possible because once the optimal outputs are determined, the corresponding payments can be set to ensure the worker's participation.

Since the contractor is the designer of the contract, she can extract the whole surplus of the contract which is $\alpha \times v\left(q_1\left(\theta_1\right)\right) - C_1^p\left(\theta_1\right) + \alpha \times v\left(q_2\left(\theta_1,\theta_2\right) - -C_2^p\left(\theta^2\right)\right.$. On the other hand, the outside option of workers is 0 .

Worker's Total Utility: The worker's total utility over the two periods is given by: using equation (2)

$$U_1^w + U_2^w = p_1(\theta_1) - C_1^p(\theta_1) + p_2(\theta^2) - C_2^p(\theta^2)$$

Given that the worker's alternative option yields zero utility, the contractor sets the payments such that the worker's total utility is non-negative: Therefore, we obtain

$$p_1(\theta^1) + p_2(\theta^2) = (1-\theta_1) * q_1(\theta^1) + (1-\theta_2) * q_2(\theta^2)$$

Reformulating the Contractor's Objective: Substituting the expression for p1 and p2 into the contractor's total benefit function, function (P) becomes equivalent to:

$$\text{Total Benefit } (P) \equiv \max_{q_1,q_2} \Big[\alpha \cdot v(q_1(\theta_1)) - (1-\theta_1) \cdot q_1(\theta_1) + \alpha \cdot v(q_2(\theta_1,\theta_2)) - (1-\theta_2) \cdot q_2(\theta_2)\Big]$$

Total Benifit formula, v(q) represents the value or utility the contractor derives from the worker's output.

Optimizing the Outputs:

To determine the optimal output level of the worker in Period 2, we solve the contractors utility maximization problem by taking the first-order condition of the utility function with respect to q_2.

The value function $v(q_t)$ is assumed to follow a concave increasing form $v(q_t) = \sqrt{q_t}$ capturing the law of diminishing returns. Solving the first-order condition, the optimal output is derived for q_2 as:

$$\left(\alpha \times \frac{1}{2(1-\theta_2)}\right)^2$$

$$q_1(\theta^1) = \left(\alpha \times \frac{1}{2(1-\theta_1)}\right)^2$$

The detailed derivation steps are provided in Appendix A.

Similar to Period 1, the contractor determines the optimal output level q_1 for the worker in Period 1 by maximizing her utility function. Taking the first-order condition of the contractor's utility function with respect to q_1, and using the concave value function $v(q_t) = \sqrt{q_t}$, the optimal output level in Period 1 is derived as:

$$q_1(\theta^1) = \left(\alpha \cdot \frac{1}{2}(1-\theta_1)\right)^2$$

The detailed derivation steps for obtaining q_1 are provided in Appendix A. By determining the optimal outputs q_1 an q_2 using the above formulas, the contractor can then set the payments p_1 and p_2 accordingly to ensure the worker's total utility is non-negative. This approach allows the contractor to maximize her total benefit while ensuring the worker is willing to participate in the contract.

4 Numerical Analysis Results and Insights

In this section, we perform sensitivity analysis to study how BOCW scheme's financial aid (e_1) influence various factors within the construction sector.

Key Assumptions:

- Financial Aid Range: The financial aid e_1 varies between 0 and 0.1.
- Initial Productivity (θ_1): The worker's starting productivity level is set at 0.1.
- Profit Distribution: On average, 60% of the total profit from a construction project goes to the worker, and 40% goes to the contractor.

4.1 The effect of e_1 on Worker's Productivity (q_2)

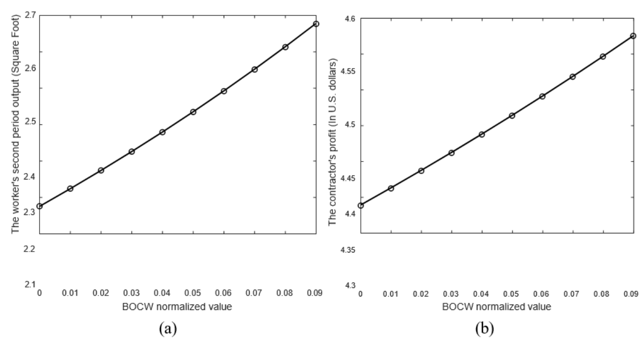


Fig. 1 The effect of e_1 on q_2 and the contractors profit

As Figure 1(a) shows, increasing e_1 leads to higher worker effort in the second period. This indicates that government financial aid (e1) positively influences worker productivity.

4.2 The effect of e_1 on the contractors profit

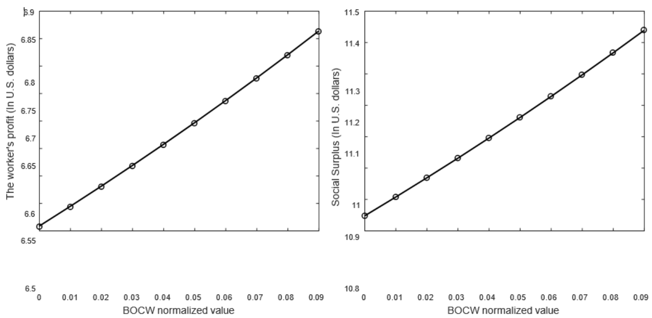
As the main result of our paper, Figure 1(b) shows that higher e_1 leads to increased contractor profit. This indicates that when the government provides more financial aid to workers, it indirectly benefits the contractors by enhancing worker productivity, which in turn increases the contractor's earnings.

4.3 The effect of e_1 on the worker's profit

As Figure 2(a) shows, increasing e_1 positively impacts the worker's profit, The financial aid not only supports the worker directly but also enables them to work more effectively, leading to higher income.

4.4 The effect of e_1 on the social surplus

As Figure 2(b) shows, increasing the value of BOCW increases the social surplus. This implies that it is advantageous for all stakeholders within the Indian construction sector for workers to receive assistance from the BOCW scheme.



(a) (b)

Fig. 2 The effect of e_1 on the social surplus and the worker's profit

Therefore, we have shown that if the contractors consider the workers as their long-term partners, and facilitate their registration process for BOCW, she benefits from the improvement in the workers productivity and her profit increases.

5 Designed Contract Practicality

5.1 Benefits to Contractors & Workers

Policymakers can integrate the contract design approach into existing labor welfare policies, enhancing their effectiveness. This approach provides a structured mechanism to improve worker welfare and productivity, ensuring better utilization of allocated budgets for social security schemes like BOCW[27].

In addition, contractors benefit from increased worker productivity and improved project quality. The contract design creates a stable and motivated workforce, reducing turnover and enhancing overall project outcomes. Contractors are incentivized to assist in worker registration as it directly correlates with improved profitability[28]. Also, construction workers receive direct benefits, including increased earnings, improved welfare, and access to social security benefits. This contract design ensures that workers contributions are recognized and rewarded, leading to better job satisfaction and long-term improvements in their livelihoods[29].

5.2 Practical Implementation Challenges

Regarding the feasibility of implementing this contract design we might face potential barriers such as administrative challenges, resistance from contractors, and logistical issues are discussed. Strategies that can be adopted to address these barriers,

- Digital platforms can streamline administrative tasks such as registration and documentation;
- Training sessions can help both contractors and workers understand and adopt the new contract structure;
- Collaboration with labour unions and NGOs can further support smooth implementation and ensure transparency[19].

By proactively addressing these challenges, the designed contract can shift from a theoretical model to a practical solution that benefits all stakeholders in the construction sector.

6 Future Research

Future research should explore the long-term impact of the contract design approach, variations in different regions, and its applicability to other sectors. Further studies can also examine the effectiveness of digital tools in facilitating the registration process and the role of continuous training in improving worker productivity. Additionally, future research could incorporate more variables to enrich the analysis and provide a more comprehensive understanding of the contract designs impact. Variables such as gender, age, and educational background can provide insights into how different demographics are affected by the contract design. For instance, examining gender-specific impacts could reveal whether the contract design equally benefits male and female workers or if adjustments are needed to ensure equitable outcomes[30]. Including these variables can also help tailor the contract design to address specific needs and challenges faced by diverse groups within the construction workforce.

We acknowledge that in our model, worker productivity in the second period (θ_2) is modelled as a function of past productivity (a), government financial aid (e_1), and an external factor parameter (β), which captures other influences on productivity such as health, training, and work environment. While we have adopted a linear representation for this relationship for modelling tractability, a standard practice in contract theory literature[23,24]. We have clearly stated that this assumption is made without loss of generality. We believe that the key insight of our model that government financial aid positively impacts worker productivity would hold true even if a non-linear or more complex relationship is modelled. Future empirical work with access to field-level data could further explore such modelling extensions.

Moreover, we highlight that the strength of our proposed contract design lies not only in the provision of financial aid but also in incentivizing the contractor to play an active role in facilitating worker registration, supporting documentation, and assisting in follow-up benefit claims. This operational aspect directly addresses a critical real-world bottleneck in the BOCW schemes implementation. Future avenue for research can also be towards Investigating the long-term behavioral impact of contractor-led registration efforts.

7 Conclusion and Limitations

In conclusion, the Building and Other Construction Workers (BOCW) scheme in India represents a crucial initiative aimed at addressing the welfare of the construction labor force. However, it faces the substantial challenge of underutilization, primarily due to factors like limited awareness and challenging registration criteria. To tackle this issue effectively, we have proposed an innovative contract design using game theoretical modeling.

Our findings show that government financial aid plays a pivotal role in increasing worker effort and productivity, especially over time. This aligns with research on Active Labor Market Programs[6], emphasizing the power of incentive structures in policy design. In doing so, our work contributes to the literature on labor market efficiency and formalization, particularly in developing countries. Furthermore, by addressing labor informality through a structured, incentive-driven contract, we build on W.F. Maloneys work and offer a practical intervention for the construction sector[7].

The proposed contract also has implications during economic shocks, such as the COVID-19 pandemic. In such contexts, informal workers are particularly vulnerable. Our approach offers a bottom-up mechanism to support these workers through improved access to insurance, healthcare, and unemployment support. This adds to the literature on resilience-building policies in developing economies.

While the proposed contract design offers a promising approach to boost enrollment in the Building and Other Construction Workers (BOCW) scheme, several significant barriers to implementation must be addressed to ensure its success. One of the primary challenges in implementing the proposed contract design is the potential resistance from contractors within the construction industry. Historically, contractors may have been hesitant to advocate for the BOCW scheme or guide laborers through the registration process due to a variety of reasons. Contractors often operate under tight project timelines and budgets, which may limit their willingness to engage in administrative tasks related to worker registration. Additionally, some contractors may be concerned that increased worker participation in the BOCW scheme could lead to higher labor costs or regulatory burdens. Overcoming this resistance will require effective communication and collaboration between policymakers, contractors, and labor organizations to demonstrate the mutual benefits of the proposed contract.

The implementation of the contract design is likely to encounter bureaucratic hurdles and administrative complexities. Streamlining the registration process for construction workers, particularly for those engaged in short-term or project-based employment, is essential. The requirement for workers to present a 90-day certificate of employment is one such administrative hurdle. Given the informal nature of many construction jobs, obtaining such certificates may be challenging for workers. Policymakers must work to simplify the application process, potentially through digital platforms, and ensure workers have access to the necessary documentation.

Finally, implementing the proposed contract design may require financial resources, not only for incentivizing contractors but also for promoting awareness of the BOCW scheme among workers. Financial constraints, particularly in a sector as labor-intensive as construction, can be a significant barrier. Policymakers must carefully allocate resources to cover the costs associated with incentivizing contractors, monitoring contract compliance, and conducting awareness campaigns. Securing the necessary funding and budget allocations will be crucial for the successful execution of the contract design.

In conclusion, while challenges remain, our proposed contract design offers a promising path forward to strengthen labor welfare, boost productivity, and promote formalization in India's construction sector. With collaborative implementation and targeted policy support, it can contribute meaningfully to the long-term resilience of both workers and the industry.

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Appendix A

This appendix provides the detailed mathematical derivations, model assumptions, and numerical analysis that support the findings of this study. The first part outlines the formulation of the dynamic contract model, key parameters, and the derivation of optimal output decisions for both periods of the contract. The second part presents sensitivity analysis conducted to test the robustness of the proposed contract design under different parameter settings. These include variations in worker productivity continuity, contractor utility functions, and the output valuation parameter . The numerical analysis aims to validate that the main insights of the research remain consistent across diverse scenarios.

Derivation of Optimal Output

Derivation of Optimal Output in Period 2

To determine the optimal output q_2, we take the derivative of the contractors utility function with respect to q_2: Step 1: First-Order Condition for q_2

$$\frac{dp}{dq_2} = \alpha \times v^{'}(q_2(\theta^2)) - (1-\theta_2) = 0$$

Since, we considered $v(q_t) = q_2^{0.5}$, then $v^{'}(q_t) = 0.5 \cdot q_2^{-0.5}$.
So, we can rewrite the above equation as

$$\frac{dp}{dq_2} = \alpha \times \frac{1}{2}(q_2(\theta^2))^{-1/2} - (1-\theta_2) = 0$$

The above equation is equivalent to

$$\equiv \alpha \times \frac{1}{2}(q_2(\theta^2))^{-1/2} = (1-\theta_2)$$

Step 2: Rearranging to Solve for the optimal output q_2

$$\equiv \alpha \times \frac{1}{2(q_2(\theta^2))^{1/2}} = (1-\theta_2)$$

$$\equiv \alpha \times \frac{1}{1-\theta_2} = 2 \cdot (q_2(\theta^2))^{1/2}$$

$$\equiv q_2(\theta^2) = \left(\alpha \times \frac{1}{2(1-\theta_2)}\right)^2$$

This gives the optimal output level of the worker in Period 2.

Derivation of Optimal Output in Period 1

To determine the optimal output q_1, we take the derivative of the contractors utility function with respect to q_1:

$$\frac{dp}{dq_1} = \alpha \times v'(q_1(\theta_1)) - (1-\theta_1) = 0$$

Since, we considered $v(q_t) = q_2^{0.5}$, then $v^{'}(q_t) = 0.5 \cdot q_2^{-0.5}$. So, we can rewrite the above equation as:

$$\frac{dp}{dq_1} = \alpha \times \frac{1}{2}(q_1(\theta^1))^{-1/2} - (1-\theta_1) = 0$$

So, we can find the optimal q_1. The above equation is equivalent to:

$$\alpha \times \frac{1}{2}(q_1(\theta^1))^{-1/2} = (1-\theta_1)$$

$$\equiv \alpha \times \frac{1}{2(q_1(\theta^1))^{1/2}} = (1-\theta_1)$$

$$\equiv \alpha \times \frac{1}{1-\theta_1} = 2 \cdot (q_1(\theta^1))^{1/2}$$

$$\equiv q_1(\theta^1) = \left(\alpha \times \frac{1}{2(1-\theta_1)}\right)^2$$

This gives the optimal output level for the worker in Period 1.

Numerical Analysis

In this appendix, we present the detailed numerical analysis performed to validate the robustness of our results. The numerical analysis is divided into three sections:

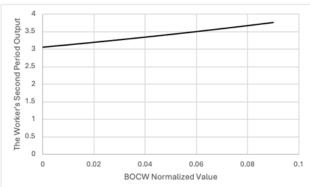
1. Continuity of Worker Productivity (a):
   We vary the parameter a to test low (a =0.05 a = 0.05 a =0.05), medium (a =0.5 a = 0.5 a=0.5), and high (a =0.95 a = 0.95 a =0.95) continuity of worker productivity.
2. Concave Utility Functions (q_t):
   We consider three different concave utility functions ($q_t^{0.1}, q_t^{0.5}$, and$q_t^{0.9}$) to ensure the robustness of our contractor utility model.
3. Output Valuation Parameter a:
   We vary a to test its impact on worker and contractor outcomes, considering small (a=33), medium (a=30), and large (a=3000) values.

In all cases, we confirm that the main insight of our paper the increasing effect of e1 on the workers second-period output, contractors profit, workers profit, and social surplus remains unchanged.

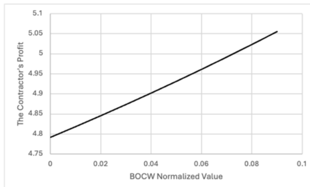
Therefore, for all the tested values of a, the main insight of our paper, which is the increasing effect of e_1 on the workers second-period output, the contractors profit, the workers profit, and social surplus, is confirmed.

Continuity of Worker Productivity (a)

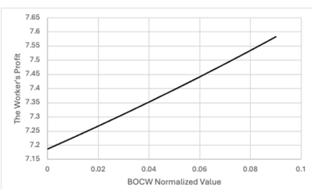
***Case* 1: $a = 0.05$:**



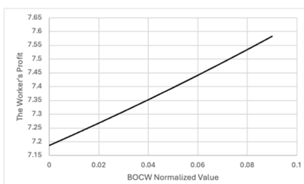
Impact of BOCW Normalized Value on Worker's Second Period Output (for a = 0.05)



Impact of BOCW Normalized Value on Contractor's Profit (for a = 0.05)

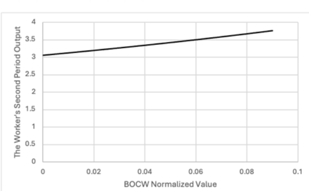


Impact of BOCW Normalized Value on Worker's Profit (for a = 0.05)

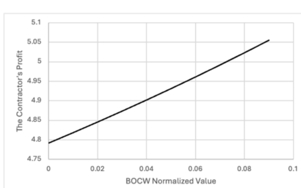


Impact of BOCW Normalized Value on Social Surplus (for a = 0.05)

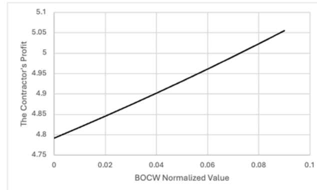
***Case* 2: $a = 0.5$:**



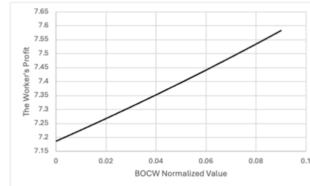
Impact of BOCW Normalized Value on Worker's Second Period Output (for a = 0.5)



Impact of BOCW Normalized Value on Contractor's Profit (for a = 0.5)

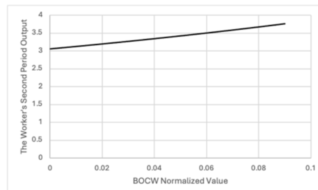


Impact of BOCW Normalized Value on Worker's Profit (for a = 0.5)

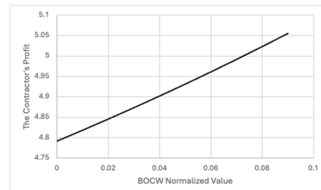


Impact of BOCW Normalized Value on Social Surplus (for a = 0.5)

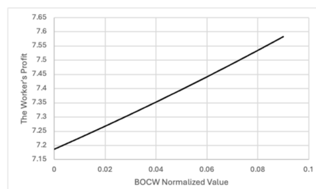
***Case* 3: $a = 0.95$:**



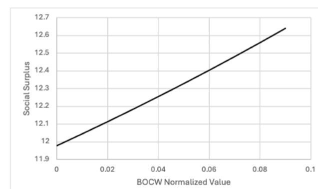
Impact of BOCW Normalized Value on Worker's Second Period Output (for a = 0.95)



Impact of BOCW Normalized Value on Contractor's Profit (for a = 0.95)



Impact of BOCW Normalized Value on Worker's Profit (for a = 0.95)

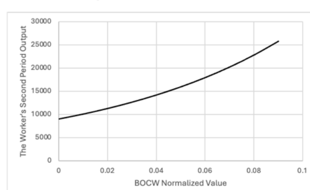


Impact of BOCW Normalized Value on Social Surplus (for a = 0.95)

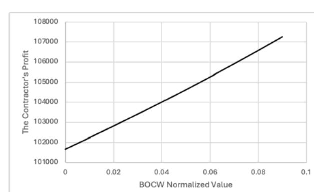
Concave Utility Functions (q_t)

In the second part of our numerical analysis, we consider different concave functions for the utility of contractors. Without loss of generality, we have considered $\sqrt{q_t}$ for our concave function in the manuscript, but here we show that the insight is the same if we consider other concave, increasing functions. We consider three different increasing concave functions here: $q_t^{0.1}, q_t^{0.5}, q_t^{0.9}$

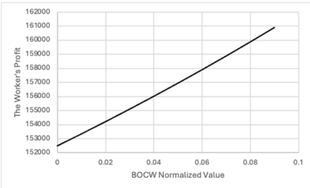
***Case* 1: $q_t^{0.1}$**



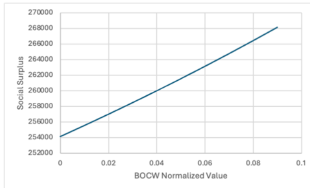
Impact of Concave Function on Worker's Second Period Output (for $q_t^{0.1}$)



Impact of Concave Function on Contractor's Profit (for $q_t^{0.1}$)

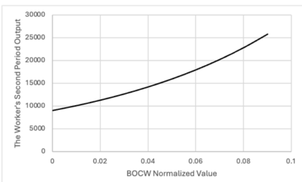


Impact of Concave Function on Worker's Profit (for $q_t^{0.1}$)

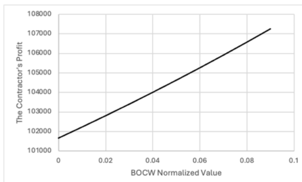


Impact of Concave Function on Social Surplus (for $q_t^{0.1}$)

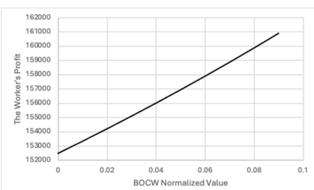
***Case* 2: $q_t^{0.5}$**



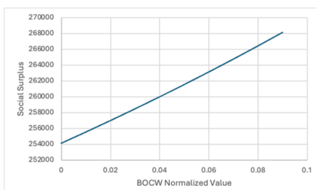
Impact of Concave Function on Worker's Second Period Output (for $q_t^{0.5}$)



Impact of Concave Function on Contractor's Profit (for $q_t^{0.5}$)

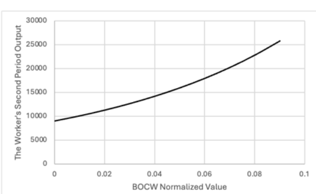


Impact of Concave Function on Worker's Profit (for $q_t^{0.5}$)

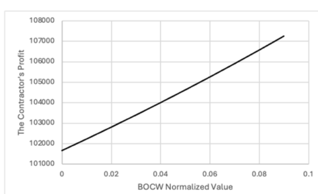


Impact of Concave Function on Social Surplus (for $q_t^{0.5}$)

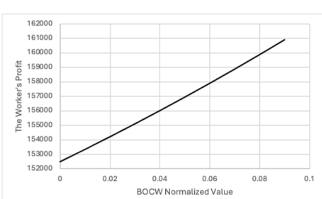
***Case* 3: $q_t^{0.9}$**



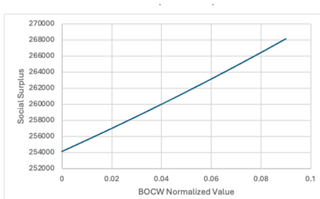
Impact of Concave Function on Worker's Second Period Output (for $q_t^{0.9}$)



Impact of Concave Function on Contractor's Profit (for $q_t^{0.9}$)



Impact of Concave Function on Worker's Profit (for $q_t^{0.9}$)

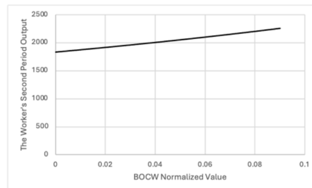


Impact of Concave Function on Social Surplus (for $q_t^{0.9}$)

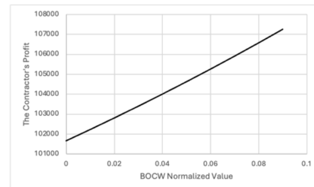
Contractor's Valuation Coefficient a

In the last part of our numerical analysis, we tested a values of 3, 30, and 3000 to explore the impact of this parameter. Across all three cases, the increasing effect of e_1 on the key metrics remains unchanged, demonstrating the robustness of our findings.

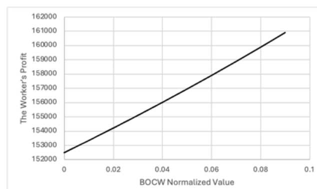
***Case* 1: $\alpha = 3$**



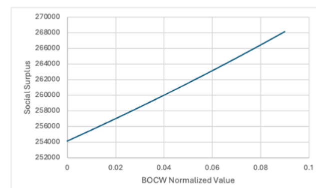
Impact of BOCW Normalized Value on Worker's Second Period Output (for $\alpha = 3$)



Impact of BOCW Normalized Value on Contractor's Profit (for $\alpha = 3$)

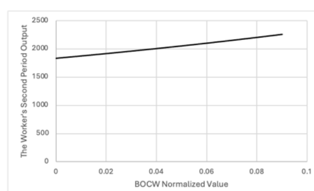


Impact of BOCW Normalized Value on Worker's Profit (for $\alpha = 3$)

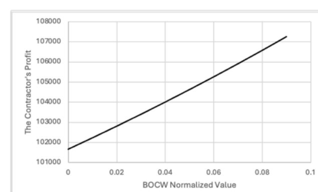


Impact of BOCW Normalized Value on Social Surplus (for $\alpha = 3$)

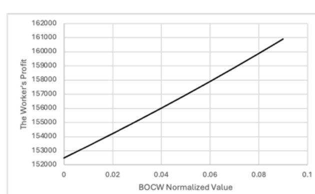
***Case* 2: $\alpha = 30$**



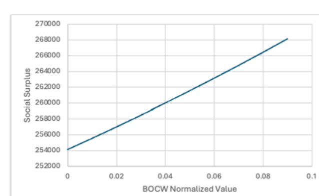
Impact of BOCW Normalized Value on Worker's Second Period Output (for $\alpha = 30$)



Impact of BOCW Normalized Value on Contractor's Profit (for $\alpha = 30$)

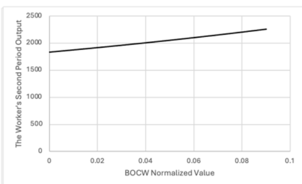


Impact of BOCW Normalized Value on Worker's Profit (for $\alpha = 30$)

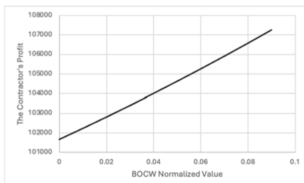


Impact of BOCW Normalized Value on Social Surplus (for $\alpha = 30$)

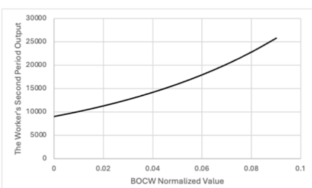
***Case* 3: $\alpha = 3000$**



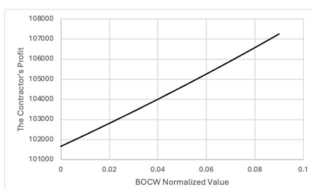
Impact of BOCW Normalized Value on Worker's Second Period Output (for $\alpha = 3000$)



Impact of BOCW Normalized Value on Contractor's Profit (for $\alpha = 3000$)



Impact of BOCW Normalized Value on Worker's Profit (for $\alpha = 3000$)



Impact of BOCW Normalized Value on Social Surplus (for $\alpha = 3000$)

In conclusion, the analytical derivations confirm the theoretical foundations of the proposed contract model, while the sensitivity analysis further demonstrates its practical robustness. Across all tested variations of key parameters-including productivity retention rate, concave utility functions, and the contractor's valuation coefficient a-the increasing impact of BOCW financial aid (e_1) on worker productivity, contractor profit, worker earnings, and social surplus remains consistent. These findings provide strong validation for the applicability of the dynamic contract design in real-world construction sector settings.