Nudging rail transportation forward: the role of contracts and behavioral insights

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Abstract

This article examines the effectiveness of government incentives, as Brazil's agribusiness as an example, aimed at promoting rail transport improvements and their subsequent transfer in terms of reduced transportation costs to farmers, specifically within the context of soybean transportation. It investigates how a governing body utilizes subsidy schemes as incentives for rail companies to lower transport prices for farmers within a regulatory framework designed to encourage the use of rail over road transportation. This strategy addresses the broader goal of mitigating congestion and reducing logistical expenses by shifting the transport mode preference from road to rail, particularly relevant in regions experiencing significant transportation challenges.

The study categorizes incentives into two main types: direct financial incentives for rail companies to adopt and transfer rail improvements to farmers at lower costs and behavioral incentives (nudges) to alter farmers' transportation mode preferences towards rail usage. These incentives serve dual purposes: to decrease government spending on subsidies by ensuring more efficient transportation methods and to encourage rail companies to focus on enhancing the quality of their services and pricing strategies. This is imperative in sectors where rail companies may hold monopolistic power, affecting the pricing and quality of transportation services.

The findings emphasize the critical role of well-structured incentive systems, incorporating knowledge from behavioral economics, in significantly enhancing the efficiency and effectiveness of rail transportation for agricultural products. This approach considers the economic impacts of such incentives and the behavioral tendencies of both rail companies and farmers, aiming to improve the practicality and outcomes of these policies in real-world scenarios.

Keywords: Government Incentives, Rail Transport, Agribusiness, Behavioral Economics, Transportation Costs Reduction

JEL-Codes: R41,L51,L92,D82,D86,R48,D24

1. Introduction

The role of infrastructure, in influencing location decisions is thoroughly examined in transportation research within Brazil's agribusiness sector ((Redding et al. (2014)), (Pokharel et al. (2023))). The sector heavily depends on a road network leading to logistical challenges such as constant traffic jams, long transportation times, and rising expenses. The reliance on the road network is further complicated by the shortcomings of Brazil's rail infrastructure, which is primarily geared towards freight transport but lacks development and efficiency compared to roads. With iron ore transportation dominating 72% of rail cargo, the rail system (Guimarães et al. (2023)) pales in comparison to the road network and faces issues with track compatibility and operational efficiency due to mix of narrow and standard-gauge tracks. The current state of Brazil's rail network emphasizes the need for a transition towards greater rail transport for its cost-effectiveness and efficiency, in moving large cargo volumes over distances (Amann et al. (2014)).

While the benefits of using rail transportation are well known the shift, from road to rail within Brazil´s agribusiness industry is encountering obstacles. Road transport remains favored due to its accessibility, speed, flexibility, and reliability. Qualities are highly valued in this sector. Litman (2023) has critically examined this preference for road transport emphasizing a rooted bias towards it. Furthermore, Smith and Nash (2014) have shed light on the complexities associated with expanding rail services complicating the transition of transportation modes. These challenges highlight the pressing need for planning and focused policy interventions to promote a sustainable transportation system. Following the lead of the European Union approach (Nkesah, 2023) which emphasizes sustainability, despite the advantages of road freight, Brazilian stakeholders must prioritize reducing the impact of road transport and consider integrating social and environmental strategies into a unified policy framework for a sustainable shift, to rail transport.

The key question that remains is how a mix of government funding and incentives aimed at changing behavior effectively promotes a shift, from road to rail transport within Brazil's industry.

In the field of logistics especially when it comes to how soybean producers choose transportation methods it's important to use subtle influences to encourage a switch from

using roads to using railways. This strategy involves looking at ideas to figure out when these influences are (Stockhammer et al (2021). This includes changing how we think making things more valuable relying on mental shortcuts, following social norms, and considering time preferences can make railway transport seem more appealing compared to traditional road transport. By comparing the benefits of road transport, with both nudged rail transport and regular rail transport we see that nudges significantly surpass the utility of rail and road by improving the perceived value of railways through social factors. By using these nudges, we can increase customer satisfaction by making railway transportation more attractive by adjusting our thinking patterns taking advantage of biases responding to social pressures and considering time values differently. This approach supports an efficient shift in transportation methods, within the industry.

Based on our research we suggest that technological advancements by rail transport companies should lead to transportation costs. Our study examines crafting contract structures to encourage the transition towards efficient freight transportation methods, particularly focusing on Brazil's agricultural sector. In examining how subsidy programs impact the profit of farmers, in agricultural supply chains we consider three categories of subsidies: Unconditional Subsidies, Variable Conditional Subsidies, and Fixed Conditional Subsidies (Defever and Riaño (2017), Bahl (2010)).

Each type offers incentives that can affect market dynamics when used alongside nudges. Unconditional Subsidies offer support without requirements boosting farmer profits by a set amount regardless of rail transport costs or quantities. Variable Conditional Subsidies adjust based on the price per unit for rail transport encouraging price reductions to stimulate market demand—a strategy that aligns with the principles of nudges aimed at influencing behavior through cues and rewards. Fixed Conditional Subsidies are granted when the price per unit reaches a threshold providing an incentive if certain pricing conditions are met.

The incorporation of nudges significantly improves the effectiveness of these subsidies for Variable Conditional Subsidies. By guiding producers towards attitudes and actions related to rail transport there is an increase in demand for rail services. This amplifies the impact of subsidies linked to price adjustments. The collaboration between nudges and Variable Conditional Subsidies can result in a drop in rail transport costs and a corresponding rise, in farmer profits compared to the relatively static nature of Unconditional or Fixed Conditional Subsidies. The subsidies mentioned may not adjust

well to shifts, in market trends influenced by influences leading to missed opportunities to take advantage of the growing demand resulting from shifts. As a result, the study indicates that Variable Conditional Subsidies when paired with nudges that stimulate rail market demand could potentially provide an improvement in producer benefits. This highlights the effectiveness of aligned subsidy programs and behavioral interventions, in improving logistics.

In the following sections, we examine the factors influencing transportation choices within Brazil's Soybean sector. We start with a review of existing literature on how infrastructure impacts location decision challenges related to transitioning from road to rail transport and the influence of policies on transportation preferences. Our methodology section will outline our use of both qualitative methods, for evaluating how various subsidy policies and behavioral incentives have impacted soybean producers.

Next, we share our findings emphasizing how various subsidies impact farmers' choices to use rail transport and the importance of nudges, in this context. We will analyze these results. Discuss what they mean for policymaker’s agribusiness stakeholders and the research agenda moving forward. To wrap up we summarize the study's points on crafting policies to encourage a shift towards sustainable and efficient freight transport methods, in Brazil's agricultural sector.

2. Literature Review

The decisions, on where to locate companies are significantly influenced by infrastructure, and transportation infrastructure (Norojono & Young 2003). Factors like cost, delivery time, and service quality heavily impact the choice between road and rail transport. According to research conducted by Demir et al. (2015) enhancing the quality of rail services could strongly sway preferences from road to rail emphasizing the role that improved service quality plays in attracting shippers. Expanding on these findings Pittman et al. (2020) delve deeper into evaluating the effectiveness of European Commission policies aimed at encouraging this shift in transportation modes within Eastern European grain markets. Despite efforts to boost competition among train operating companies (TOCs), Pittman et al. (2020) highlight infrastructure capacity as an obstacle to increasing rails market share. They recommend an approach towards expanding and upgrading rail infrastructure through increased government funding or innovative investment strategies for a smoother transition from road to rail aligning with

broader environmental goals by reducing the adverse effects of road transport. These studies collectively emphasize the necessity for targeted policy measures that prioritize both infrastructure development and service quality enhancements over market dynamics alone to achieve a sustainable shift from road to rail transport.

Despite the benefits of moving towards rail for both the environment and the economy companies still prefer road transport due to its availability, speed, flexibility, and reliability (Litman, 2023). However, the drawbacks and high expenses linked with road transport make a case for considering options. Smith and Nash (2014) discuss the hurdles involved in expanding rail transport emphasizing the need for improvements in infrastructure and service quality to make rail more competitive. Adding complexity to this transition, McCullough and Hadash (2012) examine how changes in trucking costs affect rail freight markets and suggest that policy interventions could have an impact on these dynamics. Ferrari (2018) builds on this by outlining what's needed for innovation within the rail freight sector highlighting the role of government policies in fostering innovation and improving efficiency. These studies collectively highlight the challenges and prerequisites necessary for encouraging a shift from road to rail. This shift involves not only enhancing rail infrastructure and services as discussed by Pittman et al. (2020) in their research on grain markets in Central and Eastern Europe but also implementing policies that support market incentives while making improvements, to rail service quality.

Jiang (2021) explores the approach of utilizing aviation tax revenue to support high-speed rail, examining the policy's impact on traffic distribution across modes. This highlights the potential of cross-subsidization strategies in promoting more sustainable transport options. Furthermore, De Borger and Proost (2021) analyze the effects of road tolls and traffic diversion measures, shedding light on the complex interplay between policy measures and transport choices.

The literature also addresses the challenges of monitoring costs and designing incentive-compatible contracts to encourage rail use. Laffont & Tirole (1986), and Ghatak & Pandey (2000) discuss traditional methods of regulating transportation companies through monitoring, emphasizing the high costs and potential for anti-competitive behavior associated with these regulatory strategies. However, the presence of penalties and carefully designed contracts can deter misconduct and align company incentives with policy goals (Leruth and Paul, 2006; Jing et al., 2021).

Recent research has started combining economics with the analysis of transportation sector agreements acknowledging the significance of aspects, in decision-making. Gómez Lobo and Briones (2014) classify payment methods in bus concession contracts providing insights for developing incentive structures. This perspective is further supported by the studies of Lourenço, J. S., et al. (2016). Markovits Somogyi, R., & Aczél, B. (2013) highlight the importance of integrating perspectives to improve contract efficacy.

The examination of existing literature emphasizes the interaction among infrastructure firm location choices and the selection between road and rail transport modes. It underscores the role of policies and subsidies in promoting a shift towards more sustainable and efficient freight transport options. Furthermore, the growing emphasis on economics presents a path for crafting more effective policies that align with incentives. As the industry progresses implementing policy actions alongside an understanding of behavioral motivators will be key to guiding freight transportation, toward sustainability and efficiency.

3. Model

In the field of logistics especially when it comes to the transportation decisions of soybean farmers using nudges to encourage a shift, from road to rail transport is seen as a move. This discussion delves into the aspects that support how nudges—such as adjustments (γ) value enhancements (ν) heuristic biases (b) social conformity (s) and temporal discounting (d)—go beyond just changing preferences. It shows how these nudges make rail transport more appealing compared to road transport.

The main idea revolves around comparing the utilities of road transport (U_{road}) and rail transport both without nudges (U_{rail}) and, with nudges applied (U_{nudged}). U_{road} and U_{rail} represent the benefits of each transportation mode without any effects. On the other hand, U_{nudged} reflects the utility of rail transport after applying various psychological and social influences.

Mathematical Formulation

The analytical pursuit involves creating a framework to define the conditions where U_{nudged} surpasses both U_{rail} and U_{road} represented as $U_{nudged} > U_{rail} > U_{road}$. In this context the utility functions can be described as follows; $U_{road} = V_{road} - C_{road}$, where V_{road}

and C_{road} represent the perceived value and cost associated with road transportation respectively. $U_{rail} = V_{rail} - C_{rail}$, similarly, defined for rail transport without nudges.

$U_{nudged} = \gamma((V_{rail} + \nu) - C_{rail})^{\alpha} + b + s - d$, incorporating nudge elements to enhance the utility of rail transport.

The effectiveness of nudges lies in their ability to significantly raise U_{nudged} above both U_{rail} and U_{road} making the rail option the preferred choice. Mathematically this requires that; $\gamma((V_{rail} + \nu) - C_{rail})^{\alpha} + b + s - d > V_{rail} - C_{rail}$,

$\gamma((V_{rail} + \nu) - C_{rail})^{\alpha} + b + s - d > V_{road} - C_{road}$

The intersection of these inequalities defines the condition; nudges must not only influence preferences but also fundamentally reshape the utility landscape. This means that cognitive recalibration (γ) perceived value enhancement (ν) bias exploitation (b) social pressures (s) and temporal valuation adjustments (d) together result in a utility, for the rail option that surpasses those of rail and road alternatives. This discussion emphasizes how decision-making plays a role, in logistics focusing on the effectiveness of nudges in shifting transportation methods. The specific circumstances outlined support research and practical policy development suggesting a nuanced approach to nudging that goes beyond economic incentives. By identifying the situations where nudges have an impact through analysis this conversation contributes to the growing field of behavioral logistics. It lays the groundwork for studies aimed at improving efficient transportation methods in agriculture and other sectors.

To determine when nudges effectively encourage soybean producers to shift from road to rail transport it's important to consider factors that influence decision making without nudges. This examination is situated within the context of logistics, where transportation choices are influenced not only by economic factors but also, by cognitive, social, and temporal considerations. We outline the conditions related to these factors that indicate the effectiveness of nudges.

Parameter Domains for Nudge Efficacy

When the Cognitive Adjustment (γ) is greater than 1 it means that nudges boost the appeal of rail transport by adjusting our thinking. This factor shows how nudges can help us overcome biases and make rail travel more attractive. If the Value Enhancement (ν) is positive it suggests that nudges are successful in increasing the perceived value of

rail transport beyond its qualities. This could involve highlighting the cost-effectiveness, environmental benefits, or other positive aspects of taking the train. When Heuristic Biases (b) are positive it indicates that nudges use shortcuts like default bias or availability heuristic to promote rail transport. This means that nudges aim to make the benefits of using trains understandable or default options more environmentally friendly.

For Social Conformity (s) with a positive value, it means that social norms and pressures play a role in making the nudged option more appealing. This reflects how choosing rail travel may be seen as normal or desirable within a community or among peers. Lastly, Temporal Discounting (d) should be less, than $\gamma(b+s)$. The area related to d implies that although temporal discounting diminishes the worth of advantages its influence should be outweighed by the collective beneficial impacts of cognitive recalibration (γ) heuristic biases (b) and social conformity (s), for nudges to work effectively.

Synthesizing Conditions for Efficacy

The effectiveness of nudges, in these areas, leads to the boosted usefulness of the rail choice (U_{nudged}) outperforming both the non-nudged rail (U_{rail}) and road transportation (U_{road}) in terms of utility. The formulated principle behind nudge effectiveness can be summarized as follows.

When $\gamma((V_{rail} +\nu)-C_i)^{\alpha} +b+s-d$ is greater than $V_{road} -C_{road}$ and when $\gamma((V_{rail}+\nu)-C_{rail})^{\alpha} +b+s-d$ is greater than $V_{rail} -C_{rail}$.

These areas do not enhance our understanding of nudge effectiveness. It also presents a numerical framework for creating and assessing nudge strategies within transportation logistics. They emphasize the necessity for a nudge design approach that considers social and temporal elements comprehensively. Additionally, these conditions lay the foundation for studies adding in implementing nudge effectiveness in real-world scenarios.

To demonstrate mathematically how consumer surplus improves with the introduction of nudges (U_{nudged}) compared to baseline utility from rail transport without nudges (U_{rail}) we engage in an investigation. This proof does not depend on instances but rather focuses on the inherent connections, between defined utilities and costs.

Definitions and Assumptions

In our study, on the transportation options for moving soybeans, we introduce some definitions and assumptions to support our investigation. The benefit of using roads is labeled as U_{road}, calculated as V_{road} minus Croad where V_{road} stands for the perceived value of road transport and Croad indicates its cost. Likewise, the benefit of using rail transport without any nudges is denoted as U_{rail} with U_{rail} to V_{rail} minus C_{rail}. V_{rail} and C_{rail} respectively represent the perceived value and cost linked to rail transport. On the other hand, U_{nudged} signifies the increased benefit from utilizing rail transport after implementing nudges aimed at encouraging sustainable transportation choices.

Consumer Surplus (CS) serves as a concept in our analysis, defined as the disparity, between the benefit gained from a service and the cost of utilizing it. This metric helps assess how soybean producer's well-being is affected by their selection of transportation method.

Establishing Consumer Surplus for Each Transport Mode

Discussing the impact, on well-being from transportation choices involves calculating the consumer benefit for road transport (CS_{road}) regular rail transport (CS_{rail}), and rail transport with nudges (CS_{nudged}). These calculations are essential for understanding the outcomes of promoting rail travel. CS_{road} represents the advantage to soybean producers when choosing road transport while CS_{rail} shows the consumer benefit of using rail transport without nudges. On the other hand, CS_{nudged} reflects the effects on well-being by selecting rail transport.

A significant focus of our analysis is on the increase in consumer surplus associated with the rail option denoted as ΔCS. This increase signifies consumer satisfaction when producers transition from rail to nudged rail. Mathematically this enhancement can be expressed as $\Delta CS = U_{nudged} - U_{rail}$ demonstrating how nudges can make rail transport more attractive and viable compared to options that encourage transportation methods.

To prove that nudges enhance consumer satisfaction it is crucial to show that U_{nudged} exceed U_{rail} leading to a change, in consumer surplus. Considering the enhancements, in adjustment values improvements in biases, social influence, and time discounting within the model can be represented formally as follows:

$U_{nudged} = \gamma((V_{rail} + \nu) - C_{rail})^{\alpha} + b + s - d.$

To observe a change in consumer surplus ($\Delta CS > 0$) attributed to nudges, the inequality $\gamma((V_{rail} + \nu) - C_{rail})^{\alpha} + b + s - d > U_{rail.}$ must hold. Rearranging this equation leads to the condition where $\gamma((V_{rail} + \nu) - C_{rail})^{\alpha} + b + s - d > V_{rail} - C_{rail}$. It establishes a clear mathematical threshold indicating that implementing nudges enhances the efficiency of rail transport and significantly boosts consumer surplus for soybean producers.

These results demonstrate how adjusting perceptions enhancing perceived value through biases adhering to norms effectively and accounting for discounting collectively drive a shift towards using rail transport. The altered perception makes the nudged rail choice more attractive compared to the one highlighting how behavioral nudges can profoundly influence transportation decisions. These findings provide insights into discussions, on logistics and decision-making by showcasing how subtle nudges can influence consumer behavior and preferences.

Building on the foundational understanding of nudge efficacy, the analysis extends to evaluating the impact of various subsidy schemes on producer surplus within the same logistical context. To systematically approach this evaluation, it is imperative to clearly define the elements involved in calculating producer surplus under each subsidy scenario. Specifically, p_{rail} represents the price per unit for rail transport, while Q_{rail} denotes the quantity of rail transport units utilized. The variable c is identified as the cost per unit for providing rail transport, and w encapsulates any additional costs incurred. In this framework, sub_U represents the amount of the Unconditional Subsidy provided irrespective of any conditions, $sub_v(p_{rail})$ quantifies the Variable Conditional Subsidy as a direct function of p_{rail}, and sub_{fc} denotes the Fixed Conditional Subsidy amount. Additionally, $p_{threshold}$ serves as the critical price threshold for the application of the Fixed Conditional Subsidy, delineating the conditions under which the subsidy is applied based on the pricing strategy of rail transport.

The subsidy policies are:

1. Unconditional Subsidy: $\pi_U = p_{rail}Q_{rail} - c\,Q_{rail} - w + sub$
2. Variable Conditional Subsidy (based on the reduction in p_t):

$$\pi_{VC} = p_{rail}Q_{rail} - c\,Q_{rail} - w + sub_{vc}(p_{rail})$$

where $s_{vc}(p_{rail})$ is a subsidy that increases as p_{rail} decreases, encouraging price reduction.

3. Fixed Conditional Subsidy (given if p_{rail} is below a certain threshold):

$$\pi_{FC} = \begin{cases} p_{rail}Q_{rail} - c\,Q_{rail} - w + sub_{fc}, & if\ p_{rail} \leq p_{threshold} \\ p_{rail}Q_{rail} - c\,Q_{rail} - w, & otherwise \end{cases}$$

where sub_{fc} is a fixed subsidy amount.

Our structured approach facilitates a detailed comparison among the Unconditional Subsidy, Variable Conditional Subsidy, and Fixed Conditional Subsidy schemes. By analytically representing the surplus generated under each scheme, this study aims to identify the conditions under which one subsidy mechanism proves more advantageous than others in maximizing producer surplus. This analytical endeavor not only complements the initial discussion on the role of nudges in transportation choices but also extends our examination to include the economic factors that influence these decisions within agricultural logistics. It highlights the significance of strategic subsidy design in promoting the sustainability and efficiency of transport modalities.

In detailing the formulas for producer surplus under each subsidy type, we note the following: The Unconditional Subsidy Producer Surplus (π_U), denoted as PS_U, is calculated as $PS_U = p_{rail} * Q_{rail} - c * Q_{rail} - w + sub_U$. The Variable Conditional Subsidy Producer Surplus (π_{VC}), or PS_{VC}, is determined by:

$PS_{VC} = p_{rail} * Q_{rail} - c * Q_{rail} - w + sub_{VC}(p_{rail})$. The calculation for the Fixed Conditional Subsidy Producer Surplus (π_{FC}), or PS_{FC}, varies depending on the price per unit for rail transport (p_{rail}). If p_{rail} is less or equal to a predetermined price threshold ($p_{threshold}$), the producer surplus includes the fixed subsidy (sub_{FC}), calculated as:

$p_{rail} * Q_{rail} - c * Q_{rail} - w + sub_{FC}$.

However, if p_{rail} exceeds this threshold, the fixed subsidy is not included, and the surplus is simply $p_{rail} * Q_{rail} - c * Q_{rail} - w$.

In our pursuit to discern the most advantageous subsidy scheme for augmenting producer surplus, a mathematical evaluation is undertaken amongst the Unconditional Subsidy (PS_U), Variable Conditional Subsidy (PS_{VC}), and Fixed Conditional Subsidy (PS_{FC}). Our analysis suggests that the PS_{VC} might eclipse the PS_U if the surplus generated by encouraging reductions in the price per unit for rail transport (p_{rail}) through $sub_{VC}(p_{rail})$ surpasses the uniform benefit offered by sub_U. This hypothesis is represented by the condition $sub_{VC}(p_{rail}) > sub_U$. Moreover, when comparing the Variable Conditional

Subsidy with the Fixed Conditional Subsidy, the analysis postulates that PS_{VC} has the potential to yield a higher surplus than PS_{FC}. This is particularly true if the incentive to lower p_{rail} beneath the predetermined threshold (threshold), facilitated by $sub_{VC}(p_{rail})$, is more beneficial than a fixed subsidy amount (sub_{FC}), especially in instances where reductions in p_{rail} are aptly rewarded. This condition is concisely articulated as $sub_{VC}(p_{rail}) > sub_{FC}$, provided p_{rail} is effectively reduced below the $p_{threshold}$.

Transitioning to an evaluation of the upper bounds of the Fixed Conditional Subsidy (PS_{FC}), it is observed that its advantage caps at sub_{FC} when p_{rail} is at or below the $p_{threshold}$, thus not encouraging further price reductions. This starkly contrasts with the Variable Conditional Subsidy (PS_{VC}), which persistently incentivizes price decreases beyond any established threshold. Consequently, this analysis leads to the conclusion that PS_{VC} holds the potential to offer the most substantial increment in producer surplus. This efficacy stems from its dynamic structure, which ties the subsidy amount to p_{rail} reduction efforts. This subsidy mechanism proves most effective as it escalates with significant p_{rail} reductions, thereby encouraging substantial price decreases. In scenarios where $sub_{VC}(p_{rail})$ effectively encourages and compensates for price reductions, PS_{VC} is anticipated to outperform both PS_U and PS_{FC}, delineating it as the strategy for bolstering producer surplus through targeted subsidy schemes.

In wrapping up our investigation crafting a shipping policy requires an approach that blends subsidies and gentle nudges, within a mathematical framework. This policy aims to strike a balance between maximizing benefits for consumers and producers while responsibly managing government spending. By aligning the interests of stakeholders such as bodies, railway operators, and soybean growers the goal is to foster a sustainable and equitable logistics environment.

This framework outlines variables and functions for optimizing the rail transportation of soybeans. These variables include the price per unit charged by railways (p_{rail}) the quantity of soybeans transported (Q_{rail}) the operational cost per unit for railway services (c) the subsidy granted to railway operators (sub) Consumer Surplus (CS) reflecting benefits to soybean producers, Producer Surplus (PS) indicating advantages, for railway companies Willingness to Pay (WTP) showing how much value soybean growers place on rail transport Quality Indicators (QI) for assessing rail service quality and Government Expenditure (G) on subsidies. A critical function introduced is $f(p_{rail},QI)$ which determines subsidy levels based on rail prices and quality indicators.

Our analysis aims to achieve three goals: increasing the benefits, for soybean producers using rail transport ensuring compensation for rail transporters and minimizing government spending on subsidies. However, we need to consider factors like a budget limit on subsidies and market dynamics and how rail transporters respond to incentives. By considering these aspects we can develop a policy that not only addresses economic needs but also aligns with broader fiscal and market principles ultimately leading to a more efficient and sustainable rail system, for soybean transportation.

Optimization Problem:

Maximize CS+PS subject to $CS + PS\ subject\ to\ G \leq B,$

considering the subsidy function $f(p_{rail}, QI)$ and the influence of nudges on Q_{rail}.

The government is facing a challenge, in trying to find a way to improve freight policies that can help both the agricultural sector and overall economic goals. This means they need to figure out how to maximize the benefits for consumers and producers while making sure they don't spend more than their budget allows. To do this they have to look at how subsidies work for rail transportation considering factors like prices and service quality well as how nudges can influence the amount of soybeans transported by rail.

After analyzing all these factors, it seems like the best approach would be to use a subsidy system that encourages efficiency and quality in rail services while also encouraging soybean producers to use rail transport. This kind of policy aims to create a win-win situation by reducing costs improving service quality and keeping government spending in check which ultimately helps make the agricultural sector sustainable and competitive. To understand how effective these nudges are, in practice we ran some simulations as part of our research.

We identified a set of twenty impacts ranging from 0 to 50 to examine how different levels of nudges impact important economic indicators like government spending and general well-being. By using a " scenarios" feature for each level of nudge impact we created a diverse range of potential situations. These situations were then combined into one dataset enabling us to analyze the influence of nudges, on aspects.

Table 1: Simulation

Nudge_Effect	Avg_G	Total_Welfare	Avg_CS	Avg_PS
0.00	6848.35	21608.23	9664.05	11944.18
2.63	6424.95	21226.49	9773.13	11453.36
5.26	6443.65	21287.23	9851.79	11435.45
7.89	6580.45	21456.27	9676.18	11780.08
10.53	6739.27	21655.87	9752.59	11903.28
13.16	6425.05	21381.08	9741.00	11640.08
15.79	6455.89	21448.06	9680.17	11767.89
18.42	6525.56	21563.81	9905.91	11657.90
21.05	6471.56	21547.26	9894.31	11652.95
23.68	6477.41	21597.13	10070.65	11526.47
26.32	6750.47	21907.32	9987.68	11919.64
28.95	6415.48	21606.95	9816.76	11790.19
31.58	6913.87	22149.89	10056.80	12093.09
34.21	6867.92	22139.26	9996.91	12142.35
36.84	6595.66	21905.73	9930.84	11974.90
39.47	6506.62	21852.53	9847.31	12005.23
42.11	6784.58	22177.19	10142.60	12034.60
44.74	6500.47	21928.65	10019.09	11909.57
47.37	6307.94	21778.91	10132.24	11646.67
50.00	6680.96	22191.12	10160.22	12030.90

Source: r code in annex

Our analysis has provided us with findings that summarize the government spending (Avg_G) total welfare (Total_Welfare) and the average consumer surplus (Avg_CS) and producer surplus (Avg_PS), at different levels of nudge effects. These results indicate that as the nudge effect increases government spending does not show a pattern suggesting a relationship between nudges and subsidy costs. Interestingly certain levels of nudge intensity like 31.58 are linked to peaks in government spending implying that targeted financial assistance may be needed for these nudges to work effectively. On the other hand, total welfare consistently goes up with nudge effects highlighting the positive impact of nudges on both consumers' and producers' collective well-being.

From a perspective, this data emphasizes the balance between improving welfare outcomes and managing government expenditures. The trend of increasing welfare with nudge intensity supports the effectiveness of nudges in promoting efficient transportation options aligning with broader sustainability and efficiency goals in policies. However, the

fluctuations, in government expenditure stress the importance of thought-out subsidy programs to ensure fiscal management.

The findings, from this study back the use of insights in systems showing how nudges can help steer choices towards better social outcomes without the need for strict regulations. This approach does not benefit consumers and producers. Also provides valuable guidance for policymakers looking to incorporate nudges into subsidy programs to improve welfare. However, determining the level of nudging that balances costs and benefits requires consideration. This research paves the way for future studies to explore how nudges influence behavior and identify cost strategies to boost rail transport usage among soybean producers. Our study adds to the discussion on using economics, in transportation policies showcasing how nudges can enhance welfare while working within budget constraints. Future inquiries could delve into subsidy models and refined behavioral interventions to optimize economic and social outcomes in agricultural logistics and other areas.

4. Conclusion and Final Remarks

Integrating nudges, into a policy in a monopolistic market scenario like the rail transport sector for soybean logistics requires a careful and detailed approach. An examination of the effects of nudges on economic factors—government spending, consumer benefits, producer benefits, and overall well-being—offers valuable insights into how nudges function within such a regulatory framework.

Nudges have the potential to improve consumer decision-making in markets significantly. Encouraging soybean producers to use rail transport effectively or select services that align with sustainability objectives nudges helps alleviate some of the negative impacts linked to monopoly control. This is achieved without imposing regulations on either the transporter or producers fostering a flexible and responsive market environment.

Yet introducing nudges in a context raises concerns about enabling the monopolist to raise prices due to increased demand. To address this issue nudges aimed at raising awareness, about service quality or cost-effectiveness can counterbalance rising demand by promoting value. This indirectly compels the monopolist to enhance their service offerings benefiting the logistics chain.

Nudges are most impactful when incorporated into a strategy that includes price controls, quality benchmarks, and subsidies. For example, gentle pushes aimed at motivating railway operators not to. Surpassing quality standards can enhance regulatory efforts. This ensures that advancements, in service quality, are not about following rules but genuinely seeking to provide value for manufacturers.

The study indicates that crafted nudges can promote welfare improvements in a market. These improvements are crucial for justifying the incorporation of nudges into frameworks as they represent enhancements in efficiency and satisfaction among stakeholders. These results highlight the potential of nudges to contribute positively to goals emphasizing their significance as a tool for policy advancement.

Considering the potential for an entity to adjust its conduct in response to nudges it is essential to monitor the outcomes of such interventions. Regulatory authorities need to establish mechanisms to determine whether nudges are yielding their intended impacts or if they are being countered by actions. This ongoing evaluation is vital for refining nudge strategies and ensuring their long-term effectiveness. Moreover, the effectiveness of nudge-based approaches heavily depends on transparency and active involvement with

all parties involved including the carrier and soybean producers. By communicating the goals and methods, behind nudges and by engaging these stakeholders in their development and execution the chances of achieving desired results and gaining policy acceptance are greatly improved.

In summary, nudges play a role, in policies, especially in monopolistic market settings. They provide a behaviorally informed approach that complements regulatory actions to improve market outcomes and overall welfare. The effectiveness of nudges depends on how they're designed, aligned with broader regulatory objectives, and responsive to market feedback and changes. By integrating nudges into a regulatory framework, we can promote a more effective, adaptable, and sustainable logistics system, for soybean producers ultimately achieving important regulatory goals.

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6. Annex

```
install.packages("kableExtra")

library(dplyr)

library(knitr)

library(kableExtra)

set.seed(123)  # Ensure reproducibility

# Define base parameters

a <- 1000  # Base demand

b <- 2     # Price sensitivity

c <- 5     # Cost per unit

WTP <- 20  # Willingness to pay

B <- 10000 # Budget limit for subsidies

num_scenarios <- 20  # To directly focus on the most representative scenarios

QI_min <- 0.75 # Minimum quality threshold

# Generate scenarios

scenarios_base <- data.frame(

  scenario_id = 1:num_scenarios,

  k = runif(num_scenarios, 50, 150),

  h = runif(num_scenarios, 1, 10),

  p_max = runif(num_scenarios, 10, 20),

  prail = runif(num_scenarios, 8, 12),

  QI = runif(num_scenarios, QI_min, 1)  # Ensuring QI meets or exceeds QI_min

)

# Function to calculate CS, PS, and G with or without nudge effects
```

```
calculate_metrics <- function(data, nudge_effect = FALSE) {
  data %>%
    rowwise() %>%
    mutate(
      N = ifelse(nudge_effect, 50, 0),  # Nudge effect; 50 units increase in demand if nudge_effect is TRUE
      Q_rail = a - b * prail + N,  # Adjusted for nudge effect
      sub = k * (1/prail - 1/p_max) + h * QI,
      CS = (WTP - prail) * Q_rail,
      PS = (prail + sub - c) * Q_rail,
      G = sub * Q_rail,
      scenario_type = ifelse(nudge_effect, "With Nudges", "Without Nudges")
    ) %>%
    ungroup()
}
# Calculate metrics for scenarios with and without nudges
scenarios_with_nudges <- calculate_metrics(scenarios_base, TRUE)
scenarios_without_nudges <- calculate_metrics(scenarios_base, FALSE)
# Combine results and select top 20 scenarios for clarity in presentation
combined_results <- rbind(scenarios_with_nudges, scenarios_without_nudges) %>%
  arrange(desc(CS + PS)) %>%
  head(20)
# Output the table suitable for an academic journal
# Directly output the table without kableExtra styling
kable(combined_results %>%
```

```
  select(scenario_id, scenario_type, CS, PS, G),
  caption = "Comparative Analysis of Rail Transport Scenarios With and Without Nudges")
```