Approaches and Resources for Improved Student Outcomes: Evidence from Brazil

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Abstract

It has been demonstrated widely that learning, rather than schooling, drives economic growth, improved individual earnings, and reduced inequality in the developing world. Although a high proportion of children in Brazil have access to schooling, evidence from PISA tests reveals that more than three-quarters of Brazilian youth reach the age of 15 without being able to perform at the lowest level of competence in reading and mathematics. This research paper aims to study approaches that schools and municipalities in Brazil can implement, given their current resources, to provide better student learning outcomes, lower dropout and failure rates, and increase passing rates. The Strategic Treatment Effects (STE) framework is utilized to examine the resources that maximize benefits of each approach for these outcomes. This research studies the benefits of two distinct approaches implemented by a municipality: focusing on providing a variety of physical resources in schools, and focusing on providing highly-trained human capital in schools. The results demonstrate that there exists a significant amount of variation in the distribution of benefits across different approaches. Idiscover that such variation may compel policymakers to face a trade-off while choosing the optimal approach for their municipality, and suggest how the framework can be used to eliminate the trade-off and make the optimal decision. The findings have implications for policy and practice in education in Brazil, and suggest directions for future research.

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1 Introduction

A lack of access to primary and secondary education had been a major concern in the developing world in the 1990s (Lockheed, Verspoor, and Bloch, 1991). Over the next three decades, countries in Latin America and the Caribbean (LAC) made major progress in providing access to primary and secondary education to all youth in the country (Adelman and Székely, 2016; Bassi, Busso, and Muñoz, 2015; Székely and Karver, 2021). In 2018, an average 18-year-old adult in Brazil could be expected to receive about 11.5 years of education which was the median amount of expected years of education amongst adults in LAC countries (Adelman and Lemos, 2021).

Despite these improvements in educational provision, increasing the quality of education in the developing world remains a difficult task - with much of the education provided in schools being low-quality with low learning outcomes (Bruns and Luque, 2014; Evans and Popova, 2015). Internationally comparable testing (such as PISA) revealed that 78% of Brazilian youth lacked minimally adequate competencies in Mathematics and 96% did not reach a reasonable global standard of adequacy in 2003 (Filmer, Hasan, and Pritchett, 2007). Even as of 2018, 68% of Brazilian youth still lacked minimally adequate competencies in Mathematics, and 43% of students in Brazil scored below the minimum level of proficiency in all three subjects (reading, mathematics, and science) while the OECD average was 13% for the same statistic (OECD, 2019).

This paper aims to study approaches that schools and municipalities in Brazil can implement, given their current resources, to provide better student learning and enrollment outcomes. The Strategic Treatment Effects (STE) framework is utilized to examine the resources that maximize the benefits of each approach for these outcomes. The paper studies the benefits of two distinct approaches implemented by a municipality: focusing on providing a variety of physical resources in schools, and focusing on providing highly-trained human capital in schools. The results demonstrate that there exists a significant amount of variation in the distribution of benefits across different approaches. Moreover, this paper uncovers trade-offs that exist due to the variations in benefits, and addresses solutions to eliminate the trade-offs. These findings have implications for policy and practice in education in Brazil, and suggest directions for future research.

There exists strong evidence that it is learning and consequently, upskilling of the labor force, instead of educational attainment in itself, that improves individual income and economic growth, while reducing inequality in the developing world (González-Velosa, Rosas, and Flores, 2016; Hanushek and Woessmann, 2015). An improvement in the general cognitive skills of the population has been demonstrated to improve economic growth for nations in the long run by improving the availability of skilled human capital and increasing worker productivity, which are some of the key drivers of alleviating poverty in the developing world (Hanushek, 2013). Moreover, as the average levels of cognitive abilities of people in a country are incorporated into empirical economic growth models, school attainment has no independent impact on economic growth in countries (Hanushek, 2013).

Although much of the existing literature has evaluated the reasons that hinder learning in schools in the developing world, and the provision of which resources promote learning, not much has been studied quantitatively about which bundles of resources complement the different kinds of strategies that managers in schools (or municipalities that decide to execute these strategies) would implement to improve such learning outcomes. This is an important question since there exists much heterogeneity in terms of which schools benefit from implementing a strategy based on the resources they currently have available.

This heterogeneity in benefits yielded can be explained by the existence of competitive advantage gained by some schools over other schools, due to the presence of specific resources in such schools which complement the strategy implemented better than other resources do. An institution is said to have a competitive advantage when a strategic choice by the institution would beneficial only for that institution due to its unique bundle of resources, while other institutions with a different bundle of resources may not benefit as much from the same strategic choice (Porter, 1996). While there exists literature studying competitive advantage in higher education institutions qualitatively (Mazzarol and Norman Soutar, 1991; Harman and Harman, 2008; Mainardes, Ferreira, and Tontini, 2011), there does not exist any literature studying competitive advantage in primary and secondary educational institutions, especially in an empirical setting.

This competitive advantage is studied primarily at the municipal-level, since evidence demonstrates that school managers (such as principals) in LAC countries (and especially Brazil) have low decision-making authority, and most executive decisions are primarily made at the municipal-level by local authorities (Adelman et al., forthcoming). Thus, my empirical methodology treats each municipality as an entity that makes a strategic choice, with multiple resources available at its disposal, and measures the student outcomes for students in that municipality. This research studies three primary strategies that municipalities in Brazil can implement: focusing on providing a wide variety and quantity of physical resources (a physical capital focus, such as computers, internet, and libraries) to schools, focusing on providing extensively trained teachers (a human capital focus) in schools, and focusing on trying to balance the provision of both kinds of capital and succeeding (being a 'superstar' municipality in terms of educational resource provision by providing both physical and human capital to schools successfully).

A secondary analysis is also conducted at the school level (treating schools as individual entities), with the provision of each resource being treated as a strategy in order to understand the effect of resource provision on student outcomes, and understand the inter-dependency of different resources to achieve synergies and competitive advantages in the benefits they provide. The secondary analysis is meant to supplement the primary analysis at the municipal-level to understand the pathways through which different strategies affect student outcomes - which is a major gap in the existing literature (Glewwe and Muralidharan, 2016).

This research focuses on five primary outcomes: pass rates, failure rates, drop-out rates, mathematical competency, and Portuguese competency. These outcomes help assess the benefits of the strategies in helping students continue their education, be motivated to study, and excel in their studies. All of these outcomes thus focus on learning skills and improving cognitive abilities in the long term, which eventually have positive consequences for the development of human capital in Brazil.

The Strategic Treatment Effects (STE) framework (Guzman, 2021) is utilized to examine the kinds of resources that maximize the benefits of each strategy for these five outcomes, providing us with "determinant" resources of the STE for a particular strategy[1]. This study further evaluates the "resource coherence" of each strategy, which demonstrates the additional explanatory power that the interactions between resources give to a model. Thus, this framework allows researchers to analyze the differential effects of various strategies on different entities of the population, taking into account the specific characteristics of each entity. A key feature of the STE framework is that it is able work with high-dimensional data mapping all resources available to an entity in order to explain the relationships that various resources share with different strategies and outcomes.

Key findings from the analysis show that there exists a much larger heterogeneity in how much benefit a municipality received from implementing the strategy focusing on developing physical capital in schools, in comparison to the other two strategies (Figure 1, Figure 4, Figure 5). The wider distribution of STEs for the physical capital strategy implies that the benefit a municipality receives from implementing this strategy can vary a lot based on the resources available to the municipality in comparison to the implementation of the other two strategies. Thus, implementing such a strategy is only beneficial when one is confident that current resources will promote the implementation of this strategy. For example, this effect can be seen in the secondary analysis conducted at the school-level where the provision of internet in a school was treated as a strategic choice, and it was observed that the top 2 key resources that determine the benefits from internet access were the provision of a computer lab in school and the availability of highly educated teachers (out of 853 resources and interactions in the model) respectively (Table 3).

Another key finding demonstrates that while focusing on human capital provision is a better strategy than focusing on physical capital provision in order to reduce dropout rates and increase pass rates for the average municipality, a strategy focusing on providing physical capital to schools on average is a better strategy in order to improve learning outcomes (math and Portuguese competency) and reduce failure rates. Thus, there exists variation in which strategies suit which outcomes if one does not have prior knowledge about the resources a municipality may have access to in Brazil.

[1] The analysis was conducted using the open-source R package to implement the STE framework, which is available at `https://github.com/g-vansh/STE` (Gupta and Guzman, 2022).

This paper thus contributes to four areas of existing literature, while being one of the first few papers to study strategic choices in development contexts using high-dimensional data. The findings of this study have implications for policy and practice in education in Brazil, and suggest directions for future research.

First, this research pioneers the study of the competitive advantage of different strategies in primary and secondary educational institutions. It is clear that good learning outcomes from schooling are important for economic growth, and by studying what resources provide a competitive advantage to schools, policy-makers can tailor policies (or strategies) specifically to the resources those schools have available in order to maximize the benefits in terms of learning outcomes from the policies. Through this research, further computational models can be produced which take a particular school's (or municipality's) resources as inputs and output the strategy yielding the highest competitive advantage in terms of different outcomes for a given school from a given set of strategies.

Second, this research is one of the first studies to explore the use of a novel framework to estimate treatment effects in strategy applications under a causal inference setup (Guzman, 2021). Doing so has traditionally been difficult due to the mapping of a firm's resources often implying the use of high-dimensional data. However, with the recent advances in machine learning, the Strategic Treatment Effects (STE) framework makes it possible to study the treatment effects under the Rubin Causal Model (RCM) (Imbens and Rubin, 2015) using the high-dimensional data mapping resources of firms (Guzman, 2021). This research is the first application of the STE framework in a development context as well, and opens up avenues for the framework to be applied to study competitive advantage in other development studies and contexts.

Third, this research expands on the existing literature by studying all resources of a school, multiple strategies implemented, and multiple student outcomes - all under a single framework, to provide a comparative understanding of the benefits of different strategies for different schools. While some studies have examined the relationships between the provision of physical resources and student outcomes (Ferraz, Finan, and Moreira, 2012; Krueger, 2003), and others have examined the relationships between other strategies such as the provision of trained human capital, such as skilled managers and teachers (Lavy and Boiko, 2017; Kremer, Brannen, and Glennerster, 2013), this research is one of the few to study the intricate relationship that all three of these factors (resources, strategies, and outcomes) share.

Fourth, while we know a lot about which interventions (or strategies) work, there exists a large knowledge gap in our understanding of the mechanisms through which they work or why they work (Glewwe and Muralidharan, 2016). Moreover, given the current literature, it is extremely important to study multiple and alternative strategies and compare their benefits rather than studying a single strategy and observing if it is beneficial, so that policymakers can reliably use the literature available to design policies based on the contexts in which those policies are applied (Glewwe and Muralidharan, 2016). This research addresses both of these major gaps that exist in the current literature by studying how multiple strategies cause changes in learning outcomes through various resources available in a school.

The remainder of the paper is organized as follows: section 2 provides an overview of the existing literature and a background of the empirical setting in Brazil, section 3 describes the data that were used for the analysis, section 4 explains the methodology of estimating the strategic treatment effects, section 5 presents the results of the analysis, and section 6 discusses the implications of the results and concludes.

2 Literature Review

Education is a key determinant of economic and social development, and although the average Brazilian adult has an expected 11.5 years of schooling - the quality of the education provided in schools still remains low (Bruns and Luque, 2014; Evans and Popova, 2015). Despite significant progress in recent years, there are still significant disparities in learning outcomes, dropout rates, and passing rates between different schools and municipalities in the country (Ferrão, 2014).

There exists a large body of research on the impact of various policies and characteristics on education in the developing world. Previous studies have examined a range of factors that may influence learning outcomes, including school resources, teacher quality, and students' socio-economic backgrounds. Existing literature suggests that two primary categories of interventions have been studied in relation to improved student outcomes: demand-side interventions and supply-side interventions (Glewwe and Muralidharan, 2016).

On the demand-side, interventions studied primarily are either information-based, cash transfer programs, or scholarship programs - all aimed at reducing the perceived costs of a child obtaining an education by a household. It was found that cash transfer programs tended to increase the students' time spent in schools (Baird et. al, 2013; Mo et. al, 2013), but merit-based scholarships were more effective in increasing student learning outcomes (Kremer et. al, 2009; Freidman et, al, 2015). It must be noted that although the benefits of each intervention vary based on the outcome being studied, most demand-side interventions are not considered particularly cost-effective.

On the supply-side, three kinds of interventions have been primarily studied: increased accessibility, improved teacher quality and quantity, and a large-scale provision of resources. Studies have shown that improved access to schools has a positive effect on enrollment, and subsequently, learning outcomes - with girls benefitting more from the improved access than boys (Burde and Linden, 2013; Kazianga et. al, 2013). Changes in teacher quantity and quality as interventions often imply a change in the average student-to-teacher ratio at a school. Such changes have been documented to have minimal effects across multiple studies, while often being very cost ineffective (Duflo et. al, 2015; Urquiola and Verhoogen, 2009). An early RCT provided funds to treated schools in Bolivia to enrich the schools with whatever resources they wanted, or spend it in a different way, and found no statistically significant effect on learning outcomes (Newman et. al, 2002). While some other studies provide conflicting evidence regarding the learning benefits of going to 'better' (Pop-Eleches and Urquiola, 2013) or 'elite' (Lucas and Mbiti, 2014) schools with presumably more resources, none of them can reliably attribute the treatment effect to specific resources in the schools (Glewwe and Muralidharan, 2016).

Pedagogical and governance interventions do not fit exactly into either of the demand-side or supply-side categories, but have important implications for student learning outcomes especially in the developing world. The mode of instruction is especially important since it translates the inputs provided by the schools into the outputs this study observes - the learning outcomes. Evidence from multiple RCTs conducted across India suggests that teaching students at a level that matches their level of learning significantly improves learning outcomes (Banerjee et. al, 2015). Such an individualized pedagogy in turn requires effective and trained teachers who can recognize the learning levels of their students, tying into the supply-side constraints that many schools in the developing world face. Effective governance is another essential component that helps support the students and teachers to engage in constructive learning sessions during school time. Doing so requires the coordination of governance across all levels in order for local educational systems to work well together. Across countries, it has been observed that better management of school systems result in significantly better learning outcomes for students (Bloom et. al, 2015).

However, across all of these studies, while the impact of an intervention on different outcomes has been studied, much remains unknown about the mechanisms that cause such effects (Glewwe and Muralidharan, 2016). This is partly due to the difficulty in mapping all the resources available to multiple schools, and partly due to problems that arise when analyzing the large number of resources that affect such student outcomes using high-dimensional data under a causal inference setting. Given these studies have been evaluated in different countries and settings across the world, it might also be possible that an intervention which is highly successful in one country may not yield the same results in a different country due to the heterogeneity in resource endowments that exists in schools in different countries - even in the developing world (Lee and Barro, 2003). Thus, it is important for researchers to focus on testing multiple different interventions and bench-marking them against each other in the same setting in order for policy-makers to have a fair comparison of the effectiveness of different interventions. By studying schools in Brazil under the STE framework, this research helps understand the intermediary resources that help a school achieve the best student learning outcomes given an intervention, and subsequently tests multiple interventions to benchmark their effects against each other - filling into both the knowledge gaps mentioned above in the existing literature.

While studying which interventions work is important, a large body of research has identified several factors that affect the effectiveness of teachers in the classroom – subsequently hindering learning. This includes, but is not limited to, management quality, teacher quality, students' socioeconomic backgrounds, and nutrition.

One factor that majorly influences learning quality is the management of schools, which includes aspects such as leadership, governance, monitoring, feedback, and accountability. A cross-country study of over 1,800 schools in eight countries (Brazil, Canada, Germany, India, Italy, Sweden, UK and US) found that higher management quality was strongly associated with better educational outcomes (Bloom et al., 2015). They also found that autonomous government schools (such as UK academies and US charters) had higher management scores than regular government or private schools. They argued that autonomy allows schools to adopt better practices such as hiring and rewarding good teachers, setting clear goals and standards, and using data to track progress.

Another factor that affects learning quality is teachers' own knowledge and skills, which depend on their initial training and their continuous professional development. Bruns and Luque (2014) analyzed the situation of teacher quality in Latin America and the Caribbean (LAC). They found that low standards for entry into teacher training programs resulted in a large share of teachers who lacked basic content knowledge and pedagogical skills. They also found that most in-service training programs were ineffective because they were detached from the realities of the classroom, focused on theory rather than practice, and did not provide adequate follow-up or feedback.

A third factor that influences learning quality is students' family or socioeconomic background, which can affect their motivation, expectations, attitudes, and behaviours. Engle et al. (2011) reviewed evidence from several studies on how family characteristics such as income level, parental education level, home environment, and parental involvement influence children's cognitive development and learning outcomes. They concluded that children from disadvantaged backgrounds face multiple risks that hinder their learning potential, such as malnutrition, poor health, lack of stimulation, and low-quality schooling. They recommended interventions that target both families and schools to provide comprehensive support for children's development.

A related factor that affects learning quality is nutrition, which can have long-term effects on cognitive abilities, school performance, and economic productivity. Hoddinott et al. (2013) and Maluccio et al. (2009) evaluated the impact of early childhood nutrition interventions in Guatemala and Nicaragua, respectively. They found that children who received nutritional supplements or food transfers during their first two years of life had higher test scores and completed more years of schooling than those who did not receive them. They also found positive spillover effects on younger siblings who benefited from improved household conditions.

These studies suggest that improving the quality of education in developing countries requires a multifaceted approach that addresses both supply-side factors (such as management practices, training programs, incentives, etc.), demand-side factors (such as family background, nutrition, etc.), and contextual factors (such as curriculum, assessment, resources, etc.). They also imply that interventions should start early, be sustained over time, and be tailored to local needs. By doing so, policymakers can hope to raise student learning outcomes and close the achievement gap between developing and developed countries.

To understand these issues better, this research thus evaluates and compares two primary choices: providing high-quality physical capital to schools and providing high-quality human-capital to schools. It is evident from the state of the existing literature that understanding and contrasting these two approaches is extremely crucial for designing policies that navigate the trade-offs between these two approaches efficiently. As is standard, this research studies the effects of these two approaches on learning and enrollment outcomes for students in Brazil.

3 Background

Brazil is an important case study for understanding the challenges and opportunities of education in developing countries. Brazil has made significant progress in expanding access to education at all levels, especially since the 1990s, but still faces gaps in quality and equity. One of the key features of the Brazilian education system is its decentralised governance structure, which assigns most administrative and financial responsibilities to municipalities. This means that municipalities play a crucial role in providing infrastructure, resources and support to schools, as well as implementing national and state policies. Therefore, it is essential to focus on municipalities as actors and not individual schools when studying interventions to reduce the lack of learning in schools in Brazil.

The administrative context of Brazilian education systems has been studied by several researchers who have highlighted the challenges and opportunities of municipal management. For example, one study analysed how municipal supervision systems affect school performance and found that there is a high degree of variation and inconsistency among municipalities in terms of supervision practices and quality (Adelman et al., forthcoming). UNESCO (2007) examined how municipal education secretariats organise their functions and activities and identified four types of management models: classical, centralised, close-support, and school-site supervision. Lavy and Boiko (2017) evaluated the impact of better municipal superintendents on student achievement and school climate and found positive effects on both outcomes.

With these studies, it is clear that Brazilian municipalities have a high amount of authority in implementing infrastructure-related choices in public schools in Brazil. As a result, most public school officials have little flexibility in making decisions regarding infrastructure for their schools and are limited to a supervisory role – primarily tasked with identifying and reporting issues they observe in the school to the municipality. It is the municipality that consequently makes a decision for schools in its jurisdiction from the feedback it recieves from school officials.

In addition to these studies on municipal management, there is also a rich literature on major reforms that have affected the Brazilian education system over the past decades. One of the most important reforms was FUNDEF (Fund for Maintenance and Development of Basic Education), which was implemented between 1998 and 2006. FUNDEF aimed to increase funding for basic education (pre-primary to lower secondary) by redistributing resources among states and municipalities according to enrolment numbers. Cruz (2014) analysed the effects of FUNDEF on teacher hiring and salaries, using data from school censuses and national assessments. The study found that FUNDEF had resulted in increased hiring of teachers and reduced salaries throughout municipalities harmed by the policy in Brazil – while improving salaries for teachers in the municipalities that benefited from the redistribution financially. Overall, the amount received in transfers did not lead to pay increases, contrary to the idea behind implementing the policy. This suggests that municipalities do not always make sound decisions regarding school infrastructure, and having research that provides detailed information on the trade-offs between many choices would allow for better and more informed decision.

These studies illustrate some of the main issues that need to be considered when researching interventions to reduce the lack of learning in schools in Brazil. They also show that there is a wealth of data available from various sources, such as school censuses, national assessments, municipal surveys and administrative records. These data can be used to design rigorous evaluations that can inform policy decisions at different levels of governance.

4 Data

This section describes the data used for the research. The data comes from two primary sources: the Prova Brasil exam data, and the INEP Brazil school census data.

The Prova Brasil is a national standardized test administered by the Brazilian Ministry of Education every two years to assess students' proficiency in Portuguese and Mathematics in schools. The test covers students in grades 3 and 4 of elementary school and students in grades 8 and 9 of high school. The test results are used to calculate educational indicators such as the Basic Education Development Index (IDEB) and to monitor educational quality across regions and schools.

The INEP Brazil school census data is a comprehensive survey of statistical-educational data conducted annually by the National Institute for Educational Studies and Research (INEP). The census collects information on all levels of education, from early childhood education to higher education, covering both public and private schools. The census provides data on enrollment, performance, infrastructure, and teaching staff, among other variables.

The data for this paper was obtained from the Inter-American Development Bank (IDB), which created a panel dataset of the Brazilian school census in May 2017. The dataset combines and simplifies 20 years' worth of data from the school census, educational testing, and educational indicators at both the school and municipal levels.

The paper studies two approaches that municipalities may adopt to improve student outcomes: a physical capital approach and a human capital approach. The physical capital approach is defined as a municipality providing at least 75% of schools in that municipality with access to computers, internet, computer labs, libraries, sewage, electricity, and water facilities. The human capital approach is defined as having low percentages of teachers with only a fundamental level of education or less ($< 25^{th}$ percentile of all municipalities), high percentages of teachers with secondary education degrees ($> 25^{th}$ percentile of all municipalities), advanced education degrees ($> 50^{th}$ percentile of all municipalities), average teacher years of education ($> 50^{th}$ percentile of all municipalities), and low average class sizes and student-teacher ratios ($< 90^{th}$ percentile of all municipalities). An interaction between these two approaches is also considered as a baseline variable to understand the effects of synergies that the two strategies may provide when implemented together.

The outcomes studied include enrollment outcomes and learning outcomes. Enrollment outcomes measure the percentage of students who pass, fail, or drop out of public schools in the municipality. Learning outcomes measure the standardized scores of students in math and Portuguese from the national level exam – Prova Brasil. Prova Brasil is a diagnostic assessment that tests students in grades 5 and 9 on reading and problem-solving skills. The exam is developed by the National Institute of Educational Studies (Inep) and is used to calculate the Basic Education Development Index (IDEB), which indicates the level of development of basic education in Brazil.

The paper also accounts for resources and characteristics available at both school and municipal levels. Resources are semi-fixed assets that can be accumulated over time (Caves, 1980), while characteristics are described as permanent features such as location that belong to a school or municipality. In the context of this research, both resources and characteristics are collectively referred to as resources that describe the identity of an entity. Thus, such ‘resources’ include, but are not limited to, internet provision, library, computer lab, playground, water and electricity provision, teacher education levels, region, and the location (urban/rural) of the school. This study maps 853 resources, characteristics, and their interactions for all municipalities in Brazil.

Tables 1 and 2 summarizes some descriptive statistics for the main variables used in this paper for schools in Brazil.

5 Methods

There is a large body of research on education in Brazil, with a particular focus on interventions for improving student outcomes. Previous studies have examined a range of factors that may influence these outcomes, including school resources, teacher quality, and students’ socioeconomic background.

While most methods in the development economics literature have been able to separately study the effects of interventions on learning, they have failed to account for the complementarities that these interventions share with the resources available in a school, and how they affect the outcome being studied.

With recent developments in methods of studying high-dimensional data, such complementarities can now be understood better. The Strategic Treatment Effects (STE) framework by Guzman (2021) allows researchers to study the relationships shared by different strategies, outcomes, and resources. This framework enables researchers to analyze the differential effects of various interventions on different subgroups of the population, taking into account the specific characteristics of each group.

By utilizing the STE framework, this study sits at the intersection of existing literature in development economics and strategy. The STE framework is used to examine the determinants of the benefits of various choices aimed at improving student outcomes, lowering dropout rates, and increasing passing rates in Brazil. This study further evaluates the resource coherence of each strategy, which demonstrates the additional benefits of the interactions between the resources on the outcome.

5.1 The STE Framework

5.1.1 Setup

Under the Strategic Treatment Effects framework, one considers 3 primary components: a strategy $S_i \in \{0, 1\}$, an outcome $Y_i(S_i)$, and a vector of resources for each entity indexed by X_i (Guzman, 2021). In this setup, I focus on treating each municipality in Brazil as an individual entity - since many choices relating to the strategies defined are made at the municipal level (Adelman et al., forthcoming).

Under the framework, each municipality is defined to have a 'profit function' $Y_i(.)$, where $Y_i(1)$ is the municipality's profit when the choice S_i is taken, and $Y_i(0)$ is the municipality's profit when the choice is not taken. Under a causal framework, the treatment effect of a strategy can then be defined as:

$$\Delta_i = Y_i(1) - Y_i(0) \tag{1}$$

This treatment effect can be separated into two distinct components under the STE framework: an operational benefit effect $g(S_i)$ and a strategic benefit effect $f(S_i, X_i)$. All municipalities in the population are expected to capture the operational benefit regardless of the resources they possess, while the strategic benefit effect is dependent on the resources that the municipality possesses. Since the strategy that a municipality chooses is a binary choice, $g(S_i)$ can be reduced to:

$$g(S_i) = \beta S_i \perp\!\!\!\perp X_i \tag{2}$$

Thus, the treatment effect can be summarized as:

$$\Delta_i = \underbrace{\beta S_i}_{\text{Operational Benefit}} + \underbrace{f(S_i, X_i)}_{\text{Strategic Benefit}} + \underbrace{\epsilon_i}_{\text{Randomness}} \tag{3}$$

5.1.2 Treatment Effects

Under this setup, I shall consider two treatment effects under the Rubin Causal Model (RCM): the average treatment effect (ATE) and the average treatment effect on the treated (ATT). The average treatment effect is the expected change in outcome of a municipality after a strategic choice has been executed.

$$ATE = E[\Delta_i] \tag{4}$$

The average treatment effect on the treated is the expected change for the municipalities that take the strategic choice.

$$ATT = E[\Delta_i | S_i = 1] \tag{5}$$

Since all generalized benefits of a strategic choice must be attributed to the operational efficiency, it is implied that the expected strategic benefit from any given choice under this framework must be zero. This can be understood by contradiction: since any non-zero expected strategic benefit must imply that the strategic benefit is available to all municipalities, which makes the benefit a part of operational efficiency instead of the strategic benefit - contradicting our earlier assumption.

Given that $E[f(S_i, X_i)] = 0$ and $\epsilon_i = 0$, the ATE becomes the operational benefit β.

$$ATE = E[\Delta_i] = E[\beta S_i + f(S_i, X_i) + \epsilon_i] \tag{6}$$

$$ATE = E[\beta S_i] = \beta \tag{7}$$

While the average treatment effect is the benefit experienced by all municipalities in the population, the benefit only available to a municipality defined by its unique resources X_i is more interesting to the decision making 'manager' who decides to implement a strategic choice. This is defined as the strategic treatment effect (STE) Δ_i^s as the benefit of a choice, net of any operational benefits.

$$\Delta_i^s = \Delta_i - ATE = f(S_i = 1 | X_i) - f(S_i = 0 | X_i) \tag{8}$$

This study focuses on the strategic treatment effect Δ_i^s to better understand the variation in the benefits received across all municipalities on the implementation of a strategy. Specifically, studying the distribution of these effects allows us to understand the potential risk of implementing a strategy (whether the effects are concentrated at the tails), and understand what resources X_i better determine the variation in the benefits of the choice.

5.1.3 Selection into a Strategy

It is necessary to understand that there exists a selection mechanism in the way municipalities decide to implement a strategic choice. More specifically, it is quite natural to assume under that there exists a rational selection mechanism behind the implementation of a strategic choice. This implies that municipalities that do decide to implement a strategy are already more likely to benefit from it because the benefits they expect from this choice for their performance. Thus, under this assumption, municipalities are aware of the fact that given their resources X_i, a certain strategy would benefit them more in terms of their outcomes.

To study the treatment effects under this assumption, the standard literature is followed to define a propensity score ρ_i as the probability that a certain municipality will take a certain strategy. Thus, it can be noted that:

$$\frac{\partial \rho_i}{\partial \Delta_i^s} > 0 \tag{9}$$

However, it is important to note that there may exist other unobservable factors that influence a municipality's decision to implement a choice. To incorporate these, an idiosyncratic component μ_i is introduced which is uncorrelated with the choice's treatment effect. Thus, μ_i may represent unobservable factors such as bounded rationality and the saliency of a choice (Simon, 1986), the mayor's beliefs, or the choice-maker's identity and demographics.

The propensity score can then be defined as:

$$\rho_i = P(S_i = 1) \tag{10}$$

$$S_i = 1[\beta + \Delta_i^s + \mu_i > 0] \tag{11}$$

Since S_i is a function of X_i, the propensity score for a municipality can be represented solely as a function of the vector of resources X_i that the municipality possesses. Thus, a function h exists such that:

$$\rho_i = h(X_i) \tag{12}$$

5.1.4 Strategic Treatment Effect

For a municipality with resources X^*, a propensity score ρ^* can be estimated as:

$$\rho^* = h(X^*) \tag{13}$$

The strategic treatment effect can then be estimated at a specific propensity score ρ^* for the municipality as the benefit of the treatment at ρ^* minus the average treatment effect (operational benefit).

$$\Delta_i^s(\rho^*) = E[\Delta_i|\rho_i = \rho^*] - \beta \tag{14}$$

This allows us to incorporate the mapping of municipality resources into the analysis of the heterogeneous benefits of choices for outcomes. Doing so would provide us insights into the distribution of benefits across municipalities in Brazil for multiple different choices that are studied.

5.1.5 Strategic Determinant Function and Coherence

To refine the understanding of *who* benefits from a choice, the relationship between the strategic treatment effect and the different resources that complement it is examined. It must be noted that resources are viewed as bundles in relation to their benefits for a strategy (due to the potential presence of synergies).

I thus construct a linear strategic determinant function $f(S_i, X_i)$ that estimates the effects of resources and their interactions amongst each other on the strategic treatment effect as follows:

$$\widehat{\Delta_i^s(\rho_i)} = f(S_i = 1, X_i) = \sum_j (\gamma_j x_{ij} + \sum_k \sigma_{jk} x_{ij} x_{ik}) \tag{15}$$

where γ_j is the impact of resource X_{ij} on Δ_i^s, and σ_{jk} is the impact of the interaction of resources X_{ij} and X_{ik} on Δ_i^s.

Finally, a resource coherence coefficient ζ is estimated – which demonstrates the importance of resource complementarities in explaining the variance in $\widehat{\Delta_i^s(\rho_i)}$. ζ is defined as the improvement in the fit between how the linear model explains the strategic treatment effect with and without interactions.

Defining $f'(S_i, X_i)$ as:

$$f'(S_i = 1, X_i) = \widehat{\Delta_i^s(\rho_i)} = \sum_j (\gamma_j x_{ij}) \tag{16}$$

allows us to estimate ζ as:

$$\zeta = \frac{R_f^2}{R_{f'}^2} \tag{17}$$

where the R^2 values are calculated using the out-of-bag (OOB) estimation technique.

5.2 Validation

While most decisions relating to school capital provision in Brazilian public schools are made at the municipal level, one can use actions at the school level to validate my methodology and understand which resources best complement the pre-existing resources available in a school.

Thus, as a validation technique for the framework, each school is treated as an individual entity to understand the resources that maximize the benefit from the provision of internet. A priori, one expects to see that the presence of computers would be extremely important in maximizing the benefits of internet provision in schools on Math scores of students in the school.

As Table 3 depicts, this is indeed the case. The table depicts the top five and the bottom five most influential resources and interactions that maximize the benefit of internet provision. It can be observed that the most important resource is having teachers in the school with advanced education (graduate degrees), and the next most resource is the interaction of being in an urban environment and having a computer lab in the school. Thus, it illustrates that both – well-educated teachers *and* the presence of a computer lab – are critical for the success of internet provision in schools. It can further be seen that having teachers who have completed only a fundamental level of education or less proves detrimental to the provision of internet in schools.

By confirming the a priori predictions, one can validate the results of the methodology and have confidence in the results of this research. Moreover, the validation highlights the use-case of the methodology where one can identify unique resources that provide maximal benefits from different choices that schools and municipalities implement.

6 Results

In this section, I present the results of the analysis of the effects of two approaches on student outcomes based on the resources available for schools and municipalities in Brazil. The results are evaluated in the context of Muralidharan and Glewwe (2016), who provide a comprehensive review of the evidence on improving education outcomes in developing countries. The results conform with existing literature and also contribute new insights into how resource availability and coherence affect the effectiveness of different strategies.

An analysis of the data revealed several key findings. First, I found that the relative effectiveness of an approach varies depending on the outcome one is aiming to optimize for. This is especially notable amongst the enrollment outcomes in Figures 2 and 3, where one can see that while a physical capital approach is much more effective in reducing failure rates in school, it is evidently ineffective in reducing dropout rates in schools on average. Additionally, it is notable that the interaction of both the approaches seems to provide a higher benefit overall regardless of the outcome studied, which is comparable to the current literature's findings as well. Thus, the results suggest that a multi-faceted approach to improving learning outcomes that take into account both human and physical capital available in schools is extremely effective in providing better outcomes for students in terms of enrollment and learning.

Second, this effect can be understood better by noting the resource coherence for each strategy as outlined in Table 7. Resource coherence is the improvement in the fit between how a linear model explains the effect with and without interactions. As it can be seen, resource coherence – and subsequently resource interactions – seems to be almost twice as important for the human capital approach than the physical capital approach. Moreover, looking specifically at the interaction between the two approaches, it can be noted that resource coherence is especially more important for some outcomes than others. For example, the interactions between resources for dropout rates result in a twenty times higher coherence than those for failure rates. Thus, interactions almost double the variation that resources can account for in the case of studying dropout rates as an outcome.

Third, as in Figures 1, 4, and 5, I found that the distribution of benefits is much flatter and more widespread for a physical capital approach than a human capital approach. Moreover, the distribution of effects for the physical capital focus seems roughly bimodal with its effects concentrated at either ends of the distribution. Thus, the physical capital approach can be viewed as more 'risky' than the human capital approach if one does not have information on which resources provide the best benefit for different outcomes and strategies. This is because there is a high likelihood that one may end up on either ends of the spectrum of benefits if they implement such an approach.

Fourth, as in Figure 2, one can observe that there may exist situations where one may face a trade-off between a higher expected benefit of an outcome and the variance in the amount of benefit one may eventually receive. For the effect of different strategies on the failure rate, one can see that while a physical capital approach has a notably larger expected effect in reducing failure rates, it also has a higher variance than a human capital approach. Thus, if one were unaware of the resources they have, or of which resources help place their municipality at either ends of the distribution, making such a decision with imperfect information would require a trade-off as discussed.

Finally, I also found that the effectiveness of a strategy was influenced by the specific resources already available to schools and municipalities. For instance, strategies that focused on improving teacher quality were found to be more effective in contexts where there were already high levels of physical capital available, while strategies that focused on providing additional resources to disadvantaged schools were more effective in contexts where there were fewer resources available. For example, the highest benefits reaped from a human capital approach seemed to stem in municipalities which already had science labs available in rural areas, had a good number of teachers who had completed secondary education, and had TV equipment available. On the other hand, having less educated teachers and a lot of federal schools in the municipality reduce the benefits received from a human capital approach. Similarly, for a physical capital approach, having a computer lab, a library, and internet (in order) benefit learning and enrollment outcomes the most by providing support to the new physical resources that are added to schools in the municipality. A higher proportion of teachers with incomplete fundamental education in the municipality on the other hand reduce the benefits reaped from a physical capital approach.

7 Discussion

This paper has evaluated the effect of two strategies (human capital approach and physical capital approach) on students' learning and enrollment outcomes in Brazil, taking into account the resources that schools and municipalities have. The study has found that the relative effectiveness of an approach varies depending on the outcome one is aiming to optimize for, and that this effect can be explained by the resource coherence and resource interactions for each strategy. I have also shown that the distribution of benefits is much flatter and widespread for a physical capital approach than a human capital approach, implying that the former is more risky if one does not have information on which resources provide the best benefit for different outcomes and strategies. Moreover, this study has demonstrated that there may exist situations where one may face a trade-off between a higher expected benefit of an outcome and the variance in the amount of benefit one may eventually receive. Finally, I have found that the effectiveness of a strategy was influenced by the specific resources and characteristics already available to schools and municipalities.

The findings have several implications for policy and practice. First, they suggest that there is no one-size-fits-all solution for improving education outcomes in Brazil, as different strategies may work better for different goals and contexts. Therefore, policymakers and practitioners should carefully consider their objectives and constraints before choosing an intervention. Second, they indicate that resource coherence is a key factor that determines the success of some interventions – such as the human capital approach. This means that interventions should be aligned with existing resources and capacities of schools and municipalities, as well as with local needs and preferences. Third, they highlight that information asymmetry can lead to suboptimal choices of interventions, as some approaches may entail more uncertainty than others. Thus, improving information availability and transparency about the costs and benefits of different interventions can help decision-makers make more informed choices. Fourth, they reveal that trade-offs may arise between maximizing expected benefits and minimizing risk when choosing an intervention. Fifth, they show that complementarities exist between different types of resources within each strategy across outcomes. This suggests that combining multiple interventions could enhance their overall effectiveness as well.

It should be noted that while trade-offs may arise between maximizing expected benefits and minimizing risk when choosing an approach, the use of the STE framework allows one to eliminate the trade-off. With the framework, one can identify which resources are prevalent on either ends of the distribution of benefits for various approaches – as done in section 5.2. An awareness of the resources that increase or decrease the benefits a municipality reaps from different approaches allows the municipalities to understand where they would lie on the distribution of effects if they implemented the strategy. Thus, with this knowledge and an informed perspective of their resources, this trade-off can be eliminated by utilizing the STE framework effectively.

This paper contributes to the literature on improving education outcomes in developing countries by providing a comprehensive analysis of two broad types of interventions (human capital approach and physical capital approach) across multiple outcomes (learning and enrollment) in a large middle-income country (Brazil). The paper also adds to the literature by incorporating resource coherence as a key explanatory variable for understanding why some interventions work better than others in different contexts. This research builds on previous studies such as which provide extensive evidence on various education interventions in developing countries.

There are still some limitations to the study that warrant further research. First, the analysis is based on observational data from Brazil's national education census (Censo Escolar) which may suffer from measurement errors or omitted variable bias since one cannot observe the pedagogy in the data. Additionally, although the study uses a causal inference framework, it does not provide a direct causal relation between the approaches and outcomes. Future studies could use experimental or quasi-experimental methods to establish such causal relationships between interventions and outcomes more robustly. Second, the analysis focuses on two broad types of interventions (human capital approach and physical capital approach) but does not examine specific components or mechanisms within each type. While these approaches were treated as binary implementations for the research, they are not always binary in reality – and might have different levels of implementations amongst each. Future studies could explore how different aspects or features of each intervention affect outcomes differently or interact with each other synergistically or antagonistically. Third, the analysis covers only five outcomes in two broad categories (learning and enrollment) but does not consider other important dimensions such as quality, equity, efficiency, or sustainability of education systems. Future studies could extend the framework used to include other relevant indicators or criteria for evaluating education interventions.

In conclusion, this paper has provided new insights into how two alternative strategies (human capital approach and physical capital approach) affect students' learning and enrollment outcomes in Brazil, taking into account the resources that schools and municipalities have. I hope that these findings will inform policymakers and practitioners who seek to improve education outcomes in developing countries, as well as researchers who aim to advance knowledge on this topic.

8 Conclusion

In this research paper, I aimed to study strategies that schools and municipalities in Brazil can implement, given their current resources, to provide better student learning outcomes, lower dropout rates, and increase passing rates. Utilizing the Strategic Treatment Effects (STE) framework developed by Guzman (2021), I examined the determinants of the STE and the resource coherence of each strategy. By merging the existing knowledge in the literature of development economics and strategy, this study hopes to open up pathways for researchers to utilize frameworks such as the STE framework to study the mechanisms, characteristics, and resources that interventions affect student outcomes through.

These findings suggest that different strategies for improving education outcomes in Brazil have varying effects depending on the resources available and the outcome of interest. I compare two strategies: a human capital approach that focuses on enhancing the skills and abilities of students and teachers, and a physical capital approach that focuses on providing better infrastructure and equipment for schools. I use data from a large-scale survey of schools and municipalities in Brazil, and apply econometric methods to estimate the impact of each strategy on students' learning and enrollment outcomes.

I find that the relative effectiveness of an approach varies depending on the outcome one is aiming to optimize for. For example, a human capital approach may be more effective for improving learning outcomes, while a physical capital approach may be more effective for increasing enrollment rates.

The effect of an approach can be understood better by noting the resource coherence for each strategy as outlined in Table 7. Resource coherence refers to how well the resources allocated to a strategy match the needs and constraints of the context. I find that resource coherence – and subsequently resource interactions – seems to be almost twice as important for the human capital approach than the physical capital approach. This implies that a human capital approach requires more careful planning and coordination of resources than a physical capital approach.

The distribution of benefits is much flatter and more widespread for a physical capital approach than a human capital approach. Thus, the physical capital approach can be viewed as more 'risky' than the human capital approach if one does not have information on which resources provide the best benefit for different outcomes and strategies. This is because a physical capital approach may have large positive or negative effects depending on how well it fits with the local conditions, while a human capital approach may have smaller but more consistent effects across contexts.

There may exist situations where one may face a trade-off between a higher expected benefit of an outcome and the variance in the amount of benefit one may eventually receive. For example, investing in science labs in schools may have a higher expected impact on reducing failure rates than investing in high-quality teachers, but it may also entail more uncertainty. The effectiveness of a strategy was influenced by the specific resources already available to schools. This study addresses how the framework presented can be utilized to eliminate the trade-off that could exist.

The findings have implications for policymakers who seek to design effective interventions that take into account both resource availability and outcome objectives.

9 Tables and Figures

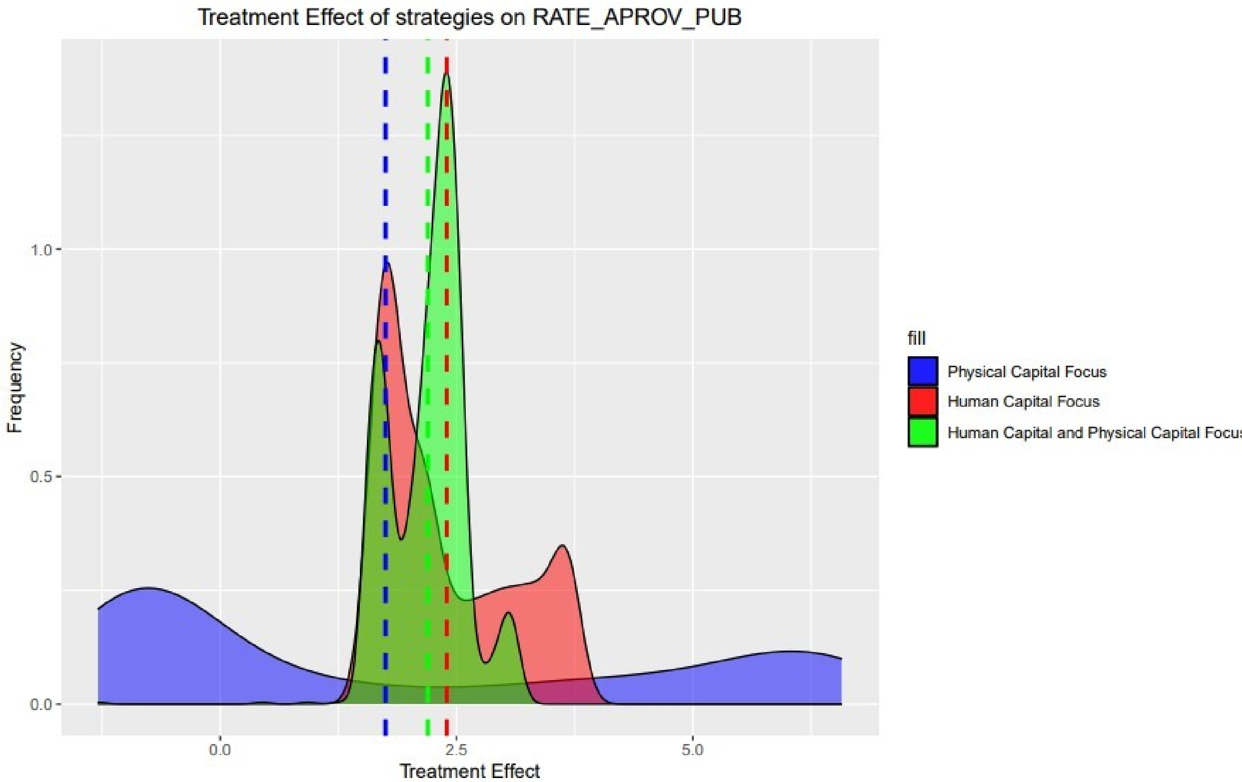

Figure 1: Effects of Approaches on Pass Rates

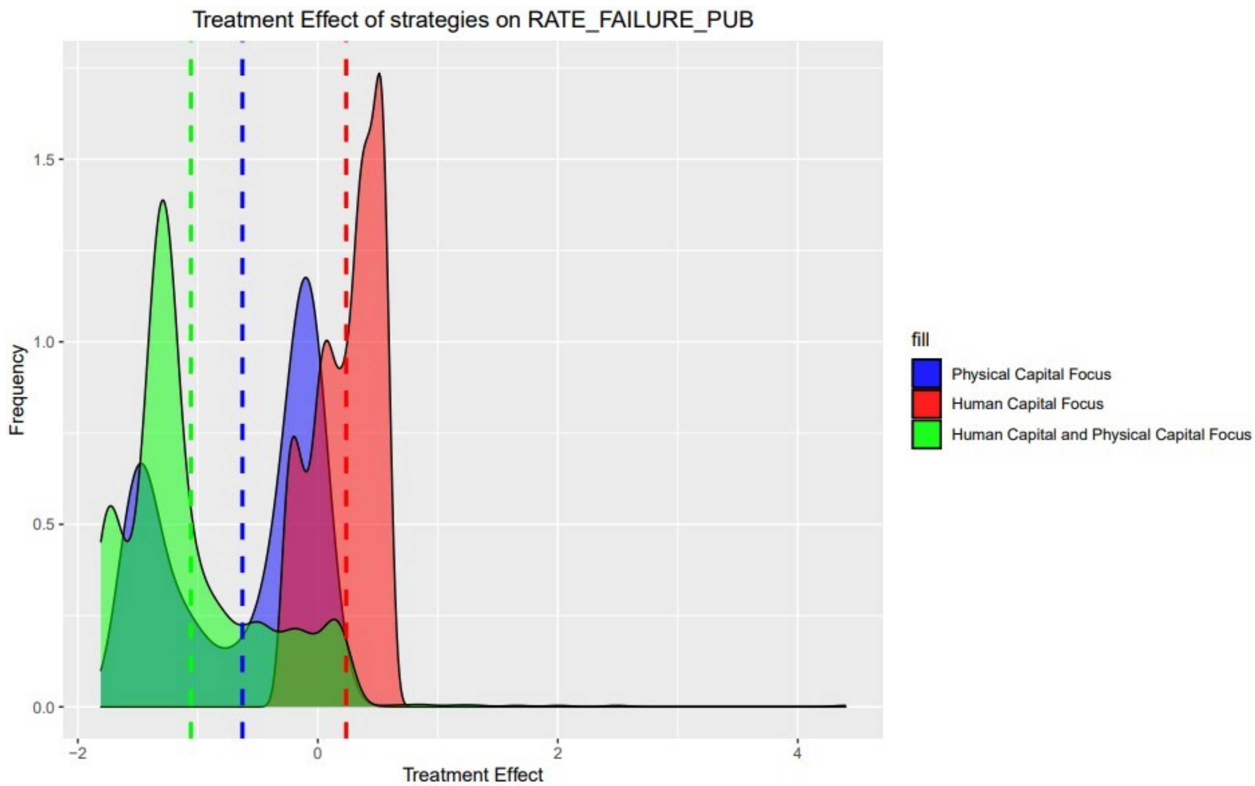

Figure 2: Effects of Approaches on Failure Rates

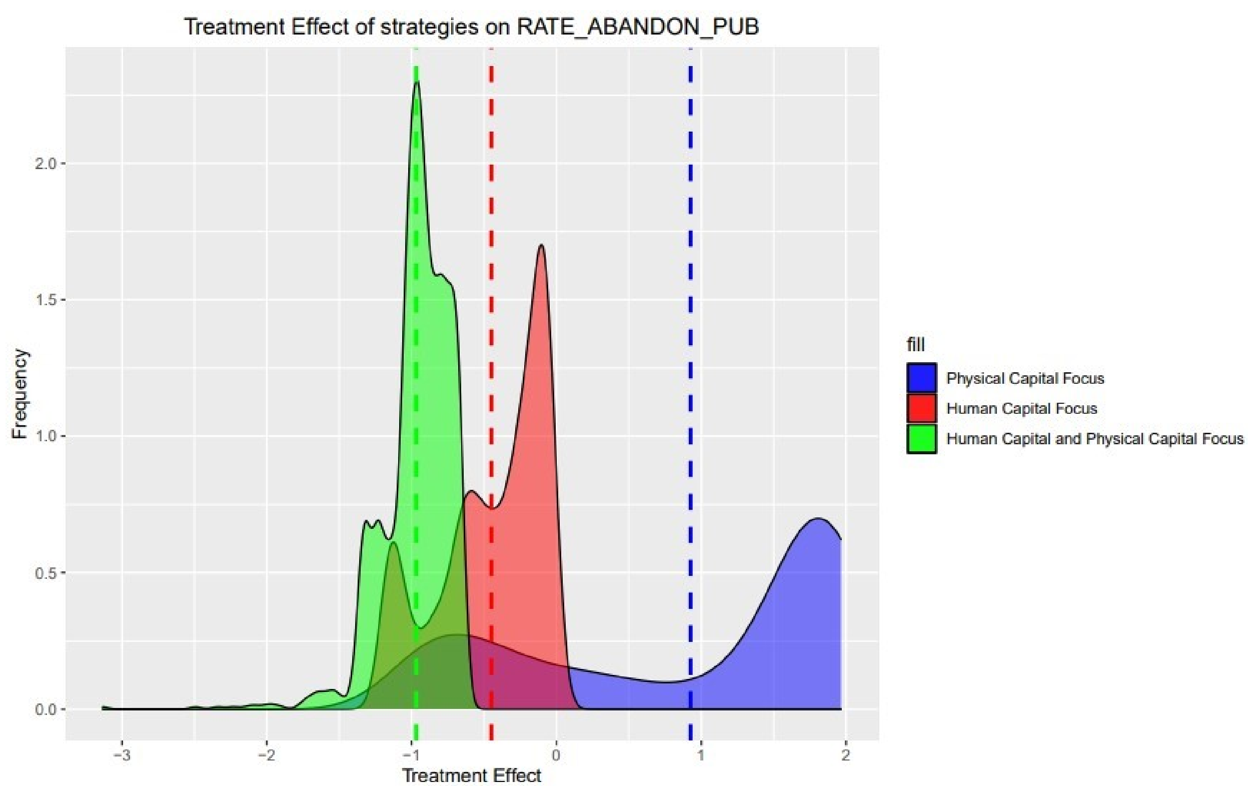

Figure 3: Effects of Approaches on Dropout Rates

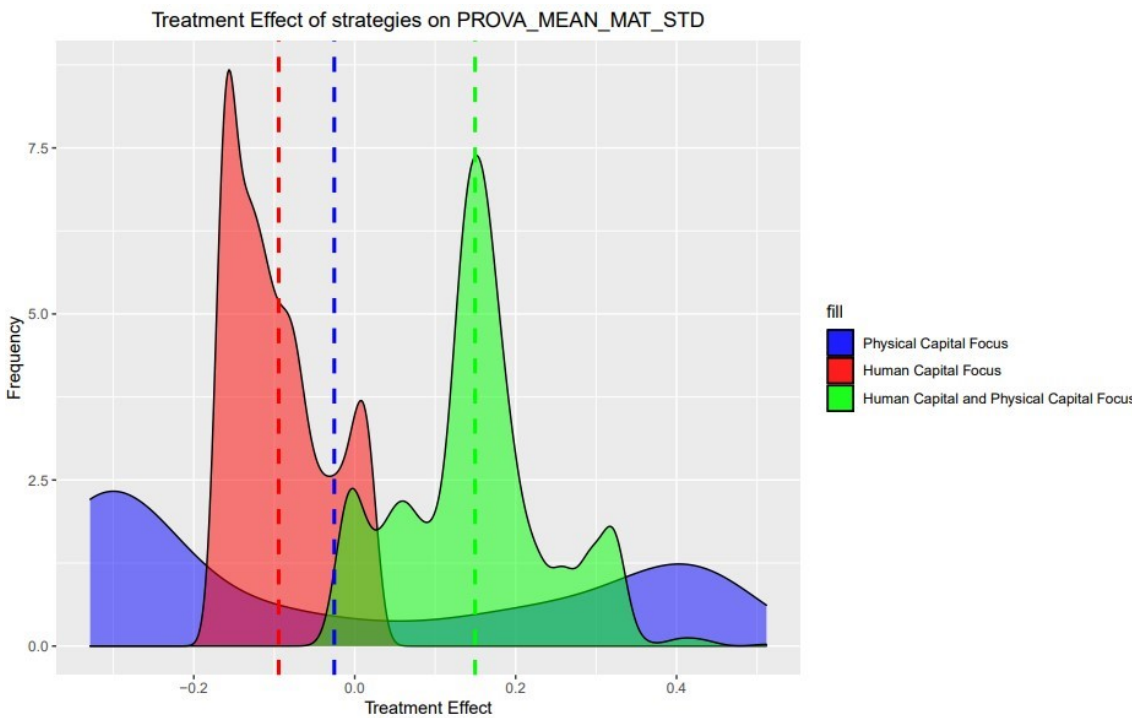

Figure 4: Effects of Approaches on Standardized Math Scores

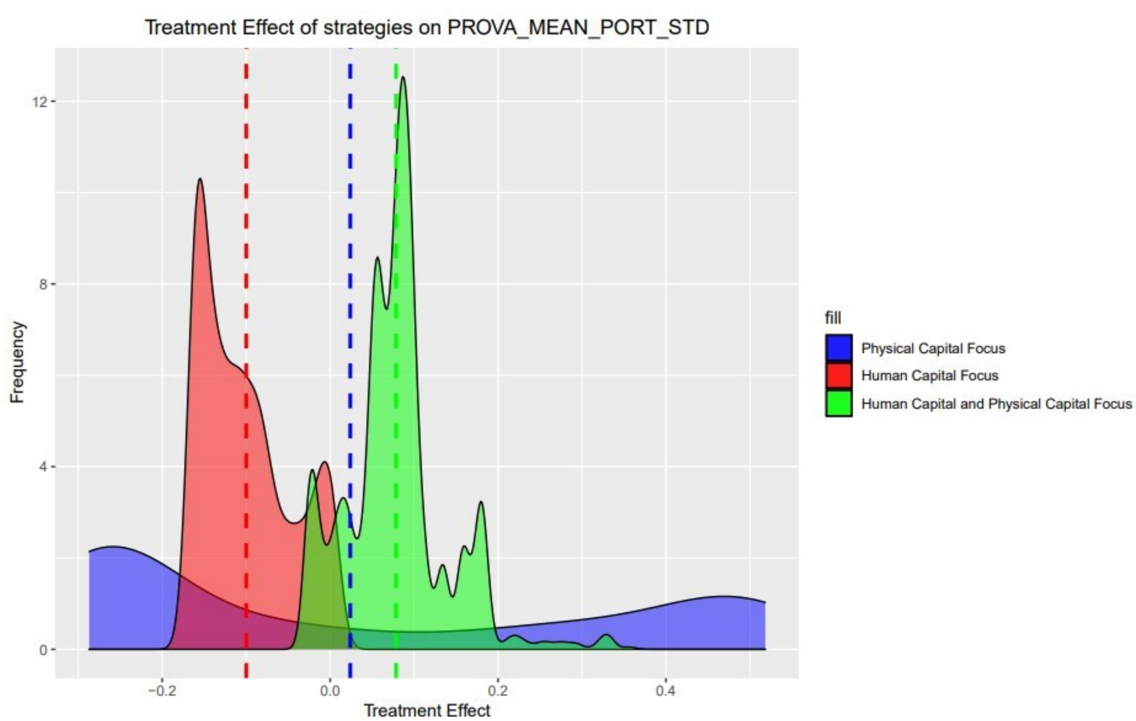

Figure 5: Effects of Approaches on Standardized Portuguese Scores

Table 1: Summary Statistics - Key Characteristics and Resources

Resource	Mean	St. Dev.	Min	Max
Library	0.874	0.331	0.000	1.000
Computer Lab	0.948	0.222	0.000	1.000
Internet	0.955	0.207	0.000	1.000
Science Lab	0.336	0.472	0.000	1.000
Sports Quad	0.799	0.401	0.000	1.000
Electricity	1.000	0.000	1.000	1.000
Total Staff	99.472	54.327	8.727	832.400
Teachers with Advanced Education	0.715	0.213	0.000	1.000
Teacher Education Years	13.876	0.839	9.850	15.000
Class Size	24.087	4.367	6.500	47.909
Class Student-Teacher Ratio	19.954	4.619	3.714	51.900

Table 2: Summary Statistics - Key Outcomes

Statistic	Mean	St. Dev.	Min	Max
Pass Rate	78.746	11.103	18.777	100.000
Failure Rate	11.860	6.926	0.000	59.185
Abandonment Rate	4.727	4.931	0.000	61.830
Math Mean Score	218.169	19.701	153.770	311.722
Portuguese Mean Score	205.292	17.469	143.490	283.161

Table 3: Outcome: Math Scores

	Variable	Coefficient	Coefficient/ATE
1	Teachers with Advanced Education	4.3059	0.25
2	Urban x Computer Lab	4.088	0.24
3	State: MG x Large School	3.6166	0.21
4	State: AC x Public Sewage Grid	2.7495	0.16
5	Urban x Public Water Supply	2.6738	0.16
260	State: MS x No Sports Quad	-3.8336	-0.22
261	State: AL x State School	-3.9767	-0.23
262	State: MG x No Sports Quad	-5.6271	-0.33
263	Teachers With Only Fundamental Education	-6.9178	-0.4
264	Teachers With Incomplete Fundamental Education	-10.7865	-0.63

Table 4: Enrollment Outcomes

	Dependent variable:								
	Approval Rate			Failure Rate			Abandonment Rate		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Physical Capital Focus	3.196^{***}			-2.700^{***}			-3.088^{***}		
	(0.185)			(0.136)			(0.096)		
Human Capital Focus		1.926^{***}			-1.570^{***}			-1.787^{***}	
		(0.114)			(0.084)			(0.059)	
Human and Physical Capital Focus			0.661^{*}			-1.598^{***}			-2.964^{***}
			(0.396)			(0.292)			(0.206)
Observations	204,420	204,420	204,420	204,420	204,420	204,420	204,420	204,420	204,420
R^2	0.164	0.164	0.162	0.099	0.099	0.098	0.109	0.108	0.105
Adjusted R^2	0.164	0.164	0.162	0.099	0.099	0.098	0.109	0.108	0.105

Note: *p<0.1; **p<0.05; ***p<0.01

Table 5: Math Scores

	Dependent variable:								
	Math Scores			Math Scores - Terminal			Math Scores - Initial		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Physical Capital Focus	0.626***			0.595***			0.589***		
	(0.040)			(0.031)			(0.027)		
Human Capital Focus		0.802***			0.721***			0.804***	
		(0.023)			(0.018)			(0.015)	
Human and Physical Capital Focus			0.673***			0.688***			0.631***
			(0.067)			(0.056)			(0.050)
Observations	17,055	17,055	17,055	29,163	29,163	29,163	40,458	40,458	40,458
R^2	0.117	0.162	0.110	0.097	0.135	0.091	0.111	0.159	0.104
Adjusted R^2	0.117	0.162	0.109	0.097	0.135	0.091	0.111	0.159	0.104
Note:									*p<0.1; **p<0.05; ***p<0.01

Table 6: Portuguese Scores

	Dependent variable:								
	Portuguese Scores			Portuguese Scores - Terminal			Portuguese Scores - Initial		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Physical Capital Focus	0.503***			0.420***			0.510***		
	(0.040)			(0.031)			(0.027)		
Human Capital Focus		0.723***			0.589***			0.735***	
		(0.024)			(0.018)			(0.015)	
Human and Physical Capital Focus			0.585***			0.481***			0.568***
			(0.067)			(0.056)			(0.050)
Observations	17,053	17,053	17,053	29,161	29,161	29,161	40,458	40,458	40,458
R^2	0.104	0.143	0.100	0.101	0.128	0.097	0.104	0.145	0.099
Adjusted R^2	0.104	0.142	0.100	0.101	0.127	0.097	0.104	0.145	0.099
Note:									*p<0.1; **p<0.05; ***p<0.01

Table 7: Resource Coherence

Outcome	Physical Capital	Human Capital	Human Capital & Physical Capital
Pass Rates	0.095	0.231	0.030
Failure Rates	0.126	0.171	0.095
Dropout Rates	0.113	0.173	1.847
Math Scores	0.111	0.235	2.085
Portuguese Scores	0.100	0.247	0.640

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