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The Harmony of Programs Package: Quasi-experimental Evidence on Deworming and Canteen Interventions in Rural Senegal*

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Abstract

This paper uses a unique and large-scale quasi-experimental data to study the effect of deworming and school meals programs as a *package* on educational outcomes (pupils' test scores: aggregate, French or math; enrollment, promotion or dropout rates) in rural Senegal. We extend the endogenous selection model *à la* Heckman to incorporate a double-index selection mechanism. We also generalize the Roy model accordingly. We develop estimation strategies based on the full information maximum likelihood and the two-step method. We derive a wide and rich collection of treatment effects ranging from exclusive to relative effects including sequential and substitution effects. The results show that the combination of deworming and school meals programs is more beneficial to pupils's achievements than taking programs separately. The sequence of implementation does matter. The two programs are complementary in increasing scores and promotion rates. However, they are substitutes in reducing dropouts. The cost-effectiveness analysis shows the deworming program is by far cheaper than the meals intervention. Implementing meals program before deworming is more cost-effective than the reverse. Lastly, unlike the deworming, meals program and the package (deworming and meals) have a welfare-enhancing effect on households.

Key words: Deworming and school meals programs, double-index selection, complementarity vs. substitutability, educational outcomes, quasi-experiment, welfare, Africa

JEL Classification: I25, C31, C34

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1. Introduction

Policymakers are often interested in comparing the relative benefits of different programs rather than the impact of a single program, as many relevant policy questions arise when multiple programs are implemented. Would the implementation of a package be more effective than each program performed separately? Are the programs complementary or substitute of each other? What is the impact of a given intervention compared to the impact of another? Would the cumulative impact of two (or more) programs be greater than the sum of impacts? Are the programs well(harmoniously)-designed to meet their target? These are the policy questions to which this study provides some answers. We contribute to this debate by examining in depth an important albeit neglected angle of the issue: the *package* aspect of public policy interventions, in particular, nutrition and health programs as well as their interaction effect on educational outcomes.

In support to educational public policies, deworming and school meals programs have been widely implemented in developing countries (in Latin America, Asia and Africa) as they are considered as important driving forces to improve educational outcomes (pupils' academic achievement and school performance). Determining the causal effects of these interventions on beneficiaries alongside the determinants of educational outcomes have been a heated debate and findings are still mixed. To this end, we develop an econometric framework that extends the basic endogenous selection models while contributing to the assessment of deworming and school meals programs as a package. We use unpublished quasi-experimental data from deworming and school meals programs conducted in rural Senegal. These data are novel in the sense that both programs have been implemented at the same time, during the school year 2007-2008, by the World Food Programme (WFP) and supported by the Senegalese government to contribute to the objectives of the Millennium Development Goals (MDGs). Therefore it is not a randomized control trial (hereafter RCT) and the population of beneficiaries (over 5000 pupils) is significantly higher compared to that usually considered in RCTs.

In addition, the design of the sampling is unique and rich in terms of program implementation as it involves mutually non-exclusive treatments. We will return to this aspect in Section 3. To date, these data have never been used and no evaluation of these programs has been undertaken. In 2009, another school lunch program supported by the Policy Impact Evaluation Research Initiative (PIERI) was coordinated by the Consortium pour la Recherche Économique et Sociale (CRES) in collaboration with the Senegalese Ministry of Education. Our data came as baseline data for the RCT of the school meals program initiated by PIERI. However, during the collection of baseline data for RCT, the evaluators discovered the existence of the package of past programs that have been implemented by WFP in 2007-2008. Thus, the baseline data for RCT was contaminated with pupils treated with deworming, school meals program and both (package). Thereafter, the RCT has been corrected, taking the contamination into account. Fortunately, the opportunity arose for us to take advantage of the existence of such unique package of programs and of the richness of information it contains. Thus, we decided to conduct an impact assessment study.[1] From a methodological perspective and as it will become clear in Sections 3, 4 and 5, such analysis requires econometric frameworks that extend on basic endogenous selection methods à la Heckman and on the Roy model.

Most of deworming and school meals interventions are part of the Food for Education (FFE) programs. Sarah et al. (2008) provide a review of the FFE programs. The authors show conflicting evidence on the ability of school meals to improve pupils' cognitive development and test performance in math and Language. The effects of these programs on promotion and dropout rates seem inconclusive. Some studies find that school meal programs lead to a significant increase in academic performance as measured by test scores. They also show that the implementation of these programs decreases dropout and repetition rates. Vermeersch and Kremer (2005) use data from a randomized breakfast program in Kenyan kindergartens. The authors show that the breakfast program improves student learning, but only for those whose teachers are more experienced at the beginning of the program. Cueto and Chinen (2008) examine the impact of an experimental school breakfasts program in primary schools in Peru. The results indicate that children in the program have higher rates of

[1] It is quite conceivable that many interventions have already been implemented in developing countries but have never been evaluated. With the popularity of the RCTs, several past recipients of these programs can be enrolled in RCTs if evaluators who set up these RCTs were not aware of similar past programs implemented in the same locations.

attendance and lower dropout rates than those who have not benefited from the program. In addition, children in the treatment group, who are in 'multigrade' schools and 'simple flow' performed better in coding tests, arithmetic and reading. Tan et al. (1999) use data on Philippines and find no evidence of school feeding program's impact on dropout and repetition rates.

The study of the impact of deworming on educational outcomes is even less widespread. Kvalsvig et al. (1991) examine the impact of deworming in South Africa and conclude that the drug treatments have some effect on school performance, but some effects are not significant. Miguel and Kremer (2004) study the impact of an experimental program of deworming on school participation, health, nutrition and scores of students in Kenyan primary schools. They show that despite the reduction in absenteeism, there is no evidence that deworming increases the scores of students. The study indicates that ignoring deworming externalities may underestimate the effect of deworming program. Miguel and Kremer (2004) also implement a cost benefit analysis and show that deworming programs are less expensive than alternatives for increasing school participation.

This research assesses the impact of school feeding and deworming programs as a package on educational outcomes (pupils' aggregate, French or math scores), enrollment, promotion and dropout rates, while elaborating on their determinants.[2] To the best of our knowledge, previous contributions used either a single program or a package of programs considered as single. Indeed, package of programs are usually implemented by policy makers because of their efficiency and also because single programs are costly compared to package. Banerjee and Duflo (2009) argued that the cost of organizing an experiment may be high. Then it is worth implementing multiple treatments at the same time on the same population to assess alternative variants of programs. However, due to the unavailability of appropriate tools that may enable researchers to estimate jointly the effect of package and at the same time to disentangle the effects within a unified setting, most studies have analyzed these programs either separately or have considered the packages as unique program or do not take a stand on the interactions between the programs in the package. Evaluating multiple programs requires the identification and the estimation of many different treatment effects and this makes the analysis more complex.

Our study is the first to assess such a package of programs. This entails developing appropriate methodologies. Moreover, we use a very rich and unique large-scale data set of approximately 5,000 pupils in rural Senegal. The data relates to deworming and school meals interventions, educational outcomes, pupils' characteristics (age, sex, etc.) and their households' and schools' characteristics. This data is interesting not only for the underlying above mentioned evaluation issues, but also because they raise methodological challenge.

1.1. Summary of results

The main results that emerge from this study are the following. First, an interesting aspect of our econometric specification is that, by incorporating a double-index selection mechanism, it enables us to study whether deworming and school meals are complements or substitutes. We observe the two programs are complements in the goal of increasing scores and promotion rates, while they are substitutes with the aim of reducing dropouts.

Second, our framework has the advantage of allowing the identification and the estimation of a wide and rich range of treatment effects: global effects (effects of programs taken together), exclusive effects (disentangled effects), relative effects (effect of a program versus the effect of another program), additional effects (effect following from having an additional program), sequential and substitution effects. For the score outcomes, we obtain positive and significant additional exclusive and global average treatment effects (ATE). The impact of the meals program on the scores is greater than the impact of deworming. The combination of the two programs (package) has a greater impact. This result reinforces the complementarity finding. Moreover, the relative effect of the package vs.

[2]Most empirical studies that evaluate nutrition or deworming programs use academic achievements (test scores) and school participation (enrollment, promotion, dropout, etc) as outcomes, see, e.g. Glewwe and Jacoby (1991,1995) and Miguel and Kremer (2004)). These outcomes are also widely used in other interventions dealing with educational outcomes; see e.g. Carrell and West (2010), Muralidharan and Sundararaman (2011), Rouse (1998), Alderman et al. (2001) and Glewwe et al. (2009).

deworming alone is greater than that compared to the canteen only. For the average treatment effects on the treated (ATET), the exclusive, global, and additional effects are positive and significant. It should be noted that the effects on the treated are larger than the ATE. For the treatment effects on the untreated (ATENT), the results show that the exclusive effect of deworming is negative while the effect of canteen is positive. The combination of the two programs greatly increases scores.

The sequential effects indicate that for pupils in the treated group, the impact of the package improves if the school meals is introduced before deworming. For pupils in the untreated group, the reverse sequence is preferable. Consistently with sequential effects, substitution effects show that for the treated group, implementing school meals for some time and replacing it with a deworming program is more beneficial than the reverse in terms of enhancing scores. Regarding enrollment, we obtain an exclusive negative ATE effect for the deworming program, an exclusive positive effect for the meals program, a negative overall effect and an additional positive effect. Moreover, when the target is to increase enrollment, the implementation of meals program alone is preferable to deworming or the package. When the objective is to increase the promotion rate or reduce dropout, the package is the best option. Overall, the results indicate that, if for a reason or another (for example funding limitations), we have to substitute a program for another, then one should replace the meals program by deworming if the goal is to improve pupils' academic achievement.

Third, the cost-effectiveness analysis indicates that, regarding the scores, deworming is far cheaper than the meals program. It also shows that introducing the meals before deworming is more cost effective than the reverse. As for the promotion rate, the combination of the two programs is more cost-effective than the single meals program. For the dropout rate, deworming is more cost effective than the canteen and the package. However, the package is more cost effective than canteen only.

Finally, we go beyond the gain deworming and school meals programs can directly represent for pupils beneficiaries by studying how these programs can also improve the living conditions of the households in which these children live. For this, relying on the intra-household information contained in the data set, we study the impact of these programs on household well being. In a context of severe poverty and vulnerability in rural areas, this can be viewed as externality effects of programs on household welfare. The externality is of two folds. First, deworming can protect other household members of any contagion or transmission of worms. Then having meals at school reduces significantly household food expenditure which accounts for more than 70% of household total expenditure. We find that the deworming program alone does not contribute significantly to improving household welfare while schools meals alone do. Furthermore, the combination of both programs (package) improves welfare more than the meals program alone. This finding is interesting and also supports the complementarity within the package.

1.2. Contribution to the literature

Our study contributes to the literature in several ways. First, it is evidently closely related to the literature on evaluating deworming and school meals programs. This literature has a long story both in development economics and economics of education as these programs seek to assess the impact of these interventions on educational outcomes (Glewwe and Jacoby, 1995; Glewwe et al., 2001; Whaley et al., 2003; Miguel and Kremer, 2004; Vermeersch and Kremer, 2005 and Kazianga et al. 2014). The novelty here is that we go beyond the evaluation of simple programs to tackle the issue of the both interventions. The rationale of this is that of policy efficiency. As we mentioned above, the implementation of single programs is costly compared to a package. As a result it is interesting for policy makers to know whether a package would be more effective than programs performed separately. As we previously outlined in the summary of results, the treatment effects differ depending on whether they are derived from a package or exclusive. This shows the relevance of taking into account the way the programs are implemented. We argue that packaging is more profitable.[3]

[3]Some 'multiple treatment experiments', albeit in a very different context and using different methodology, include among others Banerjee et al. (2007), Duflo et al. (2006) and Olken (2007). However, it is worthwhile to note that multiple treatments as previously studied in these contributions differ from what we study here. Indeed, set apart from the fact that these papers were not interested in canteen or deworming programs, the authors did not study the join effect of treatments as well as their interactions. Moreover these studies are based on RCT while our study uses

Secondly, this paper is related to the literature on the determinants of educational outcomes. However, we have put emphasis on the determinants that are of particular interest to the Senegalese context. Among these determinants, schools' characteristics and family environment were the most commonly-used determinants. Coleman et al. (1966) found significant effects of school factors and weak effects of family environment on educational outcomes for pupils in developing countries.[4] There is a common perception that school inputs have a positive effect educational outcomes. Indicators such as class size, expenditure per pupil, the ratio of pupil to teacher, salary, age, experience and academic level of the teacher have been used in some studies as school inputs. In addition to these factors, teaching practices and school composition may help to explain why some schools are more effective than others with identical levels of resources. In fact, research on the effects of reducing class size on pupils' performance has not produced consistent findings. Glass and Smith (1979) found evidence of a relationship between class size and student achievement. Furthermore they found out that the effect of reducing classes is not linear. While some studies show that students in small classes have better achievement (Piketty, 2004), others show that the reduction of the class size still leaves uncertainties (Davies, 2003). Clearly, there is no consensus about the effect of reducing class size on pupils' achievement. Here, we argue that class size does not affect pupils' outcomes in schools with canteens or for pupils in schools where both programs are implemented. On the contrary, in schools without meals program or with only the deworming program, we find that class size has a negative effect on the score in French. This is consistent with Brossard (2003) and Altinok (2006). In addition, we also find that a female teacher has a positive influence on pupils' achievement, particularly on girls, who identify themselves more easily to a female teacher. This is of particular interest in the African context where promoting the education of girls is an issue of development.

To explain the unequal achievement of pupils, studies have focused on the role of socioeconomic status, family structure (gender of household head), family size and parental practices. Many studies indicate that marked disparities in schooling and the acquisition of knowledge are associated with the socioeconomic status of parents (Ryan and Adams, 1998). Lockheed et al., (1989) found significant effects of social class on student performance in mathematics and languages. Parents' socioeconomic status has been found as a determinant of academic failure (Lawson-Body, 1993). In contrast, Curtis and Phipps (2000) found evidence of a weak link between poverty or the household income and educational outcomes of pupils. The family structure is often controlled by the variable gender of household head in the literature. In fact, in the African context, it is usually argued that a female head of household is associated with significant educational opportunities for children (Fuller and Liang, 1999 and Lloyd and Blanc, 1996).

It is important to note that apart from school, individual and family factors, other elements such as socioeconomic and health shocks can have consequences on student outcomes. There are some shocks related to schooling that can lower student achievement. These shocks are for example the delay in starting the courses and the temporary closure of classes. They reduce learning time and therefore, pupils' results. In addition, in primary education, teachers' strikes and high absenteeism rates constitute the main source of temporary closure of schools. In the context of our study, these shock variables are important and therefore of particular interest. As can be expected, we found that these variables have a negative effect on pupils' performances.

Thirdly, from a methodological perspective, this study contributes to the literature on using selection models for evaluation purposes. This literature dates back to the seminal contribution of Heckman (1978, 1979) and later on Heckman and Robb (1985, 1986). These selection models have been extended in several directions (Heckman, 2001). Furthermore, methodology for multiple treatments have been considered by some scholars. For example Lechner (2001) extended the conventional two state framework of the Rubin model to the case of multiple mutually exclusive treatment and discussed various measures of the causal effects. The author discussed the identification of these effects under the Conditional Independence Assumption (CIA). The results showed that low dimensional balancing scores, similar to the ones valid in the case of only two treatments, exist and can be used for identification of various causal effects. Lechner (2001) outlined a matching estimator and showed

quasi-experimental data.

[4] See also Fuller and Clarke (1994).

that for specific parameters, like the treatment effect on the treated, the multiple program nature of the policy can be ignored, because individuals who are not in programs of interest, are not needed for identification. Frölich (2004) examined different nonparametric strategies to solve the selection bias problem and to identify average treatment effects. The study outlines that the difference-in-difference and the instrumental variable approach often identify only the treatment effect using participation versus non-participation, and do not allow a comparison between different treatments. Lechner (2001) and Frölich (2004) are based on propensity score matching.

Heckman and Vytlacil (1998) developed models for counterfactuals and causality that build on Cowles Commission econometrics. The authors generalized the IV approach to consider models with multiple outcomes. They proposed both ordered and unordered choice models and defined treatment effects for a general multiple treatment problem and presented conditions for the application of IV for identifying a variety of new treatment parameters. Rather than relying on IV to estimate the local average treatment effect, Wooldridge (2003) imposed assumptions that identify the average effect for general kinds of treatment based on the *correction function* approach. The author developed a correlated random coefficient model with multiple treatments which is more robust than the plug-in estimators of Heckman and Vytlacil (1998).

Our approach departs from the previous studies on several aspects. First, the foregoing contributions aim at providing a framework for analyzing experimental data such as RCTs. We do not require instrumental variables like Wooldridge (2003), although this may be an alternative estimation method as we will highlight in Section 5. Moreover, we are not in a pure propensity score matching paradigm like Lechner (2001) and Frölich (2004). Indeed, our framework requires the joint estimation of selection and outcome equations. Propensity score matching for multiple treatments can easily be retrieved from the first step estimation of our procedure by elaborating on multiple selection. Lastly, our sampling process generates mutually non-exclusive data as will become clear in Section 3. We propose a structural framework for double-index selection where treatment indicators are endogenous. Firstly, we use a double-index selection model (DISM) and secondly we use a generalized Roy (1951) framework. For each specification, we propose two estimation procedures: full information maximum likelihood (FIML) and control function (two-step estimation) *à la* Heckman (1978, 1979). One difficulty in the two-step procedure as well as in the computation of treatment effects is that, the conditional expectations in the second step regression function involve 'truncated trivariate normal distribution'. We compute these expectations relying on the moment-generating function formula along the lines of Muthén (1990). As for the inference, it is well known that the conventional standard errors of the parameters estimated in the second step are not valid and need to be corrected by generalizing the results of Heckman (1978, 1979), or by using simulation or bootstrapping methods.

The remainder of the paper proceeds as follows. Section 2 takes the stock of the literature on deworming and canteen programs and their effectiveness on educational outcomes in developing countries. Section 3 describes the data and variables. We propose two econometric frameworks: the double-index selection model and the generalized Roy model. Section 4 describes the first framework and the related estimation strategy. Section 5 describes the second framework. Section 6 presents the treatment effects that follow from these two frameworks. Estimation results are discussed in Section 7. The penultimate section proposes a policy analysis that includes cost-effectiveness and welfare analysis. The last section discusses implications of the results and highlights research perspectives.

2. Literature on deworming and school meals programs: A brief insight

In this section, we discuss salient features and evaluation studies from the literature, focusing on issues related to the nature of interventions: school meals vs. deworming. Have these programs achieved their ultimate objectives? We also highlight the main conclusions to which studies have led. This brief review is by no means exhaustive and will target the nature of the interventions.

2.1. Some facts

School feeding and deworming interventions became the subject of great interest in many developing countries. They are considered as strategies to achieve the goals of 'Education for All' set up by the international community in 2000 in Dakar. To meet these objectives, the Global Initiative Food for Education was launched by USA in 2001 and was replaced in 2002 by the 'Food for Education' (FFE). These programs are often accompanied by medical treatment aiming at eliminating intestinal helminths. They bring and keep pupils at school while improving their academic performance. Most of them are initiated by the World Food Program (WFP).

The FFE program including meals served at school and the rations given to families conditional on sending their children to school have recently become a policy instrument for achieving the Millennium Development Goals (MDGs) especially primary universal education and reducing hunger in developing countries. These programs have the potential not only to bring children to school by providing nutritious meals, but also to stimulate learning and cognitive development of malnourished children (Sarah et al., 2008).

For ethical purposes, school feeding programs are generally provided to all children in targeted schools. This practice increases the cost of achieving program objectives such as increasing attendance rates, because many children would attend school even if they did not benefit from the program. Take-home ration programs are less criticized because they can be easily implemented thanks to an easy identification of targeted groups. Some empirical studies found that school meals and take-home ration programs induce a significant increase in student achievement as measured by test scores. However, some other studies found no evidence or a significant negative effect of the programs on test scores (Ahmed and del Ninno, 2002 and Kazianga et al., 2009).

Another well-known intervention, but rather connected to medical treatment is deworming. Indeed, intestinal worms are endemic in tropical and subtropical areas. Their consequences are devastating, particularly for children, and can lead to malnutrition, increased susceptibility to infections and slow growth during a critical period of development. Children who are not dewormed fall ill. Consequently, this will slow down their cognitive development, increase absenteeism from school and negatively affect their performance. The impact of deworming on educational outcomes is therefore considered as an important issue in poor countries.

2.2. School meals

Most empirical studies that evaluate school meals programs conclude that school meals programs have a significant positive impact on attendance and enrollment. Other studies outlined that school feeding programs have a positive impact on learning outcomes measured by test scores. As pointed out by Ahmed (2004), Vermeersch and Kremer (2005), Powell et al. (1998), Jacoby et al. (1996) and Akakpo (2004), school feeding does not have the same impact on all recipients which suggests causal heterogeneity may exist.

Ahmed (2004) evaluated the impact of the school lunch program in Bangladesh on student outcomes using test scores for 1648 students in fifth grade elementary school. The author found that the aggregate scores of students who received the program are 15.7% higher than students in the control group. Relying on disaggregated scores, the author found that the improvement is mainly due to an increase in math score. By controlling for the characteristics of children, households and schools, in particular the number of pupils, he observed that the program has a significant and negative effect on scores in English. However, the impact is not sizeable. Ahmed and del Ninno (2002) found that the FFE program in Bangladesh had a negative and significant impact on test scores for pupils who benefited from the program in fourth-year primary schools. The authors also indicated that the difference between the two groups came from a decrease in scores of pupils who enjoyed the program. This finding stems from the low socioeconomic status of beneficiaries. Vermeersch and Kremer (2005) quantified the effects of subsidized school meals on student outcomes using randomized data from a breakfast program in kindergarten in western Kenya. The results show that children in the treatment group attended school 35.9% of the time, compared to 27.4% in the control group. The difference is almost one third of attendance in the comparison group. They also showed that there is an improvement in student learning, but only for children in schools where teachers were more experienced at the beginning of the program. Kazianga et al. (2009) used a randomized trial to assess the impact of school meals and take-home ration on health and education outcomes for poor children in northern rural Burkina Faso. They found that both programs increased girls' enrollment but there was no significant impact on raw scores in mathematics. Also the interventions had caused an increase in absenteeism in households with low use of child labor while it decreased for household that had a relatively large use of child labor.

Powell et al. (1998) used data on 814 children in the fifth year in primary schools in rural Jamaica. The children were randomly divided into two groups. The treated group received a breakfast containing 576 to 703kcal and 27g of protein. The control group received a placebo consisting in a slice of orange with 18kcal every day during eight months of school year. School attendance rates records showed a slight increase for children in the control group. This impact was greater for malnourished children than for well fed children. However, these impacts are relatively small compared to the extent of the real impact because participation rates were about 70% in both groups. Jacoby et al. (1996) found that a breakfast program in Peru increases attendance rates of pupils in fourth and fifth year of primary school. The authors found that there was no significant difference in the rates of school attendance between the two groups before the implementation of the program. During the implementation of the program they found that attendance increased by 0.58% in schools of the treatment group and decreased by 2.98% in the control group.

Akakpo (2004) examined the impact of school canteens on enrollment and attendance and on student achievement with certificates of completion of elementary study (FEAC) in rural public schools in three regions (Fatick, Kaolack and Tambacounda) of WFP intervention in Senegal. The results showed that school attendance is much better in schools where WFP operates as enrollment grew by 12% per year while the increase is only 8% in the group of schools where WFP does not operate. The schooling of girls is particularly high in schools where WFP was operating and the number pupils grew by 15% per year against 10% in schools without canteens. Cueto and Chinen (2007) examined the impact of an experimental program of school breakfasts in primary schools in three departments of Peru. The outcome variables were test scores on standardized coding, arithmetic and reading as well as attendance, enrollment and dropout rates. The results showed that children in the program have high rates of attendance and low dropout rates, compared to children not receiving the program. In addition, children in the treatment group and who are enrolled in multigrade schools performed better in coding test, arithmetic and reading.

Several studies have sought to measure the impact of feeding programs at schools on the cognitive development of children. Simeon and Grantham-McGregor (1989) used data on rural Jamaica and found that breakfast had no effect on the cognitive performance of children with normal weight and height for their age while breakfast increases the performance of children at risk. Whaley et al. (2003) studied the impact of animal foods (meat and milk) on the cognitive development of children at primary school in rural Kenya using a randomized program. The authors concluded that the quality and quantity of food can predict the performance in arithmetic. The study shows that food of animal origin as well as energy have a positive effect on the results of children in cognitive tests such as arithmetic and perceptions.

2.3. Deworming

Compared to school feeding, the effect of deworming programs is less documented. Miguel and Kremer (2004) assessed the impact of a randomized deworming program in Kenyan schools. The results showed that absenteeism in the treatment group was 25% lower than in the control group. Moreover, deworming increases school attendance by 0.14 per treated student on average. They also studied the impact of deworming on test scores. The results showed that despite the reduction in absenteeism, there is no evidence that deworming increased students scores. Additionally, the authors use the Kenya Life Panel Survey (KLPS) to document the long-term impact of deworming program on school achievement, cognitive skills, labor market, fertility, marital choice, health, physical strength and personal happiness. The authors found that children's health and participation in school are increasing not only for students in the treatment group but also for students whose primary schools are located within 6km from treated schools. In particular the impact was significant on schools located within 3km. The impact on nearby schools seems to be due to the reduction of transmission of the disease (positive externalities) thanks to the intervention. A key finding of the study is that the failure to take these externalities into account leads to a significant underestimation of the benefits of the intervention and the actual cost of deworming. However, increased participation in schools is not reflected in the results of tests score. In addition, the authors presented a cost-effectiveness analysis showing that the intervention is cost effective, and the intervention does also improve basic skills.

Bobonis et al. (2006) conducted a randomized trial in India as part of a health program that provides iron supplementation and deworming to children aged from 2 to 6 years in 200 kindergartens in poor urban areas of Delhi. After five months of treatment, the authors found significant weight gains and a reduction of one fifth of absenteeism. This finding is consistent with Miguel and Kremer (2004). Subsequently, Bobonis et al. (2006) have tried to obtain estimates after two years of program implementation. But the attrition of the sample and the apparently non-random entry of new children in kindergartens make it difficult to obtain unbiased estimates of impacts in the long run. An important channel through which the gains of preschool attendance in Bobonis et al. (2006) could affect the long run entry of new children in kindergartens is an improvement over time in academic performance in primary school. In fact 71% of the parents in the field study of India argued that the improved outcomes in primary school has been a motivation for sending their children to preschool. In this study, children received both iron supplementation and deworming. However, the study does not distinguish between the effects of both treatments meaning that iron supplementation and deworming were considered together as one program.

Other studies focus on the impact of parasitic infection on cognitive development. Kvalsig et al. (1991) examined the impact of whipworms and other parasites in South Africa and found no association between drug treatment and educational attainment or memory function. Nokes et al. (1992) evaluated a treatment of whipworms in Jamaica and concluded that cognitive functions improved after undergoing the treatment, but other outcomes, particularly those related to academic performance, do not seem to have changed significantly.

The main lesson from this brief literature review is that school meals and deworming interventions as well as the potential policy implications have received substantial attention by scholars. The debate has reached a state of maturity thanks to all the impact evaluation studies that helped accumulate a rich and substantial knowledge of the success and failure of these programs. However, still consensus has emerged yet as the conclusions are highly mixed and controversial. This paper aims at contributing to this heated debate by exploring in depth an important aspect of the problem which has so far been neglected: the *package* aspect of nutrition and health interventions.

3. Data: The package of deworming and school meals

As we have outlined earlier, the design of the sampling of the two programs is unique and rich. This richness follows from the fact that the two treatments are mutually non-exclusive meaning that having deworming does not prevent pupils from benefiting from meals. As a result, some of pupils get only deworming, some only meals, some get both and others receive nothing. This section presents the data we use. To understand the data structure and the motivation of the econometric specification, we first give a flavor of the data generating process. Then we describe the actual sample and programs.

3.1. Data generation process (DGP)

Our DGP is a multiple non-exclusive kind of interventions. In the case of a package consisting in two treatments denoted by T_1 and T_2, we have four regimes: T_1T_2, $T_1(1-T_2)$, $(1-T_1)T_2$ and $(1-T_1)(1-T_2)$. This DGP tells that some individuals receive only T_1 whereas others receive only T_2. Some others receive both T_1 and T_2 and the remaining nothing. The latter represents the control group. As a result, the treatments are typically mutually non-exclusive events. In the case of 3 treatments we have 8 regimes. The general case of n interventions lead to 2^n regimes. It is clear that higher order treatments become extremely difficult to handle, the empirical analysis being no longer easily tractable and excessively data consuming.

In terms of impact analysis, this type of data sampling makes the study particularly rich compared to the case where all individuals in the treated group receive both treatments or when the interventions are mutually exclusive meaning that deworming and meals cannot be implemented at the same time.[5] In other words, the occurrence of deworming does not automatically rule out the occurrence of meals and vice versa. This kind of data arrangement offers the possibility to study only the impact of each intervention as single, but also the impact of the combination of the two programs and several relative effects. Moreover, its enables to design a specification that aims at testing the complementarity vs. substitutability of the two programs.

3.2. Programs package: Area covered and sampling

The school feeding or Food For Education (FFE) is the activity through which the World Food Programme (WFP) has supported the education sector in Senegal since the 1960s. This intervention aims at providing pupils with a regular diet and to promote children's access to basic education quality, especially girls. This intervention supports the government in achieving universal education for all children by the year 2015 which is one of the goals of the Ten-Year Education and Training (PDEF) and the Millennium Development Goals (MDGs). WFP activities are implemented within the framework of two programs, namely, the Country Programme which extends from 2007 to 2011 and the Programme of Protracted Relief and Recovery Operation (IPSR) for the 2008-2009 and later. To be assisted by WFP, the school must meet the following requirements: i) be located in an area of food insecurity or be particularly affected by higher prices, ii) be in a rural or peri-urban area, iii) have a minimum size of 50 pupils and a maximum of 600 (management concerns requirement), iv) have an operational management committee, v) have the commitment of the local community to develop infrastructure such as storage, even cooking based on local materials, vi) have an acceptable standard of hygiene.

Initially, WFP's school feeding covered the regions Fatick, Kaolack, Tambacounda and Matam (under the Country Programme 2007-2011) and the regions Ziguinchor, Kolda and Sédhiou (under the IPSR successively carried out since 2003 in Casamance Natural). Under the action plan, WFP has strengthened the school feeding program in its initial intervention areas: Fatick, Kaolack, Kaffrine, Tambacounda, Kedougou, Matam, Ziguinchor, Kolda and Sédhiou considered as priority areas. Later on, the action plan has been extended to other regions: Diourbel, Louga and Thies. The program involves a total of 12 regions out of 14 in Senegal.

In addition, the Ministry of Education, through the Direction of General Administration and Equipment (DAGE) also funds a program for canteens implementation. Its division of the medical school (DCMS), also leads to another program which focuses exclusively on deworming and medical monitoring in rural public schools. In this study, we used primary data collected by CRES and the Ministry of Education as part of an intervention of school canteens (meal) and deworming. For intervention areas, four regions (Fatick, Kolda, Diourbel and Sédhiou) of Senegal were chosen. Central regions (Diourbel and Fatick) are mainly composed of farmers and are closer to the capital (Dakar), while those in the South (Kolda and Sédhiou) are very isolated and livestock farming is the main economic activity. The southern regions also suffer from poor living conditions and lack of access to basic infrastructure, which prevents people from getting out of poverty. The regions of Kolda and Sédhiou belong to southern regions and in 2003, they are classified as having a very low risk management capacity whereas Fatick has average risk management capacity and Diourbel a good capacity to manage risk (PAM, 2003).[6] These four regions are characterized by weak school enrollment

[5]See e.g. Brodaty et al. (2001) and Lechner (2001) for multiple mutually exclusive treatments analysis with non-experimental data.

[6]In Senegal, rural areas, most risks that people are facing are natural hazards such as drought, land degradation, animal diseases, pests and flooding. The consequences of these risks are felt on agricultural production (production loss, lower yields), livestock (cattle decreased, decreased production of animal products) and household incomes because they will lose a portion of income from the sale of agricultural and animal products. In addition there are other risks such as economic risks associated with rising prices of basic necessities, lower prices for agricultural products and livestock and

and high prevalence of poverty and vulnerability. Because of low harvests, food insecurity in these regions reduced not only households' income, but also impoverished their diet. Therefore children are exposed to acute malnutrition. Indeed, 31% of nutritional deficiency cases at school age and adolescence and a prevalence of nutritional anemia for children at 4 to 14 years, with 62% of boys and 38% of girls were recorded (PAM, 2006).

The sample study is made up of pupils in the second and fourth year of primary school (hereafter CP and CE2) in these four regions. Several reasons have guided the selection of these two groups of pupils. On one hand, for reasons of investigation costs, it was difficult to include into the interventions all pupils in each school. It should be noted that all pupils within a school benefit from school lunch. On the other hand, if at the end of the second year the pupil cannot read and write, the probability to fail before the end of the education cycle is very strong. In addition, if after four years of primary education, skills in reading and writing are not vested, it is unlikely that the pupils can learn the basic skills that education is supposed to provide. The interventions take about two years. We have an observational database of 159 schools with about 5650 pupils of whom 2800 are in second year (CP) and 2850 in fourth year (CE2) randomly selected from a large population. The pupils were offered the two programs: deworming (T_1) and/or meals (T_2) as described above. Relying on that we formed the four groups: a group of pupils who benefit from the meal program only, a group of pupils who are dewormed only, a group of pupils who receives the two programs and a control group who receives nothing.

To conclude the presentation of the programs, it is important to note that, for the population involved, deworming is free of charge whereas the school meals program is not. For a child to benefit from the canteen, the household must pay a lump sum contribution of 200 FCFA per pupil and per month.[7] However, a pupil is not excluded from canteen if her/his family does not pay the contribution. Unfortunately, we did not have the identification of households who pay and those who do not. We do know that most households make the payment. There is a debate in the literature about the role of price in evaluating programs (see, e.g. Cohen and Dupas, 2010). The idea is that people value more the interventions if they don't have it for free. In our case, the meals program does not suffer from this problem. The case of deworming is special. Indeed, deworming is a health intervention. If this program becomes cost-sharing, it is likely that households could easily adopt traditional medicines of deworming, which in practice, are made without medical supervision. One of the objectives of this program is indeed to combat traditional deworming.

3.3. Variables and descriptive statistics

The variables used in this study are of two types: the outcome or performance variables (aggregate, French and math scores; enrollment, promotion and dropout rates) and the determinants of performance or control variables. We have gathered the controls into four categories: pupils' characteristics, households' characteristics, schools and teachers' characteristics, the characteristics of the community where pupils live and the geographical location or regions (Diourbel Fatick, Kolda and Sédhiou). The treatment indicators are the response variables in the selection mechanism. The definitions of all variables are summarized in Table 20. The control variables were chosen based on data availability from the survey sample and their relevance for the analysis. Some of them are specific to the context of the study and therefore are of particular interest. We mention them as such and also elaborate on the rationale of their use.

3.3.a. Variables

The characteristics of pupils. Pupils' characteristics are: gender, age, class, having attended a Koranic school, early childhood institution, being sick in the last three months preceding the survey, eat at

cattle theft. Any region that doesn't have the ability to manage risk is highly vulnerable to food insecurity. This has a negative impact on children's education, their nutrition and school performance.

[7]Note that 200 CFA is equivalent to 0.419 U.S. dollars. Although this amount is very small, it is sufficient to sensitize rural households.

fill, bring a snack to school and be dewormed at home. It is worth noticing that deworming at home is not part of the deworming program studied. The latter consists only of being dewormed at school.[8]

The gender of pupils can influence their academic performance. As pointed out by Felouzis (1997), boys perform better than girls in mathematics and in science. On the other hand, Ma (2007) found that gender difference is not statistically significant and sometimes results are mixed. In the context of rural Senegal, we anticipate that boys perform better than girls because the latter are often confined to domestic tasks. In addition, some families still question the value of education of girls and are very reluctant to promote the schooling of girls. The age of pupils may have a negative effect on their achievement in cases where there is a delay in school progress due to the repeated repeating. However, if one considers that the delay follows from late entry to school, the literature mentions a positive relation between age and academic achievement (Schwille et al., 1991). Health status is a major determinant of performance. In the survey sample, it was asked whether a pupil had being sick during the last three months preceding the survey. Intuitively, being sick will reduce learning ability and school attendance time.

Attending an early childhood institution and a Koranic school are specific to the context of the study. Indeed, the development of structures like nursery that aims at supporting children of young age are still underdeveloped.[9] The Koranic school, usually found in Muslim countries, is an informal private structure that provides religious education to children. In Senegal, 95.9% of the population practice Islam. Albeit informal, attending Koranic schools is a common practice. Children usually go to Koranic school between the ages of 5 and 6. These schools are very popular and contribute to a tremendous development of children's capacity to learn and memorize at young age. We can say that the learning mechanism in these schools is a memory based learning. We hypothesize that these two variables (early childhood institution and a Koranic school) will positively influence the academic performance of pupils. Two other variables that are not frequently used in the literature are the fact to eat one's fill at home and bringing a snack to school. Remember that the study focused on rural population. These food indicators provide information on the nutritional well-being of children. We also anticipate that these two variables act positively on pupils' performance.

The characteristics of schools and teachers. The following schools' characteristics have been taken into account: the number of classes in provisional shelters, the distance between school and the home of pupils, the class size, the number of pupils per textbook, the existence of latrines, hand washing device, association of pupils' parents, water point, opportunity for pupils to eat near school, disruptions that delay the kick-off of classes, absenteeism of teachers and schools stating that the tuition fee or schooling expense is high. Among these variables, those that allow us to contextualize the study are classes in provisional shelters, hand washing device, association of pupils' parents, the opportunity for pupils to eat near their school and disruptions that delay the start of classes.

For the variable temporary shelters, we expect a negative effect on the scores but a positive effect on enrollment, promotion and dropout rate. Indeed, in Senegal, temporary shelters have been set up to overcome the lack of classrooms in some rural areas. They are usually precarious straw constructions which become unusable during the rainy season. Through the office of the association of parents, the community can control the school, which could have a positive effect on the effectiveness of schools. We take into account the quality of sanitation in schools through the variables latrines and hand washing device. We expect a positive effect of these variables on pupils' performance. The same goes for the ease with which students have a meal near their school. The existence of disturbances having driven delays in the start of the course reduces the learning time. We hypothesize a negative effect of this variable on pupils' achievement. In the Senegalese context, there are often disruptions or strikes by teachers and also disruptions due to floods that delay the starting of classes. This reduces the learning time of pupils. The schooling expense variable may impact negatively on the enrollment rate because if costs are too high households may not be able to enroll their children.

The following teachers' characteristics are used: gender, age, receive training, professional and

[8] Remark: Deworming at home usually involves the use of traditional medicines or drugs by families without any control of a practitioner.

[9] In relation to the provision of education, institutions to support early childhood in Senegal are: community houses, houses for toddlers, nursery schools and kindergartens. However, enrollment in kindergarten is very low.

academic qualifications and absenteeism. In the Senegalese context, we expect a female teacher has a positive influence on pupils' achievement particularly on girls who identify themselves more easily to a female teacher. Regarding the age of the teacher we assume a positive effect. We introduced the square of the age of the teacher to take into account a possible nonlinearity that may exist between the age and pupil's performance. It is important to note that in the literature, some authors have found no evidence between the age of the teacher and pupils' scores. Concerning the academic degree of teachers, we made the distinction between the national certificate which is a diploma certifying the acquisition of general knowledge at the end of the secondary education and the 'High School Diploma' which is the national graduate certifying the acquisition of high school.[10] The literature reports mixed results regarding the effect of the academic level of teachers on pupils' achievement (Clotfelter et al., 2006). Regarding the variable teachers' teaching training, we expect a positive effect on pupils' achievement. Indeed, training improves the teaching skills of teachers. There is no consensus in the literature as to the effect of the professional degree of teacher. According to CONFEMEN (1999), the teachers trained for a year in Burkina Faso and Cameroon have less satisfactory results than those who received five years of training. In Senegal, the same phenomenon is reflected for teachers who received two years of training compared to those who only received one year.

The characteristics of households. We have included some control variables usually found in the literature such as education spending, health care spending, literacy of the household head, gender of household head and marital status. Two other control variables which are important for our context but not often mentioned in the literature are whether the household owns arable land and cattle. These two variables could be considered as indicators of wealth and we expect they will have a negative effect on pupils' academic performance and also on enrollment, promotion and dropout rates. Indeed, as we previously outlined, especially in rural areas, it is likely that pupils living in households with farmland are required by the families to work in the fields or for domestic work.[11] This will result in keeping them away from school. The same rationale applies to the number of cattle owned by the household. Indeed, the more the head of cattle the higher the probability that pupils's labor is demanded. This variable is relevant in explaining the dropout because the communities who mainly practice livestock farming are generally nomadic and move permanently with their families.

As regards marital status, more than 95% of household heads are married. We then created two marital status consisting of married and unmarried people where unmarried includes singles, unmarried, divorced and widowed. We expect that pupils living in a household with married parents will have a much better performance. Some facts suggest that children living with a divorced or widowed mother are generally more successful than children living in a large polygamous household.

The community characteristics. Studies that have examined the effects of neighborhood or community factors on pupils' performance are still scarce. These factors could have both positive and negative effects on pupils'performance. In our study, we use the following indicators: the existence of a college in the village, living in a community in which some children do not go to school because parents are not interested in school, or where some children do not attend school because they only go to a Koranic school, and the number of primary schools in the village. These variables are context-specific and can enrich our understanding of the determinants of pupils' achievement.

Regarding the existence of a college, we expect a positive effect on performance. Indeed, parents who have no way to help their children to pursue studies in a remote village after their primary certificate will invest little in the education of their children. This could lead to premature termination of schooling. In addition, living in a village where there is a college implies that there are facilities for further study and possibly also that there are elders in these colleges who can help the younger pupils in primary schools. Regarding the variable parents who are not interested in school, we expect a negative effect. The number of primary schools in a community informs about the educational opportunities, so

[10] In the French system, the national certificate is denoted 'Le diplôme national du brevet (DNB)' and the High School Diploma is called 'Baccalauréat'. The latter does not mean bachelor's degree. It is equivalent to the 'General Education Diploma'.

[11] Note that agriculture (crops and livestock farming) is the main economic activity in the target rural regions of the programs under study.

it is expected that this variable will have a positive effect on enrollment. Lastly, to take into account certain unobserved characteristics of the areas where the programs were implemented, we introduced region dummies. The region of reference is Fatick because it has the largest number of schools and students.

3.3.b. Descriptive statistics

The distribution of the pupils according to programs received are shown in the bottom of Table 1. About 4% of pupils receive both programs, 8% receive deworming but not meal, 23% receive meal but not deworming and 65% did not receive any of the two programs. Table 1 also summarizes descriptive by treatment status.[12] To check whether there is any pairwise difference in treatment status, we provide mean difference tests. In what follows, we describe salient features on outcome indicators: scores (aggregate, French and math) and enrollment rate, promotion and dropout rates.

Include Table 1

On average, pupils who received the package of two programs have the highest academic results: 47.66, 45.24 and 50.08 respectively for the aggregate scores and the scores in French and math. Those who have only deworming have the lowest aggregated average score and score in French (36.69 and 35.36 respectively). The lowest average score in math is 36.96 and this occurs in the untreated group. As indicated in the test of mean difference, the differences between groups are significant except between untreated and deworming groups for the aggregate score and score in math.

We observe negative average rate of enrollment for the deworming group, package and untreated. This rate is positive for the meal group (7.6%). Negative values mean that the number of students enrolled in school at year $t-1$ is greater than the number of entries in t. In our data we observe that some schools that reported no registration at t, had registered in $t-1$, resulting in significant negative rates as shown on the distributions. These enrollment statistics are particularly instructive in several respects. Recall that earlier (Section 2) we discussed issues related to the objectives of the school meals and deworming programs and we pointed that several criticisms and doubts persist as for the objectives assigned to them. This is due to the fact that these programs can be diverted from their original objectives, which would explain the particularly high attractiveness of schools where these programs are implemented because they could allow families to meet the food needs of their children. With a lot of caution, we may tentatively say that the observed positive average enrollment rate applies only for the meals group – while the average rates of other groups are negative.

The average rate of promotion is highest in the group of pupils who received the package (81.89%), followed by the untreated group (79.15%), meal group (78.76%) and deworming group (73.34%). Regarding the dropout rate, it is lowest in the package group (10.2%) and highest in the untreated group (16.6%). Note that the test of mean difference indicates that the average enrollment rate between the deworming group (-32.28%) and the untreated group (-31.40%) was not significantly different. The same goes for the average promotion rate between the untreated group (79.15%) and the meal group (78.76%), and the average dropout rate between deworming group (15.18%) and meal group (15.07%).

Include Figures 1, 2, 3 and 4

Figures 1, 2, 3 and 4 display the distribution of outcomes according to the treatment status. For the group of pupils who received the deworming program only (Figure 1), the distributions of scores are basically bimodal with a main mode on the left side. This means that two main populations of pupils emerge: those (but few) with large scores and those with low scores. The same pattern can be observed in Figure 2 for pupils having only the meals program. However, the second modality is less pronounced here. This trend almost vanishes for the last two groups (Figures 3 and 4) for which one observes a unimodal distribution. The major information we draw from the distribution of scores

[12] We do not report the minimum and maximum of variables. Moreover, for dummy variables only the mean is reported as it is well known that the standard deviation for dummies can easily be retrieved from their mean as $p(1-p)$ where p denotes the mean.

is that the academic performance of pupils is quite low. Indeed, most of them have scores below the central value (50). It is therefore clear that improving the academic performance of pupils became an objective of policy makers. Aside from the group of pupils having only the meals program and for whom the enrollment rate has a unimodal distribution (Figure 2), we see a bimodal distribution for other groups. Promotion and dropout rates also show unimodal distribution for all groups except the dropout rate for pupils who only get the deworming program.

To complete the description of the data, as indicated by the test of mean differences in Table 1, we observe significant differences between some outcomes and control variables. This clearly came as support to the fact that experimental methods (e.g, RCTs) are not suited to assess the impact of the package of programs we are studying.[13] In the two subsequent sections, we develop the econometric frameworks.

4. The double-index selection model (DISM)

Let T_{1i}^* and T_{2i}^* denote two *latent* (unobserved) variables denoting the reasons for pupil i ($i = 1, \cdots, N$) to receive treatment 1 (deworming) and treatment 2 (school meals) respectively. These variables are assumed to be functions of *observed* characteristics of the pupil or the household he/she belongs to, which we denote by $\mathbf{w}_{ji}$ ($j = 1$ or 2). Formally,

$$T_{1i}^* = \boldsymbol{\gamma}_1' \mathbf{w}_{1i} + \mu_{1i}, \tag{1}$$

$$T_{2i}^* = \boldsymbol{\gamma}_2' \mathbf{w}_{2i} + \mu_{2i}, \tag{2}$$

where $\boldsymbol{\gamma}_j$ denotes the vectors of parameters to be estimated, and μ_{ji} denotes the error terms. We assume that $\mu_{ji} \perp \mathbf{w}_{ji}$. The observed counterparts to T_{1i}^* and T_{2i}^*, denoted by T_{1i} and T_{2i}, are defined as

$$T_{1i} = \mathbf{1}_{[T_{1i}^* > 0]}, \tag{3}$$

$$T_{2i} = \mathbf{1}_{[T_{2i}^* > 0]}, \tag{4}$$

where $\mathbf{1}_{[\cdot]}$ denotes the indicator function which takes on the value 1 if the corresponding latent variable is positive, and 0 otherwise. In other words, if the unobserved reasons for pupil i to receive treatment j are sufficiently valid, i.e. $T_{ji}^* > 0$, the pupil does receive the treatment, in which case $T_{ji} = 1$. Otherwise, the pupil does not receive the treatment, i.e. $T_{ji} = 0$. The outcome for pupil i, y_i, in terms of achievement (e.g. scores, enrollment, promotion and dropout rate) is given by

$$y_i = \boldsymbol{\beta}' \mathbf{x}_i + \delta_1 T_{1i} + \delta_2 T_{2i} + \theta T_{1i} T_{2i} + \varepsilon_i, \tag{5}$$

where $\mathbf{x}_i$ denotes the control variables, $\boldsymbol{\beta}$, δ_j and θ are parameter vectors to be estimated;[14] $\mathbf{x}_i$ also contains an intercept whose coefficient will be the effect of the absence of treatment on the outcome; ε_i denotes the error term that captures among other things the effect of unobserved factors on the outcome. Since T_{1i} and T_{2i} are endogenous, $\mathbb{E}(\varepsilon_i | T_{1i}, T_{2i}, \mathbf{x}_i) \neq 0$. By including the interaction term, $T_{1i}T_{2i}$ as additional regressor in Eq.(5), we can isolate the exclusive effect of either treatment and their joint effect. Moreover, depending on the sign, θ reflects the complementarity (positive sign) or the substitutability (negative sign) between T_1 and T_2.

The model consisting of Eqs.(1)-(5) is a generalization of the dummy endogenous variable model of Heckman (1978) in that we have two endogenous dummy variables. To estimate the model, we consider two approaches: the Full Information Maximum Likelihood (hereafter FIML) and a generalized two-step Heckman method as described in the next section.

[13] The beauty of RTCs which makes it very popular as a powerful tool for impact assessment is its ability to make the treatment and control groups equal on average in all aspects, i.e, observed and unobserved characteristics of units (see e.g. Duflo et al. (2008)). This is the case when randomization is perfect. However, in reality, randomization is not free from imperfection and selection bias is always likely, examples of which are among others noncompliance and/or non-response (see Horiuchi et al., 2007).

[14] The vectors and matrices are bold faced while scalars are typeset normally.

4.1. FIML estimation

We make the following distributional assumption: conditionally on $(\mathbf{w}_i, \mathbf{x}_i)$, $(\mu_{1i}, \mu_{2i}, \varepsilon_i)'$ is normally distributed with vector mean $\mathbf{0}$ and covariance matrix $\mathbf{\Sigma} = \begin{pmatrix} 1 & & \\ \rho_{\mu_1\mu_2} & 1 & \\ \rho_{\mu_1\varepsilon}\sigma_\varepsilon & \rho_{\mu_2\varepsilon}\sigma_\varepsilon & \sigma_\varepsilon^2 \end{pmatrix}$.[15]

The likelihood function of the model consists of four parts due to the combination of the two treatments. The contributions to the likelihood are as follows: those of pupils who benefit from deworming and canteen meals ($T_{1i} = 1 \wedge T_{2i} = 1$), from deworming only ($T_{1i} = 1 \wedge T_{2i} = 0$), from canteen meals only ($T_{1i} = 0 \wedge T_{2i} = 1$), and from neither one ($T_{1i} = 0 \wedge T_{2i} = 0$). For all four categories of pupils, the outcome is observed. Formally, the likelihood is written as

$$
\begin{aligned}
\mathscr{L} = \prod_{i=1}^{N} & \left[\int_{-\gamma_1'\mathbf{w}_{1i}}^{\infty}\int_{-\gamma_2'\mathbf{w}_{2i}}^{\infty} f_3(\mu_{1i},\mu_{2i},y_i)d\mu_{1i}d\mu_{2i}\right]^{T_{1i}T_{2i}} \\
& \left[\int_{-\gamma_1'\mathbf{w}_{1i}}^{\infty}\int_{-\infty}^{-\gamma_2'\mathbf{w}_{2i}} f_3(\mu_{1i},\mu_{2i},y_i)d\mu_{1i}d\mu_{2i}\right]^{T_{1i}(1-T_{2i})} \\
& \left[\int_{-\infty}^{-\gamma_1'\mathbf{w}_{1i}}\int_{-\gamma_2'\mathbf{w}_{2i}}^{\infty} f_3(\mu_{1i},\mu_{2i},y_i)d\mu_{1i}d\mu_{2i}\right]^{(1-T_{1i})T_{2i}} \\
& \left[\int_{-\infty}^{-\gamma_1'\mathbf{w}_{1i}}\int_{-\infty}^{-\gamma_2'\mathbf{w}_{2i}} f_3(\mu_{1i},\mu_{2i},y_i)d\mu_{1i}d\mu_{2i}\right]^{(1-T_{1i})(1-T_{2i})},
\end{aligned} \tag{6}
$$

where $f_3 = f_2(\mu_{1i}, \mu_{2i}|y_i)f_1(y_i|\mathbf{x}_i, \mathbf{w}_i)$ denotes the trivariate normal density function and where f_2 and f_1 denote respectively the bivariate and the univariate normal density function. Substituting $f_2(\cdots)f_1(\cdots)$ for f_3 into equation (6) yields

$$
\begin{aligned}
\mathscr{L} = \prod_{i=1}^{N} & \left[\int_{-\gamma_1'\mathbf{w}_{1i}}^{\infty}\int_{-\gamma_2'\mathbf{w}_{2i}}^{\infty} f_1(y_i|\mathbf{x}_i,\mathbf{w}_i)f_2(\mu_{1i},\mu_{2i}|y_i)d\mu_{1i}d\mu_{2i}\right]^{T_{1i}T_{2i}} \\
& \left[\int_{-\gamma_1'\mathbf{w}_{1i}}^{\infty}\int_{-\infty}^{-\gamma_2'\mathbf{w}_{2i}} f_1(y_i|\mathbf{x}_i,\mathbf{w}_i)f_2(\mu_{1i},\mu_{2i}|y_i)d\mu_{1i}d\mu_{2i}\right]^{T_{1i}(1-T_{2i})} \\
& \left[\int_{-\infty}^{-\gamma_1'\mathbf{w}_{1i}}\int_{-\gamma_2'\mathbf{w}_{2i}}^{\infty} f_1(y_i|\mathbf{x}_i,\mathbf{w}_i)f_2(\mu_{1i},\mu_{2i}|y_i)d\mu_{1i}d\mu_{2i}\right]^{(1-T_{1i})T_{2i}} \\
& \left[\int_{-\infty}^{-\gamma_1'\mathbf{w}_{1i}}\int_{-\infty}^{-\gamma_2'\mathbf{w}_{2i}} f_1(y_i|\mathbf{x}_i,\mathbf{w}_i)f_2(\mu_{1i},\mu_{2i}|y_i)d\mu_{1i}d\mu_{2i}\right]^{(1-T_{1i})(1-T_{2i})},
\end{aligned} \tag{7}
$$

where $f_1(y_i|\mathbf{x}_i, \mathbf{w}_i) = \frac{1}{\sigma_\varepsilon}\phi_1\left(\frac{y_i - \boldsymbol{\beta}'\mathbf{x}_i - A_i(T_{1i},T_{2i})}{\sigma_\varepsilon}\right)$, ϕ_1 denotes the univariate standard normal density function and $A_i(T_{1i}, T_{2i})$ is given by

$$A_i(T_{1i}, T_{2i}) \equiv \delta_1 T_{1i} + \delta_2 T_{2i} + \theta T_{1i}T_{2i}. \tag{8}$$

The difficulty consists in evaluating the double integrals of Eq.(7) which result in bivariate (standard) normal cumulative distribution functions (cdfs) conditional on a third random variable, y_i. It is known that

$$(\mu_{1i}, \mu_{2i})'|y_i \sim N\left[\begin{pmatrix} \frac{\rho_{\mu_1\varepsilon}}{\sigma_\varepsilon}\left[y_i - \mathbb{E}\left(y_i|T_{1i},T_{2i},\mathbf{x}_i\right)\right] \\ \frac{\rho_{\mu_2\varepsilon}}{\sigma_\varepsilon}\left[y_i - \mathbb{E}\left(y_i|T_{1i},T_{2i},\mathbf{x}_i\right)\right]\end{pmatrix}; \begin{pmatrix} 1-\rho_{\mu_1\varepsilon}^2 & \\ \rho_{\mu_1\mu_2.\varepsilon} & 1-\rho_{\mu_2\varepsilon}^2\end{pmatrix}\right], \tag{9}$$

[15] With $\rho_{12} \neq 0$, Eqs.(1)-(4) form a bivariate probit where σ_{μ_1} and σ_{μ_2} are not identified. Thus, $\sigma_{\mu_1} = \sigma_{\mu_2} = 1$.

with $\mathbb{E}\left(y_i|T_{1i},T_{2i},\mathbf{x}_i\right)=\boldsymbol{\beta}'\mathbf{x}_i+A_i(T_{1i},T_{2i})+\mathbb{E}(\varepsilon_i|T_{1i},T_{2i},\mathbf{x}_i)$, where $\mathbb{E}(\varepsilon_i|T_{1i},T_{2i},\mathbf{x}_i)\neq 0$ and $\rho_{\mu_1\mu_2.\varepsilon}$ denotes the *partial correlation* between μ_{1i} and μ_{2i} conditional on y_i and is given by:[16]

$$\rho_{\mu_1\mu_2.\varepsilon}=\frac{\rho_{\mu_1\mu_2}-\rho_{\mu_1\varepsilon}\rho_{\mu_2\varepsilon}}{\sqrt{(1-\rho^2_{\mu_1\varepsilon})(1-\rho^2_{\mu_2\varepsilon})}}. \tag{10}$$

Using the symmetry property of the normal distribution, we derive the final expression of the likelihood as

$$\begin{aligned}\mathscr{L}=\prod_{i=1}^{N}&\Big[f_1(y_i|\mathbf{x}_i,\mathbf{w}_i)\Phi_2\left(\zeta_1,\zeta_2;\rho_{\mu_1\mu_2.\varepsilon}\right)\Big]^{T_{1i}T_{2i}}\Big[f_1(y_i|\mathbf{x}_i,\mathbf{w}_i)\Phi_2\left(\zeta_1,-\zeta_2;-\rho_{\mu_1\mu_2.\varepsilon}\right)\Big]^{T_{1i}(1-T_{2i})}\\ &\Big[f_1(y_i|\mathbf{x}_i,\mathbf{w}_i)\Phi_2\left(-\zeta_1,\zeta_2;-\rho_{\mu_1\mu_2.\varepsilon}\right)\Big]^{(1-T_{1i})T_{2i}}\Big[f_1(y_i|\mathbf{x}_i,\mathbf{w}_i)\Phi_2\left(-\zeta_1,-\zeta_2;\rho_{\mu_1\mu_2.\varepsilon}\right)\Big]^{(1-T_{1i})(1-T_{2i})}\end{aligned} \tag{11}$$

where Φ_2 denotes the bivariate standard normal cdf, and ζ_k is defined as

$$\zeta_k\equiv\frac{\boldsymbol{\gamma}_k'\mathbf{w}_{ki}+\frac{\rho_{\mu_k\varepsilon}}{\sigma_\varepsilon}\left(y_i-\boldsymbol{\beta}'\mathbf{x}_i-A_i(T_{1i},T_{2i})\right)}{\sqrt{1-\rho^2_{\mu_k\varepsilon}}},\quad k=1,2 \tag{12}$$

To obtain FIML estimates of the model, we can maximize the log-likelihood $\ln\mathscr{L}$ using standard numerical techniques (e.g. Newton-Raphson). Standard errors of the estimates are obtained using the inverse Hessian or the outer product of gradient.

4.2. *Two-step estimation*

The regression equation Eq.(5) is the equation of interest. The population regression can be written in the form of a conditional expectation, i.e.

$$\mathbb{E}(y_i|T_{1i},T_{2i},\mathbf{x}_i)=\boldsymbol{\beta}'\mathbf{x}_i+\delta_1T_{1i}+\delta_2T_{2i}+\theta T_{1i}T_{2i}+\mathbb{E}(\varepsilon_i|T_{1i},T_{2i},\mathbf{x}_i). \tag{13}$$

Since T_{1i} and T_{2i} are endogenous, $\mathbb{E}(\varepsilon_i|T_{1i},T_{2i},\mathbf{x}_i)\neq 0$ and the ordinary least squares (OLS) estimator of $\boldsymbol{\beta}$, δ_1,δ_2 and θ is inconsistent. The endogeneity of T_{ji} ($j=1$ or 2) comes from the fact that T_{ji} depends on μ_{ji} and the latter is correlated with ε_i. Hence, the endogeneity is accounted for by taking the correlations $\rho_{\mu_1\varepsilon}$ and $\rho_{\mu_2\varepsilon}$ into account. The conditional expectation $\mathbb{E}(\varepsilon_i|T_{1i},T_{2i},\mathbf{x}_i)$ can be written as

$$\begin{aligned}\mathbb{E}(\varepsilon_i|T_{1i},T_{2i},\mathbf{x}_i)=\ &T_{1i}T_{2i}\mathbb{E}(\varepsilon_i|T_{1i}=1,T_{2i}=1,\mathbf{x}_i)\\ &+T_{1i}(1-T_{2i})\mathbb{E}(\varepsilon_i|T_{1i}=1,T_{2i}=0,\mathbf{x}_i)\\ &+(1-T_{1i})T_{2i}\mathbb{E}(\varepsilon_i|T_{1i}=0,T_{2i}=1)\\ &+(1-T_{1i})(1-T_{2i})\mathbb{E}(\varepsilon_i|T_{1i}=0,T_{2i}=0,\mathbf{x}_i).\end{aligned} \tag{14}$$

Note the similarity between the four types of likelihood contributions. Using the definition of T_{1i} and T_{2i} (Eqs.3–4) and the latent equations (Eqs.1–2), Eq.(14) can be written as

$$\begin{aligned}\mathbb{E}(\varepsilon_i|T_{1i},T_{2i},\mathbf{x}_i)=\ &T_{1i}T_{2i}\underbrace{\mathbb{E}(\varepsilon_i|\mu_{1i}>-\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\mu_{2i}>-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\mathbf{x}_i)}_{\mathbb{E}(\varepsilon_i|>,>)}\\ &+T_{1i}(1-T_{2i})\underbrace{\mathbb{E}(\varepsilon_i|\mu_{1i}>-\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\mu_{2i}\leq-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\mathbf{x}_i)}_{\mathbb{E}(\varepsilon_i|>,\leq)}\\ &+(1-T_{1i})T_{2i}\underbrace{\mathbb{E}(\varepsilon_i|\mu_{1i}\leq-\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\mu_{2i}>-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\mathbf{x}_i)}_{E(\varepsilon_i|\leq,>)}\\ &+(1-T_{1i})(1-T_{2i})\underbrace{\mathbb{E}(\varepsilon_i|\mu_{1i}\leq-\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\mu_{2i}\leq-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\mathbf{x}_i)}_{\mathbb{E}(\varepsilon_i|\leq,\leq)}.\end{aligned} \tag{15}$$

[16] See for instance Kotz et al. (2000).

The conditional expectations in Eq.(15) involve the truncated trivariate normal distribution. Using the moment-generating function formula along the lines of Muthén (1990), these expectations are shown to be (detailed calculations are gathered in the Supplementary Appendix A):

$$\mathbb{E}(\varepsilon_i|>,>) = \frac{\sigma_\varepsilon \rho_{\mu_1\varepsilon}\phi_1(\boldsymbol{\gamma}_1'\mathbf{w}_{1i})}{\Phi_2\left(\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\boldsymbol{\gamma}_2'\mathbf{w}_{2i}-\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_1'\mathbf{w}_{1i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right)$$

$$+\frac{\sigma_\varepsilon \rho_{\mu_2\varepsilon}\phi_1(\boldsymbol{\gamma}_2'\mathbf{w}_{2i})}{\Phi_2\left(\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\boldsymbol{\gamma}_1'\mathbf{w}_{1i}-\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_2'\mathbf{w}_{2i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right), \tag{16}$$

$$\mathbb{E}(\varepsilon_i|>,\leq) = \frac{\sigma_\varepsilon \rho_{\mu_1\varepsilon}\phi_1(\boldsymbol{\gamma}_1'\mathbf{w}_{1i})}{\Phi_2\left(\boldsymbol{\gamma}_1'\mathbf{w}_{1i},-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},-\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_1'\mathbf{w}_{1i}-\boldsymbol{\gamma}_2'\mathbf{w}_{2i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right)$$

$$-\frac{\sigma_\varepsilon \rho_{\mu_2\varepsilon}\phi_1(\boldsymbol{\gamma}_2'\mathbf{w}_{2i})}{\Phi_2\left(\boldsymbol{\gamma}_1'\mathbf{w}_{1i},-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},-\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\boldsymbol{\gamma}_1'\mathbf{w}_{1i}-\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_2'\mathbf{w}_{2i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right), \tag{17}$$

$$\mathbb{E}(\varepsilon_i|\leq,>) = -\frac{\sigma_\varepsilon \rho_{\mu_1\varepsilon}\phi_1(\boldsymbol{\gamma}_1'\mathbf{w}_{1i})}{\Phi_2\left(-\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\boldsymbol{\gamma}_2'\mathbf{w}_{2i},-\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\boldsymbol{\gamma}_2'\mathbf{w}_{2i}-\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_1'\mathbf{w}_{1i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right)$$

$$+\frac{\sigma_\varepsilon \rho_{\mu_2\varepsilon}\phi_1(\boldsymbol{\gamma}_2'\mathbf{w}_{2i})}{\Phi_2\left(-\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\boldsymbol{\gamma}_2'\mathbf{w}_{2i},-\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_2'\mathbf{w}_{2i}-\boldsymbol{\gamma}_1'\mathbf{w}_{1i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right) \tag{18}$$

and

$$\mathbb{E}(\varepsilon_i|\leq,\leq) = -\frac{\sigma_\varepsilon \rho_{\mu_1\varepsilon}\phi_1(\boldsymbol{\gamma}_1'\mathbf{w}_{1i})}{\Phi_2\left(-\boldsymbol{\gamma}_1'\mathbf{w}_{1i},-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_1'\mathbf{w}_{1i}-\boldsymbol{\gamma}_2'\mathbf{w}_{2i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right)$$

$$-\frac{\sigma_\varepsilon \rho_{\mu_2\varepsilon}\phi_1(\boldsymbol{\gamma}_2'\mathbf{w}_{2i})}{\Phi_2\left(-\boldsymbol{\gamma}_1'\mathbf{w}_{1i},-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_2'\mathbf{w}_{2i}-\boldsymbol{\gamma}_1'\mathbf{w}_{1i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right), \tag{19}$$

where we use the symmetry property of the normal distribution (i.e., $\forall\xi$, $\phi_1(-\xi)=\phi_1(\xi)$) and Φ_1 and Φ_2 denote respectively the univariate and bivariate standard normal cdf. For notational convenience, let

$$\lambda_1^{++} \equiv \frac{\phi_1(\boldsymbol{\gamma}_1'\mathbf{w}_{1i})}{\Phi_2\left(\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\boldsymbol{\gamma}_2'\mathbf{w}_{2i}-\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_1'\mathbf{w}_{1i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right), \tag{20a}$$

$$\lambda_2^{++} \equiv \frac{\phi_1(\boldsymbol{\gamma}_2'\mathbf{w}_{2i})}{\Phi_2\left(\boldsymbol{\gamma}_1'\mathbf{w}_{1i},\boldsymbol{\gamma}_2'\mathbf{w}_{2i},\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\boldsymbol{\gamma}_1'\mathbf{w}_{1i}-\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_2'\mathbf{w}_{2i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right), \tag{20b}$$

for pupils who receive both deworming and meals,

$$\lambda_1^{+-} \equiv \frac{\phi_1(\boldsymbol{\gamma}_1'\mathbf{w}_{1i})}{\Phi_2\left(\boldsymbol{\gamma}_1'\mathbf{w}_{1i},-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},-\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_1'\mathbf{w}_{1i}-\boldsymbol{\gamma}_2'\mathbf{w}_{2i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right), \tag{20c}$$

$$\lambda_2^{+-} \equiv \frac{\phi_1(\boldsymbol{\gamma}_2'\mathbf{w}_{2i})}{\Phi_2\left(\boldsymbol{\gamma}_1'\mathbf{w}_{1i},-\boldsymbol{\gamma}_2'\mathbf{w}_{2i},-\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\boldsymbol{\gamma}_1'\mathbf{w}_{1i}-\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_2'\mathbf{w}_{2i}}{\sqrt{1-\rho^2_{\mu_1\mu_2}}}\right), \tag{20d}$$

for those who get deworming but not meals,

$$\lambda_1^{-+} \equiv \frac{\phi_1(\boldsymbol{\gamma}_1'\mathbf{w}_{1i})}{\Phi_2\left(-\boldsymbol{\gamma}_1'\mathbf{w}_{1i}, \boldsymbol{\gamma}_2'\mathbf{w}_{2i}, -\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\boldsymbol{\gamma}_2'\mathbf{w}_{2i} - \rho_{\mu_1\mu_2}\boldsymbol{\gamma}_1'\mathbf{w}_{1i}}{\sqrt{1-\rho_{\mu_1\mu_2}^2}}\right), \tag{20e}$$

$$\lambda_2^{-+} \equiv \frac{\phi_1(\boldsymbol{\gamma}_2'\mathbf{w}_{2i})}{\Phi_2\left(-\boldsymbol{\gamma}_1'\mathbf{w}_{1i}, \boldsymbol{\gamma}_2'\mathbf{w}_{2i}, -\rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_2'\mathbf{w}_{2i} - \boldsymbol{\gamma}_1'\mathbf{w}_{1i}}{\sqrt{1-\rho_{\mu_1\mu_2}^2}}\right), \tag{20f}$$

for those who get meals but not deworming, and

$$\lambda_1^{--} \equiv \frac{\phi_1(\boldsymbol{\gamma}_1'\mathbf{w}_{1i})}{\Phi_2\left(-\boldsymbol{\gamma}_1'\mathbf{w}_{1i}, -\boldsymbol{\gamma}_2'\mathbf{w}_{2i}, \rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_1'\mathbf{w}_{1i} - \boldsymbol{\gamma}_2'\mathbf{w}_{2i}}{\sqrt{1-\rho_{\mu_1\mu_2}^2}}\right), \tag{20g}$$

$$\lambda_2^{--} \equiv \frac{\phi_1(\boldsymbol{\gamma}_2'\mathbf{w}_{2i})}{\Phi_2\left(-\boldsymbol{\gamma}_1'\mathbf{w}_{1i}, -\boldsymbol{\gamma}_2'\mathbf{w}_{2i}, \rho_{\mu_1\mu_2}\right)}\Phi_1\left(\frac{\rho_{\mu_1\mu_2}\boldsymbol{\gamma}_2'\mathbf{w}_{2i} - \boldsymbol{\gamma}_1'\mathbf{w}_{1i}}{\sqrt{1-\rho_{\mu_1\mu_2}^2}}\right), \tag{20h}$$

for those that don't receive any of the treatments (untreated group). The λ's are generalizations of the inverse Mill's ratio. Replacing the expressions of Eqs.(20a)-20h) into the conditional expectations of Eq.(15) yields

(21)

$$\begin{aligned}\mathbb{E}(\varepsilon_i|T_{1i}, T_{2i}, \mathbf{x}_i) = {} & T_{1i}T_{2i}(\sigma_\varepsilon\rho_{\mu_1\varepsilon}\lambda_1^{++} + \sigma_\varepsilon\rho_{\mu_2\varepsilon}\lambda_2^{++}) + T_{1i}(1-T_{2i})(\sigma_\varepsilon\rho_{\mu_1\varepsilon}\lambda_1^{+-} - \sigma_\varepsilon\rho_{\mu_2\varepsilon}\lambda_2^{+-}) \\ & + (1-T_{1i})T_{2i}(-\sigma_\varepsilon\rho_{\mu_1\varepsilon}\lambda_1^{-+} + \sigma_\varepsilon\rho_{\mu_2\varepsilon}\lambda_2^{-+}) + (1-T_{1i})(1-T_{2i})(-\sigma_\varepsilon\rho_{\mu_1\varepsilon}\lambda_1^{--} - \sigma_\varepsilon\rho_{\mu_2\varepsilon}\lambda_2^{--}),\end{aligned}$$

which after factorization yields

(22)

$$\begin{aligned}\mathbb{E}(\varepsilon_i|T_{1i}, T_{2i}, \mathbf{x}_i) = {} & \sigma_\varepsilon\rho_{\mu_1\varepsilon}\underbrace{\left[\lambda_1^{++}T_{1i}T_{2i} + \lambda_1^{+-}T_{1i}(1-T_{2i}) - \lambda_1^{-+}(1-T_{1i})T_{2i} - \lambda_1^{--}(1-T_{1i})(1-T_{2i})\right]}_{h_1(T_{1i},T_{2i})} \\ & + \sigma_\varepsilon\rho_{\mu_2\varepsilon}\underbrace{\left[\lambda_2^{++}T_{1i}T_{2i} - \lambda_2^{+-}T_{1i}(1-T_{2i}) + \lambda_2^{-+}(1-T_{1i})T_{2i} - \lambda_2^{--}(1-T_{1i})(1-T_{2i})\right]}_{h_2(T_{1i},T_{2i})}.\end{aligned}$$

Since $\mathbb{E}(\varepsilon_i|T_{1i}, T_{2i}, \mathbf{x}_i) \neq 0$, one approach to estimate consistently the population regression (Eq.13) consists in using the control function approach (Heckman 1978, 1979). In other words, we rewrite the regression equation as

$$y_i = \boldsymbol{\beta}'\mathbf{x}_i + \delta_1 T_{1i} + \delta_2 T_{2i} + \theta T_{1i}T_{2i} + \underbrace{\sigma_\varepsilon\rho_{\mu_1\varepsilon}}_{\eta_1}h_1(T_{1i}, T_{2i}) + \underbrace{\sigma_\varepsilon\rho_{\mu_2\varepsilon}}_{\eta_2}h_2(T_{1i}, T_{2i}) + \nu_i, \tag{23}$$

where $\mathbb{E}[\nu_i|\mathbf{x}_i, h_1(T_{1i}, T_{2i}), h_2(T_{1i}, T_{2i})] = 0$ and η_1 and η_2 are additional parameters to be estimated. In theory, the coefficients of Eq.(23) can be consistently estimated using OLS. In practice, one problem occurs in that $h_1(T_{1i}, T_{2i})$ and $h_2(T_{1i}, T_{2i})$ are unobserved as they are functions of the unobserved parameters $\boldsymbol{\gamma}_1$, $\boldsymbol{\gamma}_2$ and $\rho_{\mu_1\mu_2}$, hence the two-step approach:

1. Obtain consistent and efficient (under normality) estimates for $\boldsymbol{\gamma}_1$, $\boldsymbol{\gamma}_2$ and $\rho_{\mu_1\mu_2}$ by estimating a bivariate probit using maximum likelihood. Compute $\widehat{h}_1(T_{1i}, T_{2i})$ and $\widehat{h}_2(T_{1i}, T_{2i})$ by estimating the different λ's given in Eqs.(20a)-(20h) using $\widehat{\boldsymbol{\gamma}}_1$, $\widehat{\boldsymbol{\gamma}}_2$ and $\widehat{\rho}_{\mu_1\mu_2}$.

2. Use $\widehat{h}_1(T_{1i}, T_{2i})$ and $\widehat{h}_2(T_{1i}, T_{2i})$ as regressors in Eq. (23) alongside $\mathbf{x}_i$, T_{1i} and T_{2i} and apply OLS to Eq.(23). Since we use their estimates in lieu of $h_1(T_{1i}, T_{2i})$ and $h_2(T_{1i}, T_{2i})$, the conventional standard errors are not valid and need to be corrected by generalizing the results of Heckman (1976, 1979), or by using techniques of simulation or bootstrap.

5. The generalized Roy model

Roy (1951) introduced a framework of self-selection that aims to analyze occupational choice with heterogeneous skill. This framework is one of the most important in economics and has been widely applied in many other contexts including evaluation. The Roy (1951) model has been extended in several directions and many generalizations have been proposed (see e.g. Heckman and Taber, 2008 and Heckman and Vytlacil, 2007, Chap.70). By generalized Roy model, we mean here multiple selections in the Roy framework also known as endogenous switching regression.

Based on the four regimes: $(1,1)$ for those who receive both treatments; $(1,0)$ for those who receive only treatment T_1; $(0,1)$, those who receive only receive T_2; and $(0,0)$ for those who receive neither treatments, let us define the four corresponding outcomes as y_{i11}, y_{i10}, y_{i01} and y_{i00} respectively. The generalized model of Roy consists of Eqs.(1)-(4) and the following equations:

(24a) $$y_{i11} = \boldsymbol{\beta}'_{11}\mathbf{x}_i + \varepsilon_{i11},$$

(24b) $$y_{i10} = \boldsymbol{\beta}'_{10}\mathbf{x}_i + \varepsilon_{i10},$$

(24c) $$y_{i01} = \boldsymbol{\beta}'_{01}\mathbf{x}_i + \varepsilon_{i01},$$

(24d) $$y_{i00} = \boldsymbol{\beta}'_{i00}\mathbf{x}_i + \varepsilon_{i00}.$$

An individual unit cannot be present in two different regimes at the same time so the correlations between the error terms of Eqs. (24a)-(24d) are not identified and hence set to zero.

5.1. *Maximum likelihood estimation*

In order to estimate the generalized Roy model, we maintain the normality assumption. In this case, $(\mu_{1i}, \mu_{2i}, \varepsilon_{i11}, \varepsilon_{i10}, \varepsilon_{i01}, \varepsilon_{00})'$ is normally distributed with vector mean $\mathbf{0}$ and covariance matrix $\boldsymbol{\Omega}$ defined as

$$\boldsymbol{\Omega} = \begin{pmatrix} 1 & & & & & \\ \rho_{\mu_1\mu_2} & 1 & & & & \\ \rho_{\mu_1\varepsilon_{11}}\sigma_{\varepsilon_{11}} & \rho_{\mu_2\varepsilon_{11}}\sigma_{\varepsilon_{11}} & \sigma^2_{\varepsilon_{11}} & & & \\ \rho_{\mu_1\varepsilon_{10}}\sigma_{\varepsilon_{10}} & \rho_{\mu_2\varepsilon_{10}}\sigma_{\varepsilon_{10}} & 0 & \sigma^2_{\varepsilon_{10}} & & \\ \rho_{\mu_1\varepsilon_{01}}\sigma_{\varepsilon_{01}} & \rho_{\mu_2\varepsilon_{01}}\sigma_{\varepsilon_{01}} & 0 & 0 & \sigma^2_{\varepsilon_{01}} & \\ \rho_{\mu_1\varepsilon_{00}}\sigma_{\varepsilon_{00}} & \rho_{\mu_2\varepsilon_{00}}\sigma_{\varepsilon_{00}} & 0 & 0 & 0 & \sigma^2_{\varepsilon_{00}} \end{pmatrix}.$$

The likelihood function of the model is given by

(25) $$\begin{aligned} \mathscr{L} = \prod_{i=1}^{N} & \left[\int_{-\boldsymbol{\gamma}'_1\mathbf{w}_{1i}}^{\infty}\int_{-\boldsymbol{\gamma}'_2\mathbf{w}_{2i}}^{\infty} f_3(\mu_{1i},\mu_{2i},y_{i11})d\mu_{1i}d\mu_{2i}\right]^{T_{1i}T_{2i}} \\ & \left[\int_{-\boldsymbol{\gamma}'_1\mathbf{w}_{1i}}^{\infty}\int_{-\infty}^{-\boldsymbol{\gamma}'_2\mathbf{w}_{2i}} f_3(\mu_{1i},\mu_{2i},y_{i10})d\mu_{1i}d\mu_{2i}\right]^{T_{1i}(1-T_{2i})} \\ & \left[\int_{-\infty}^{-\boldsymbol{\gamma}'_1\mathbf{w}_{1i}}\int_{-\boldsymbol{\gamma}'_2\mathbf{w}_{2i}}^{\infty} f_3(\mu_{1i},\mu_{2i},y_{i01})d\mu_{1i}d\mu_{2i}\right]^{(1-T_{1i})T_{2i}} \\ & \left[\int_{-\infty}^{-\boldsymbol{\gamma}'_1\mathbf{w}_{1i}}\int_{-\infty}^{-\boldsymbol{\gamma}'_2\mathbf{w}_{2i}} f_3(\mu_{1i},\mu_{2i},y_{i00})d\mu_{1i}d\mu_{2i}\right]^{(1-T_{1i})(1-T_{2i})}, \end{aligned}$$

where f_3 still denotes the trivariate normal density function. Using the results of Section 4.1, the likelihood function can be written as

(26) $$\begin{aligned} \mathscr{L} = \prod_{i=1}^{N} & \left[\Phi_2\Big(\omega_{11},\xi_{11};\rho_{\mu_1\mu_2.\varepsilon_{11}}\Big)\varphi_{11i}\right]^{T_{1i}T_{2i}} \left[\Phi_2\Big(\omega_{10},-\xi_{10};-\rho_{\mu_1\mu_2.\varepsilon_{10}}\Big)\varphi_{10i}\right]^{T_{1i}(1-T_{2i})} \\ & \left[\Phi_2\Big(-\omega_{01},\xi_{01};-\rho_{\mu_1\mu_2.\varepsilon_{01}}\Big)\varphi_{01i}\right]^{(1-T_{1i})T_{2i}} \left[\Phi_2\Big(-\omega_{00},-\xi_{00};\rho_{\mu_1\mu_2.\varepsilon_{00}}\Big)\varphi_{00i}\right]^{(1-T_{1i})(1-T_{2i})}, \end{aligned}$$

where ω_{jk}, ξ_{jk} and φ_{jki} $(j,k \in \{0,1\})$ are defined as follows

(27a)
$$\omega_{jk} \equiv \frac{\boldsymbol{\gamma}_1'\mathbf{w}_{1i} + \frac{\rho_{\mu_1\varepsilon_{jk}}}{\sigma_{\varepsilon_{jk}}}\left(y_{ijk} - \boldsymbol{\beta}_{jk}'\mathbf{x}_i\right)}{\sqrt{1-\rho^2_{\mu_1\varepsilon_{jk}}}}$$

(27b)
$$\xi_{jk} \equiv \frac{\boldsymbol{\gamma}_2'\mathbf{w}_{2i} + \frac{\rho_{\mu_2\varepsilon_{jk}}}{\sigma_{\varepsilon_{jk}}}\left(y_{ijk} - \boldsymbol{\beta}_{jk}'\mathbf{x}_i\right)}{\sqrt{1-\rho^2_{\mu_2\varepsilon_{jk}}}}$$

(27c)
$$\varphi_{jki} \equiv \frac{1}{\sigma_{\varepsilon_{jk}}}\phi_1\left(\frac{y_{ijk} - \boldsymbol{\beta}_{jk}'\mathbf{x}_i}{\sigma_{\varepsilon_{jk}}}\right)$$

In order to obtain ML estimates of the generalized Roy model, $\ln\mathscr{L}$ can be maximized using standard numerical methods.

5.2. *Two-step estimation*

In order to estimate the model using the two-step approach, we write the regression of the subpopulations as

(28) $$\mathbb{E}(y_{i11}|T_{1i}=1,T_{2i}=1,\mathbf{x}_i) = \boldsymbol{\beta}_{11}'\mathbf{x}_i + E(\varepsilon_{i11}|T_{1i}=1,T_{2i}=1,\mathbf{x}_i),$$

(29) $$\mathbb{E}(y_{i10}|T_{1i}=1,T_{2i}=0,\mathbf{x}_i) = \boldsymbol{\beta}_{10}'\mathbf{x}_i + E(\varepsilon_{i10}|T_{1i}=1,T_{2i}=0,\mathbf{x}_i),$$

(30) $$\mathbb{E}(y_{i01}|T_{1i}=0,T_{2i}=1,\mathbf{x}_i) = \boldsymbol{\beta}_{01}'\mathbf{x}_i + E(\varepsilon_{i01}|T_{1i}=0,T_{2i}=1,\mathbf{x}_i),$$

(31) $$\mathbb{E}(y_{i00}|T_{1i}=0,T_{2i}=0,\mathbf{x}_i) = \boldsymbol{\beta}_{00}'\mathbf{x}_i + E(\varepsilon_{i00}|T_{1i}=0,T_{2i}=0,\mathbf{x}_i),$$

where each regression is estimated using data for the corresponding subsamples. Using the results of the conditional expectations of Section 4.2, we can write the regression equations (eqs. (24a)-(24d)) as

(32a) $$y_{i11} = \boldsymbol{\beta}_{11}'\mathbf{x}_i + \sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}}\lambda_1^{++} + \sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}}\lambda_2^{++} + \nu_{i11},$$

(32b) $$y_{i10} = \boldsymbol{\beta}_{10}'\mathbf{x}_i + \sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}}\lambda_1^{+-} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}}\lambda_2^{+-} + \nu_{i10},$$

(32c) $$y_{i01} = \boldsymbol{\beta}_{01}'\mathbf{x}_i - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}}\lambda_1^{-+} + \sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}}\lambda_2^{-+} + \nu_{i01},$$

(32d) $$y_{i00} = \boldsymbol{\beta}_{00}'\mathbf{x}_i - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}}\lambda_1^{--} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}}\lambda_2^{--} + \nu_{i00},$$

with $\mathbb{E}(\nu_{i11}|\mathbf{x}_i,\lambda_1^{++},\lambda_2^{++}) = \cdots = \mathbb{E}(\nu_{i00}|\mathbf{x}_i,\lambda_1^{--},\lambda_2^{--}) = 0$, and where the expressions of the λ's are given in equations (20a)-(20h). Equations (32a)-(32d) can be estimated separately by OLS using the two-step approach described in Section 4.2, i.e.

1. Obtain consistent and efficient (under normality) estimates for $\boldsymbol{\gamma}_1$, $\boldsymbol{\gamma}_2$ and $\rho_{\mu_1\mu_2}$ by estimating a bivariate probit using maximum likelihood. Compute the $\widehat{\lambda}$'s, given in Eqs.(20a)-(20h), by using $\widehat{\boldsymbol{\gamma}}_1$, $\widehat{\boldsymbol{\gamma}}_2$ and $\widehat{\rho}_{\mu_1\mu_2}$.
2. Use the $\widehat{\lambda}$'s as regressors in Eqs.(32a)-(32d) alongside $\mathbf{x}_i$, and apply OLS to these equations. Since we use the estimates of the λ's, the standard errors of the estimates must be corrected once again by generalizing the results of Heckman (1976, 1979), or by using techniques of simulation or bootstrap.

General remarks

Remark 1 (Performance of DISM vs. Roy) *Several comments are in order about the rationale of the use of the two frameworks (DISM vs. Roy) as well as their economic performance. Both models complement each other. They are different and deliver different estimations and treatment effects as it will become clear in Section 6. i) The DISM model uses the selection processes alongside one outcome* *equation for the full sample. It allows to estimate the Average Treatment Effects (ATE). Moreover, as Eq.(5) embeds the interaction term T_1T_2, the DISM model enables us to test for complementarity vs. substitutability within the programs. ii) The generalized Roy model is a switching regression framework with four regimes.*[17] *It also uses the two selection equations but allows for different outcome equations (one for each regime). As a result, in addition to the ATE, we can also estimate heterogenous effects: the Average Treatment Effect on the Treated (ATET) and the Average Treatment Effect on the Non-Treated (ATENT). In both cases (DISM and Roy), the double-index selection given by relations (1-4) is endogenous.*

Remark 2 (Alternative estimation: IV approach) *The Instrumental Variables (IV) can be an alternative approach to the methods developed here (maximum likelihood and two-step control function). IV has the advantage of being simpler and less dependent on distribution assumptions whereas the ML based estimation is known to be efficient. Relying on Imbens and Wooldridge (2007)*[18]*, the IV (for the DISM framework in Section 4) can be summarized as follows:*

1. *Estimate the bivariate probit model using maximum likelihood method.*
2. *Compute* $\hat{\rho}(T_{1i} = 1|\mathbf{w}_i)$, $\hat{\rho}(T_{2i} = 1|\mathbf{w}_i)$ *and* $\hat{\rho}(T_{1i}T_{2i} = 1|\mathbf{w}_i)$.
3. *Use these variables as IV for* T_1, T_2 *and* T_1T_2 *in the estimation of Eq.(5). Moreover the estimation of the covariance matrix of parameters does not require correction related to the estimation in step 1.*[19]

6. Treatment effects

As outlined earlier, our framework allows to identify and estimate a wide range of treatment effects depending on the model used. In the double endogenous selection model we identify a class of average treatment effects. For the generalized Roy model, in addition to the average treatment effects, we provide several heterogenous treatment effects as well.

6.1. Treatment effects in the double-index selection model

Relying on the first model, we can identify several average treatment effects as summarized in Table 2. Let us consider them in turn.

i) *Exclusive effect.* Assume the two programmes T_1 and T_2. The exclusive effect of T_1 respectively T_2 is the marginal effect of T_1 resp. T_2 conditional on the fact that agents are not in the alternative programme. Such effects allow to measure the impact T_1 or T_2 only on the outcome y, given controls $\mathbf{x}$. This leads to the exclusive effects of T_1 and T_2.

ii) *Global effect.* The global effect is the effect of both programmes taken together.

iii) *Additional effect.* The additional effect is the effect following from having additionally another programme. It is given by the difference between the global effect and the exclusive effect. This effect should be distinguished from the global and the sequential effects (see below defined in Section 6.2) even if they are closely related. It is different from the global effect because the implementation starts only with one program, either meal or deworming, contrary to the global effect for which both programs are administered together starting from the beginning of the implementation. It is also different from the sequential effect because the order doesn't matter.

iv) *Relative effect.* Within our framework, we are able to assess the effectiveness of implementing (T_1, T_2) vs. T_1 or T_2. Thus, we have the effect of package (T_1, T_2) vs. T_1 and the effect of

[17]See e.g., Heckman and Taber (2008) for an exposition of the Roy model.

[18]Imbens and Wooldridge (2007): *Control Function and Related Methods, Lecture Notes 6, Summer 2007.*

[19]To save space, we do not report estimation results from the IV method. Estimates are available from authors upon request.

package (T_1, T_2) vs. T_2. We can also assess the effect of a programme vs. the effect of the other programme. For example, in the case of exclusive effects, taking the difference also yields a relative effect between the two programs.

Include Table 2

6.2. Treatment effects in the generalized Roy model

The Roy model allows to compute the average treatment effects as in the case of the double-index endogenous selection model, but also to derive several heterogenous average treatment effects: the effects on the treated and on the untreated. For each of these effects, we also compute the associated exclusive, global, additional and relative effects. In addition, some new effects can be identified viz, sequential and substitution effects. Both effects are relevant for policy analysis.

i) *Sequential effect.* This effect is of particular interest. Depending on which treatment is implemented first, the overall effect may differ. This means that we will not have the same effect if the school meals program is implemented before deworming, and vice versa. In our empirical application where T_1 and T_2 denote deworming and meals programs respectively, it is expected that the sequence T_1T_2 be more efficient than T_2T_1.

ii) *Substitution effect.* By substitution effect, we mean replacing one program with another. For example, what would happen if after having started a program, it is stopped and replaced by another. The substitution effect is different from the sequential effect. The substitution effect is particularly interesting when the substitution is made with programs targeting the same goal. For instance, in the case of the deworming and canteen programs the question arises whether the substitution makes sense. The answer is yes. On one hand, the two programs have the same goal: improve pupils' performance. On the other hand, if during the implementation of programs, a program appears to be more expensive than anticipated compared to the other, and in case of lack of resources, the organizers may face such choices. In this case, it seems clear that the cheapest program will be substituted for the more expensive one. Experience has shown that the deworming program is cheaper than the canteen because the resources mobilized are cheaper. This fact is supported by cost-benefit analysis (see Miguel and Kremer, 2004).

In our data, although both treatments (deworming and meals) have not been implemented sequentially or been substituted, we can identify and estimate these effects. Thus we are able to provide decision makers with powerful policy analysis tools. These effects are summarized in Table 3.

Include Table 3

7. Estimation results

Remember that this study focuses on two things: the treatment effects from the package of deworming and school meals programs alongside the determinants of the academic performance of pupils. Both objectives have motivated our modeling strategy in the previous section. We have estimated the two models presented in the previous section: the DISM model in Eqs.(1, 2 and 5) and the generalized Roy in Eqs.(1, 4 and 24a-24d).[20] The estimation results are provided in Tables 4, 5 and 6 for the score outcomes (aggregate, French and math) and Tables 7 and 8 for the rate outcomes (enrollment, promotion and dropout).

Include Tables 4, 5, 6, 7, 8

[20] All the computations are performed with STATA. Authors developed their own code. Simulated data based codes are available upon request. Despite the complexity of the procedures, the codes are optimized to run fast.

7.1. Selections

The bivariate selection equations (1–2) describe the participation mechanisms in the two programs (deworming and school meals). As documented in the data section, we used the criteria set by World Food Program and the Ministry of National Education of Senegal to motivate the choice of the control variables for the selection equations. Among these criteria, some were recorded by the survey such as being located in an area with food insecurity, or being particularly affected by rising prices. The variables that we use are the existence of a management committee in the school, storage, school cooperative, association of pupils' mothers, grant from the Rural Council, distance to home, the total number of pupils in the school, disruptions that delayed the starting of the courses, the gender of pupils, medical box. These factors of selection are the same regardless of the outcome. This implies that we have the same selection equations for each outcome (aggregate, French and math scores; enrollment, promotion and dropout rates).

For the deworming program, the results show that the total number of pupils, the existence of a management committee of the school, association of pupils' mothers, school cooperative, existence of water point in the school and the gender of pupils have a positive effect on the probability of benefiting from the program. Indeed, the existence of school infrastructure and various associations in schools promote the supply of food and health programs. The existence of a medicine chest in the school reduced the likelihood of benefiting from the deworming program. This suggests that pupils in schools with first aid box are less affected by parasitic worms so that the concerned schools are less likely to get into the deworming program. This may be because schools with medicine box are likely to have already an established medical facility.

On the school meals program, the results show that the total number of pupils, the distance between pupils' home and school, the existence of association of pupils' mothers, a grant from the rural council, storage, disturbances that have caused delays in starting the academic year act positively on the probability of receiving a meals program at school. On the contrary, the existence of school cooperative reduces the probability of receiving school meals program. Indeed, the school cooperative plays several roles (cleanliness of the school, gardening activities, etc.). In reality, in some schools, the school cooperative is not operational. In other schools, the school cooperative plays its role fully and even goes further to organize activities to enable children to enjoy their lunch.

The variable distance to school (distance between school and the pupils' home) is also one of the selection criteria listed by the government for establishing canteens. In our sample, most schools have benefited from the so-called canteens 'price increase'. These were established to respond to the rising prices of food staples. This could explain the fact that we found a positive effect of the distance control on the probability of benefiting from the meal program.

7.2. Outcomes

7.2.a. Scores

It is usually accepted that pupils in schools that are well equipped with 'appropriate' textbooks are likely to perform better.[21] Our results show a nonlinear relationship between the number of pupils for a textbook and test scores. Indeed, the coefficient of the linear term of the control 'Manual' is positive and significant (for all score outcomes) while its square is negative (for the aggregate and French scores). In other words, scores increase with the number of pupils who share a textbook up to a certain threshold from which the scores drop. This threshold is 4 pupils per textbook for the French score. For the aggregate score, the square term is negative but not significant and the turning point is 7, which corresponds to the maximum of pupils per textbook. Observe that the decreasing part of the curve is out of sample. This result could be explained by the fact that the learning time decreases when the number of pupils by textbook increases. This result corroborates the findings of Michaelowa

[21] A well known result in the literature is that of Glewwe et al. (2009). This study evaluates a program of textbook delivered to pupils in Kenya. The authors found that the textbook program lessens pupils' achievement. The problem was that the textbooks were in English which was not the language commonly used by Kenyan pupils at this level of education.

(2006). According to CONFEMEN (1999), French and mathematics textbooks have a positive impact on learning, with a larger effect for the French textbooks.

Another interesting control variable is class size. Our results show a negative but not significant effect of class size on scores (see Tables 4, 5). Estimates based on the Roy model (see Table 6) sometimes show a positive effect, sometimes a negative one depending on the regime. Indeed, for pupils who benefit from deworming, we find a negative and significant relation between class size and the aggregate and French scores. For those who receives the meals program or the package (deworming and meals), the results show a positive and significant relation between class size and test scores. For the untreated group, the effect of class size on French score is negative and significant. Along the lines of Altinok (2006), we could argue that class size does not affect pupils' outcomes in schools with canteens or for those in schools where both programs are implemented. On the contrary, in schools without meals program or with only the deworming program, we find that class size does negatively impact the score in French. This is consistent with Brossard (2003). It is worthwhile noticing that in the Senegalese context, there is a decline of the French language compared to national languages in particular the 'Wolof' language (ANSD, 2006).[22]

We observe a nonlinear relationship between the age of the teacher and scores. The linear term is negative while the square is positive drawing a U shaped relation. As a result, the age of the teacher has a negative effect on pupils' performance up to a threshold from which the relation becomes positive. This threshold is 32 years old for the aggregate score, 34 years old for the French score and 31 years old for math score. In our sample, the age of the teachers varied between 20 and 53 years old with an average age of 31 old for the whole sample. Thus the age of teacher impacts positively on scores when it reaches the average age of 31 years old. This finding regarding the age of the teacher probably reflects an experience effect. Indeed, if we assume that mastering a classroom is positively related to teachers' experience, we can expect a positive effect of the age of the teacher on pupils' performance (Schwille et al., 1991). It is important to remember that in the literature, there is no consensus on the relation between the age of the teacher and pupil's achievement. Indeed, the age of the teacher can interact with both experience and education. This means that teachers of the same age but with different levels of education and different experience will not necessarily have the same effects on pupils' achievement. In conclusion, the effect of age of teachers is much more akin to a cohort effect. The profile we observe is certainly binds to the quality of education they themselves received.

The age of pupils is another potential determinant of their performance. The results obtained from the DISM model (see Tables 4, 5) show a positive and significant effect of pupils' age on scores. UNESCO (1987) considers that the common age for primary school ranges between 6 and 11 years. In our sample, the age of pupils varies between 6 and 15 years. This means that either pupils entered school late, or they failed several times. If we consider the case of late entry, a positive relation can be observed (Schwille et al., 1991). In the case of promotion, one generally expects a negative relation between age and pupils' performance. In fact, when pupils have a high rate of repetition, this indicates a low academic performance. The Roy model (see Table 6) shows a negative relation between the age of pupils and the aggregate and French scores for the group of pupils who benefit from the package. This finding could follow from the fact that this group of students is the youngest on average, meaning the less mature compared to pupils in other groups (see descriptive statistics in Table 1: the average age is about 9.3 against 9.5, 9.7 and 9.9 respectively for pupils in the deworming, canteen and untreated groups).

Another interesting evidence is the positive relation between education spending and the aggregate and French scores. This result is not surprising because the more parents invest in the education of their children the higher achievement we could expect. The estimates also show that disturbed courses, gender of the teacher, level of study or class of students, absenteeism of teachers, deworming at home and living in a community where parents are not interested in school have a negative effect on students' scores. Indeed, disruption and teacher absenteeism decreased the learning time of pupils. According to UNESCO (2005), teacher absenteeism affects much of the time devoted to learning and hence learning

[22]Wolof is the most widely spoken language in Senegal (by the Wolof ethnic group which represents about 45% of the total population, as well as non-Wolof people). This language, which is also spoken in Gambia and Mauritania, is experiencing a cultural expansion.

outcomes. The result regarding the gender of teacher is consistent with the finding of Jarousse and Mingat (1989). Indeed, the authors found similar results relying on data from Togo meaning pupils with female teachers perform better than those with male teachers. For deworming at home, the relation found could be explained by the nature of the drug used for deworming children. Indeed, rural households use either traditional or modern deworming drugs. As we have mentioned in Section 2, many side effects (fatigue or triggered diarrhea) have been reported. Also, the use of traditional drugs is not without consequences. This could lead to a decline in pupils' performance.

The control variables like Koranic school, early childhood institution, existence of latrine, existence of hand washing device, existence of a college in the village where the school of pupils is located have a positive effect on the scores. These results are expected. For example, the effect of college in the village where the school of pupils is operating can be viewed as indirect effect of more advanced sisters or brothers of pupils in this college. They could act as mentors for the younger ones who are in primary school. Unfortunately, we have no direct information on the fact that a pupil would have a brother or sister in a college town. One can also argue that having a college in the village will motivate pupils. The results concerning modern preschool (also known as early childhood institution) and informal school (here Koranic school) are fairly well known in the literature. Indeed, the Koranic school, usually found in Muslim countries, is an informal private educational structure that provides religious education based on memorization. The Koranic school is known for developing the capacity of learning and memory because children learn by heart very early.

On the qualification of teachers, the results show that pupils taught by a teacher with the teachers' teaching training qualification CEAP perform better than those supervised by a teacher with another teachers' teaching training degree (the reference).[23] A surprising result is that pupils taught by teachers without teachers' teaching training qualification perform better than those supervised by teachers with teachers' teaching training degree. In the case of Senegal, CONFEMEN (2007) has reported no evidence or negative correlation between teachers' teaching training and pupils' achievement. Especially in rural areas, this can be explained by two factors. First, in practice, it may be that those teachers in the category without teachers' teaching training degree are awaiting to graduation because most often they have already passed the written examination. Second, they are teachers whose motivation is much more important than those with teachers' teaching training degree. Indeed, they can be inspected at any time. This control is crucial for their career. The performance of pupils under their care is reflected in the state of their job. As a result, it is likely that this motivation is a push factor which leads them to supervise pupils very well. This may also explain why pupils supervised by these teachers are more effective.

Regarding the academic degree of teachers, the results from the DISM model show that pupils supervised by a teacher with the High School Diploma perform better in mathematics than those supervised by a teacher with the national certificate. As pointed out by Rivers and William (2002), this result suggests that teachers with High School Diploma and more have a higher level of knowledge in mathematics than those with the certificate. When we use the Roy model, we get a positive relation between the scores and the proportion of teachers with High School Diploma for the group of pupils who received the deworming program. On the contrary, the effect is negative for pupils who received the meals program only or the package. This finding is consistent with the results of CONFEMEN (1999). The results also show that pupils taught by teachers who have received teachers' teaching training are less successful in mathematics than those taught by teachers who have not received such training. This result is surprising but could be explained by the length of the teachers' teaching training. As pointed out by UNESCO (2000), the impact of the training on pupils' achievement becomes positive only if the training covers several periods, otherwise one can observe a negative effect.

On the geographical area, the results show that students living in Diourbel perform better than those living in Fatick (reference) unlike those living in Kolda and Sédhiou who record weak performance. As we have already stated in the data section, Kolda and Sédhiou are isolated southern regions

[23]It is worth remembering that the two most important professional degrees in Senegal are the CAP (Certificat d'Aptitude Pédagogique, meaning 'Pedagogical Aptitude Certificate') and CEAP (Certificat Elémentaire d'Aptitude Pédagogique, which is 'Basic Pedagogical Aptitude Certificate').

with very weak risk management capacity and which practice mainly livestock. Fatick and Diourbel are located in the center with a good ability to manage risk. These two regions are predominantly involved in agriculture.[24] In the southern regions, the livestock system is traditional and extensive. The combination of heavy rainfall, dense water system and the availability of crop residues (e.g. rice straw, stalks of millet and corn, peanut vines, etc.) after the rainy season promote the development of a rich and varied pasture capable of maintaining the herd throughout the year (ANSD 2010). However, the frequency of bushfires leads to food deficits at the end of the dry season (by end of May, June and July). It is worth noticing that this period also corresponds to the exams period for pupils. This means that at the end of the school year, farmers are concerned by the search of food for livestock. As some pupils are requested by their family to help with the economic activities, this increases their absenteeism and negatively impacts their performance.

The coefficient of the treatment dummy T_1 for the deworming program is negative and significant whereas the dummy of the meals program is of the opposite sign for all scores except for the score in math for which T_2 is not significant. Note that these effects are not the treatment effects of the programs as the estimated partial correlation coefficients are also significant. Consequently, the treatment effects will be computed as derived in Section 6. As we outlined in Section 4, an interesting aspect of our specification (see Eq.5) is that it enables to investigate whether deworming and meals programs are complementary or substitutes. This is given by the sign of the interaction term T_1T_2. The coefficient is positive and significant for the aggregate and French scores meaning that in the perspective of improving pupils' achievement, the two programs are complementary.

7.2.b. Enrollment, promotion and dropout

The estimation results for enrollment, promotion and dropout rates are reported in Table 7 and 8.

Enrollment. The control variables temporary shelters, association of pupils' parents, age of teacher, Koranic school, snack, pupils who eat their fill and literacy of the household head have a positive effect. Particularly, we find a U shape relation between the age of teacher and the enrollment rate with a threshold at 32 years old from which the age of teacher has a positive effect. On the contrary, determinants like class size, health expenditure, distance between pupils' home and their school, disturbances that have delayed the starting of courses, gender of the teacher, holding a farmland and school expenses have a negative effect. The coefficients of these variables are all of expected sign except for the variable distance from pupils' home to their school for which we do not anticipate a particular sign. The result shows that living less than one kilometer from the school has a negative effect.

Another interesting and intuitive result is that having a literate household head increases the enrollment rate. On the contrary, the enrollment rate declines with schooling expense. This result is important for education policy in improving the literacy rate in rural areas where the living standard are rather low. Indeed, if policy makers want to encourage families to send their children to school, it would be interesting to ensure that the cost of schooling is not too high. Two other results are worth noting: having a male teacher and holding arable land have negative effect. In the first case, in rural areas, the enrollment of girls is not always well received. The promotion of female teachers may be desirable and may help in that respect. In the second case, arable land increases the practice of child labor, which would in turn reduce enrollment. The geographical location or regions also influence the rate of enrollment. Indeed, contrary to Kolda and Sédhiou that have a negative effect on the enrollment rate compared to Fatick (reference), Diourbel has a positive effect.

Relying on the Roy model, for the pupils who participate in the deworming program and those receiving the package, we see that the number of classes in temporary shelters have a negative effect. On the contrary, for the group of pupils in the meals program and those in the untreated group, the effect is positive. We also have a negative relation between enrollment and the proportion of children who have experienced early childhood institution and those who bring a snack for the group receiving meals program. Indeed, as the pupils in our sample are at second and fourth year class, if there are

[24] In our sample, the number of head of cattle by household varied between 0 and 500 in the region of Kolda, 0 to 502 in Sédhiou, 0 to 111 in Fatick and 0 to 48 in Diourbel. As for agriculture, we have the following proportions of arable land holding in each region: 97% in Diourbel, 92% in Fatick, 96% in Kolda and 87% in Sédhiou.

no children of school age in the family and even if the pupils had experienced an early childhood institution or bring food to school, it is possible to find a negative relation between these variables and the enrollment rate.

Promotion. The variables temporary shelters, age of teacher, age of pupil, distance to school, association of pupils' parents, gender of the teacher, teachers' teaching training, Koranic school, early childhood institution, pupils who eat their fill and ownership of arable land have a positive effect. Indeed, as in the case of enrollment rate, there is U shape relation between the age of the teacher and the promotion rate with a turning point at 38 years old. On the contrary, health expenditure, number of head of livestock owned, disturbance that have caused delay in courses and absenteeism have a negative effect. Note that holding an arable land has a positive effect, while the number of head of livestock affects the promotion negatively. As we have already mentioned, this result may be related to the economic characteristics of the study areas. On the one hand, Kolda and Sédhiou have low capacity to manage risk and these two regions are those where households have the greatest number of heads of cattle. On the other, Diourbel and Fatick are more agriculture oriented. In addition, the practice of livestock based on a system of transhumance in which farmers often move with their families is not beneficial to children who go to school. On the geographical locations, the results show a positive effect of Diourbel and Sédhiou compared to the Fatick region. This effect is negative for the Kolda region.

The deworming program has a positive effect while the meals program has a negative and significant effect. The sign of the coefficient of the interaction term T_1T_2 reveals that the two programs are complementary. The estimates derived from the Roy model support the previous findings except for the control variable eat at fill in the group of meals program.

Dropout. The variable temporary shelters, class size, age of pupil, distance to school, association of pupils' parents, gender of teacher, teachers' teaching training, Koranic school, early childhood institution, pupils who eat their fill, ownership of arable land and the existence of a college in the village have a negative effect. Remember that now (in the case of the dropout rate), a negative sign on a coefficient is a positive result as we seek to reduce the dropout rate. On the contrary, the controls health spending, number of cattle, disturbances that caused delay in starting the courses, the gender and the literacy of household head have a positive effect on the dropout rate. The coefficient of the variable arable land is negative while the number of cattle is positive. This means that children in households that keep livestock are more likely to drop, while the possession of arable land reduces the dropout rate. This result is very interesting in two respects. On the one hand, as we have already widely documented, farmers are mainly located in the regions of Kolda and Sédhiou which are landlocked with low capacity of risk management. These farmers often face problems of feeding livestock at the end of each school year. On the other hand, we can link this result with that obtained from the scores outcome so that the two results complement each other. Indeed, we obtain a negative effect of the variable number of cattle on the scores while the effect on the dropout rate is positive. As for regions, the results show that there is a negative relation between the dropout rate and Diourbel and Sédhiou compared to Fatick, unlike the Kolda region where the effect on the dropout rate is positive. Deworming and meals programs have respectively a negative and a positive effect on the dropout rate. The coefficient on the interaction term T_1T_2 shows that both programs are substitutes with the aim of reducing dropouts.

The estimates obtained from the Roy specification pointed to the same direction as those observed from the DISM model except for temporary shelters, class size and the age of pupils for the deworming regime. With regard to the gender of pupil, the estimation results for the deworming and package regimes show a negative effect of male pupils on dropout rate.

7.3. Treatment effects

As we have described in Section 6 and summarized in Tables 2 and 3 the package of deworming and meals programs and the data sampling allow us to estimate a wide range of treatment effects. Depending on the specification, we have computed these effects for the entire population: Average

Treatment Effect (ATE) and for subpopulations of treated (ATET) and untreated (ATENT). For each, we distinguish the exclusive, global, additional and relative effects in the case of DISM model. In addition, we include sequential and substitution effects in the case of the Roy model. The results are presented in Tables 9, 10 and 11 for the score outcomes, and in Tables 12 and 13 for the enrollment, promotion and dropout rates. Let us now take them in turn.

Include Tables 9, 10, 11, 12, 13

7.3.a. Scores

Exclusive effects. Remember the exclusive effects are the effects of each program separately. These effects are positive and significant. Thus, having only the deworming program has a positive and significant effect on pupils' achievement (aggregate, French and math). The exclusive effect of meal is also positive and significant. In other words, each program taken separately has a positive and significant effect on pupils' achievement. It is important to note that the effect of the meals program is more pronounced than the deworming. The generalized Roy model provides exclusive effects that point to the same direction as those obtained from the DISM specification.

Global effects. The global or overall effect is the effect of the package, i.e, the combination of deworming and meals. The global effects are positive and significant for all scores. Note that the global effects are larger than the exclusive ones. This implies that pupils who get both deworming and meals experienced greater improvement in their academic performance compared to pupils who receive only one of the two programs. This result is very interesting and is consistent with our expectations. Indeed, as we have mentioned earlier from the estimation results, the two programs are complementary. This means that the global effect is expected to be higher than the sum of exclusive effects. The global effects computed from the generalized Roy model tell the same story as those obtained from the DISM.

Additional effects. These effects are positive and significant both from the DISM and the Roy framework. This means that if pupils have already enjoyed the meals (or deworming), then taking deworming (or meals) in addition improves their scores. The sign of this effect can be seen as a corollary of the complementarity of the two programs. Remember that the additional effect is different from the global and the sequential effects as we have shown in Section 6.

Relative effects. Relative effects seek to compare pairwise programs, including the fact of having the package vs. a single program. We observe that the relative effects of the package vs. deworming is positive and significant. The same holds for package vs. meals. It is worth noticing hat the relative effect of the package vs. deworming is larger than package vs. meals. This is not surprising as the exclusive effect of the meals is higher than that of deworming. We observe that the relative effect of deworming vs. meals is negative and significant for all scores. This result makes sense because the exclusive effect of meals is larger than the exclusive effect of deworming. The relative effects calculated from the generalized Roy model tell the same story.

In addition to the average treatment effects (ATE) discussed above, the generalized Roy model allows us to estimate the effects on the treated (ATET) and on the untreated (ATET). As in the case of ATE, here we also have exclusive, global, and additional effects.

Average treatment effects on the treated (ATET). Except for the French score, we observe that the exclusive effects on the treated are larger than their analogue ATE. The global effects of both programs are greater than the exclusive effects and greater than the sum of the exclusive effects. Observe that for the math score, the exclusive effects of deworming are larger than the effects of the meals program. This explains why we have a positive and significant relative effect of deworming vs. meals.

Average treatment effect on the untreated (ATENT). Regarding the effect on the untreated, i.e, the group of pupils who received neither deworming nor meals, the purpose is to inform policy makers on the rationale for extending the programs to a wider population. Indeed, such extension could result in significant costs of implementation. The results show that the exclusive effects of deworming are negative while those of the meals program are positive. It is important to note that the combination of the two programs greatly improves pupils' achievement. We also obtain positive additional effects. The relative effects of deworming vs. meals are negative because the exclusive effects of meal are larger than those of deworming. So for untreated pupils, it is recommended to combine the two programs to increase scores.

Sequential effects. The sequential effect is of particular interest as it accounts for the order in which the programs are implemented. Indeed, we expect the effect to differ depending on whether pupils got school feeding first and deworming next or vice versa. From a nutritional perspective for example, the ideal order would be to deworm first, hence the rationale of the sequence. Unfortunately, we do not have a nutritional outcome indicator for which it may be expected that the sequence T_1T_2 might be more efficient than T_2T_1. For the group of treated pupils, there are positive sequential effects. However, the sequence T_2T_1 proves to be more effective. Thus, it seems more advantageous to introduce the meals program before deworming. As we have discussed in Section 2, this result could be related to the negative perception that some families have towards deworming as consequences of the sides effects of drugs used. On the contrary, for pupils in the untreated group, it is better to do deworming first. For this group, introducing the meals program before deworming significantly lowers pupils' achievement.

Substitution effects. For pupils in the treated group, we observe a very interesting result. Indeed, introducing the canteen until a certain time and replacing it with a deworming program is more beneficial in terms of improving pupils' academic achievement than the reverse. This is important for policy analysis in particular for policy makers and NGOs who fund these kind of programs. Indeed, we know that a deworming program is far less expensive than meals program. We will come back to this aspect in the next section for further details through the cost-effectiveness analysis. What this result says is that, if for one reason or another, we have to substitute a program for another (for example funding limitations), then it is more interesting to replace the meals program by the deworming if we seek to improve pupils' academic achievement. This result is consistent with the sequential effect.

For the untreated group, deworming pupils first before replacing the program by meals would positively act on scores. However, unlike pupils in the treated group, it is not beneficial to introduce meals program, and then replace it with deworming. Again, this is consistent with the sequential effect results. Overall, the combination of the two programs is more beneficial in terms of increasing pupils' academic achievement.

7.3.b. Enrollment, promotion and dropout

Enrollment. We expect positive effects of programs on enrollment rate. The estimates give us expected impacts for the meals program and unexpected effects for the deworming. The exclusive effect of meals and deworming is respectively positive and negative. Even if the additional effect is positive, it is not high enough to offset the negative impact of deworming. We also observe the global effect is negative which means that putting the two programs together decreases the enrollment rate.

The relative effect of the package vs. deworming is positive. This is not surprising because we have an exclusive effect of deworming which is negative and an additional effect which is positive. So the relative effect of the package vs. deworming simply means that when you set as goal to increase enrollment, among deworming alone and the combination of the two programs, it is better to choose a combination of both. The relative effect of the package vs. the meals is negative. This implies that when we set the target of increasing enrollment, the implementation of the meals program alone is better than the package. The relative effect of the meals program compared to deworming is positive. This is normal because the exclusive effect of meals is positive while that of deworming is negative. This means that the meals program would better help to increase enrollment compared to the deworming program.

Promotion. Here positive effects are expected. The exclusive effect of deworming is negative while other effects are positive and significant. The global effects show that combining the two programs is the best option. For the DISM model the global effect is computed as 7.040 which is larger than the effect of the meals (2.727) and deworming (-5.198). For the generalized Roy model, the global effect is computed as 2.547 which is lower than the meals (5.021) and higher than the deworming (-8.290).

The relative effects clearly reveal that the package perform better than the single programs. The relative effect of the meals program vs. deworming shows that if one has to choose between the two alternatives, implementing the meals program fits better the target of achieving a higher rate of promotion. The exclusive effects lead to the same conclusion.

Dropout. Here we expect negative effects. Note that negative treatment effects here mean that the program has reduced the dropout rate. The exclusive effect for deworming is negative as well as the effect of the meals program. The global effect indicates that the combination of the two managed to reduce significantly the dropout rate compared to the single programs. Indeed, the global effect is computed as -9.029 in the DISM and -8.100 in the generalized Roy model whereas the figures for the exclusive effects are -1.443 and -4.797 for the deworming and the meals in the DISM and -1.263 and -5.430 in the generalized Roy model, respectively.

The relative effect of the package vs. deworming shows that the package performs better in terms of reducing dropouts. The relative effect of the package vs. meals is slightly lower than the exclusive effect of the meals program. The relative effect of meals compared with deworming shows that the former performs better.

8. Policy analysis

8.1. Cost-effectiveness

A major policy issue of impact analysis is whether other alternatives are more effective than the programs under study in terms of cost-effectiveness. Cheung and Perrotta (2011) outlined that there are very few papers that studied the cost per outcome for school meals programs. Relying on an experiment in Cambodia, they found that on-site school feeding is the most cost-effective program while distributing take home rations is relatively expensive. They also found that adding the deworming intervention to both on-site feeding and take home ration make the full package much more cost-effective thanks to the fact that the complete package attracts many more pupils and the deworming medications are extremely cheap. Miguel and Kremer (2004) found that the cost per additional year of school participation for the deworming is very cost-effective compared to other programs. In this section we conduct a cost-effectiveness analysis for our package. We will compare various alternatives in terms of cost effectiveness in improving pupils' performance.

A first step in this analysis consists in determining the operation cost of the programs. Tables 14 and 15 report the average cost per year of running deworming and meals programs. These costs have been calculated using information obtained from the Division of School Canteens (DCS) of the Ministry of Education of Senegal. Indeed, the World Food Program has planned 16,900 tons of food for a total cost of 7,165,413,861 CFA in 2011. This is intended for 3,400 schools or 560,000 pupils, in elementary schools in few regions, including Fatick, Kolda, Sedhiou, Diourbel and Matam.

We used this information to compute the cost per child of the meals program in 2011. To these costs, we added costs related to strengthening capacities and resources of the Division of School Canteens, personnel responsible for the canteens and school management committees. For expenses related to deworming, we used the information obtained from the division of school canteens (DCS) and the DCMS of the Ministry of education. In fact, in 2011, it was planned for some regions to receive 400,000 mebendazole tablets for 200,000 pupils meaning two tablets per pupil and per year. The estimated cost of a tablet is about 16 CFA, so the total cost of the drug is 6.4 million CFA. To these costs, we added estimated costs of transportation, mission of advocacy and surveillance. To assess the cost-effectiveness we used the cost of a program divided by the percentage of additional outcome due to the program.

Include Tables 14, 15

8.1.a. Scores

The results for the cost effectiveness analysis are reported in Tables 16 and 17. Our findings are consistent with the results in the literature. The deworming program is by far the most cost effective in increasing pupils' achievement compared to the meals program. Indeed, with the deworming program it takes about 37,038 CFA per year and per pupil to increase the French score by one point, whereas this figure is about 761,227 for the meals program. As a result, the meals program is twenty times more expensive. The combination of both programs cost about 237,166 CFA per pupil and per year to increase the score in French by one point. To increase the score in math by one point it will take about 1,540; 557,089 and 107,304 CFA per year and per pupil for deworming, meals and for the package respectively. It is important to note that deworming alone is more cost effective in terms of increasing scores than the combination of the two programs.

Include Table 16

This makes the deworming program the easiest and least expensive to implement, because it does not require all the material required by the establishment of a canteen. However, at the same time deworming is not the program that has the greatest impact for pupils (in terms of academic results) and for the families given their attitude towards deworming. Also, most families would prefer canteens as they contribute directly to the alleviate food poverty which is a serious problem in rural areas.

The analysis also shows that the introduction of canteen before deworming is more cost effective than introducing deworming first. For example, to increase math score by one point, the meal-deworming sequence cost about 132,302 CFA and the deworming-meal sequence cost about 238,903 CFA. The substitution of the deworming program to the meal is more cost effective compared to the reverse. Overall, compared to the meals program alone, the combination of both programs, whatever the order of implementation or substitution, the deworming alone is much more cost effective.

8.1.b. Enrollment, promotion and dropout

The results show that it takes about 1,172.046 CFA to increase the enrollment rate by one percent with the school feeding program. In terms of promotion rate, we find that the package (with 1,871.323 CFA) is more cost effective than the meals program (4,803.801 CFA). It is not surprising that deworming only is not enough to increase promotions. Indeed, we know that deworming improves the health of children and so it must be combined with another program (here meals) to be more beneficial.

Include Table 17

For the dropout rate, we find evidence that deworming is more cost effective than the meals program only and the package. However, the package is more cost effective than the meals program. Indeed, to reduce the dropout rate of 1%, it takes 51,386 CFA per year and per pupil about for the deworming program, 2,730.866 CFA for meals program and 1,459.089 for the package.

8.2. Welfare-enhancing effect of deworming and meals programs

In this section, we discuss the welfare implications of the two programs for households. The question is whether having pupils benefiting from the programs improves households' welfare. We call this effect, *intra-household externality.* As outlined earlier, this externality occurs at two levels: firstly deworming can protect other household members of contagion or transmission of worms. Then, having meals at school reduces significantly household food expenditure contributes to or more than 70% of the total household expenditure.

As we have discussed earlier, health and nutrition programs are part of economic and social policies that aim at poverty alleviation in developing countries. The surveys used in this study have been also designed to collect data on households' living standards as well as community and school characteristics. We use this rich information to study how the access of pupils to the deworming and meals programs has impacted household welfare. Of course, we do not aim at explaining household welfare solely in terms of the access of their pupils to the programs. Other driving factors such as inequality, food intake, the access to various services and so on will be accounted for.

8.2.a. Welfare measurement

Welfare is ideally reflected by the total utility obtained from all goods and services consumed. In practice the comparison of welfare levels across households can rely on money metric utility, meaning the minimum cost of reaching a given utility level given a vector of prices (see Deaton and Muellbauer, 1980 and Deaton, 1980, for further details). This implies that for a utility maximizing household, money metric utility is given by that household's total expenditure. In order to compare welfare across households, on assumes that households with a given set of characteristics (size, composition, wealth, etc.) have a same utility function. As a result, when all households face the same prices (which is usually the case under perfectly competition), one can translate the quantity of goods and services into expenditure and aggregate these expenditures across items. Such expenditures are proxy of real consumption of goods and services from which we can hypothesize that households derive welfare. However, the measurement of welfare needs further behavioral assumptions about the utilities which are not observable.

Let us assume that we have j items for i households for which expenditures $\omega_i = (\omega_1, \cdots \omega_j)$ are available. So ω_i is the aggregate expenditure over all j items for household i. As the data concern households of different demographic composition, this directly introduces the question of equivalence scales. An equivalence scale may be a simple per capita measure or a more sophisticated way to account for the fact that, within any given household, economies of scale may operate via the consumption of certain goods. Here we made the correction by using expenditures by *adult equivalent*.[25]

In our application below ω_i is the sum of $j = 9$ expenditure items: food, leisure, clothing, telephone, water, electricity and gas, transportation, education, health and others. We use this welfare measure and intra-households data (*household characteristics such as composition, age, economic activity, etc.*), *village characteristics* and *inequality measures* that our data set make available to perform the welfare analysis. As discussed by Deaton and Muellbauer (1980), endogeneity of household characteristics such as household composition may be an issue. Indeed, the decisions on the number of children and expenditure might be simultaneous and introduces statistical bias if the model specification does not fit well. However, as outlined by Deaton and Muellbauer (1980), in the short run, the family composition is much less endogenous than expenditures as the decision on whether to have another child is not daily and is likely to depend on future expectations. As nicely phrased by Tobin (1973) and cited by Deaton and Muellbauer (1980), 'children are not chattels that can be readily sold or otherwise disposed of'.

Another source of potential endogeneity may come from the inequality measure. As pointed by Deaton and Muellbauer (1980), in practice, there is reasonably wide assent that inequality should not depend on the level of expenditures, but on their distribution. In that sense, we could make the inequality regressor as function of the distribution of expenditure.

8.2.b. Welfare estimation

Based on the above, our empirical strategy is a system of equations regression:

$$\omega_i = \boldsymbol{\eta}'\mathbf{z}_i + \xi I_i + \epsilon_{1i} \qquad i = 1, \cdots, H \tag{33}$$

$$I_i = \alpha + \beta F(E_i) + \epsilon_{2i} \tag{34}$$

[25] Expenditure per *adult equivalent* is the ratio between total expenditure and household size per adult equivalent. To calculate the size of the household per adult equivalent, we used the equivalence scale of Oxford A which is the old OECD scale and is widely used in poverty analysis (note that Oxford B scale corresponds to Atkinson and al., 1995). With this scale, the household head is counted as 1, other adults in the household are worth 0.7 adults while children (less than 14 years) account for 0.5 adults. This leads to the following definition: Adult equivalent size = 1 + 0.7(number of other adults) + 0.5(number of children less than 14 years).

where i denotes a household, ϵ_{1i} and ϵ_{2i} are error terms with zero mean and allowed to be heteroskedastic. The first equation is the equation of interest that relates welfare ω_i to a set of controls $\mathbf{z}$ and inequality measure I. In the second equation, inequality is function of the distribution of expenditure $F(E_i)$. In the estimation, we use the density of E_i. The determinants of welfare $\mathbf{z}$ include:

i) *Treatment status*: number of children in household i benefiting from programs (deworming and meals).

ii) *Household characteristics*: includes household composition (number of children aged between 0-5, 6-14 and 15 and more), area of arable land owned the household in hectare (dummy: between 0-5 which is the reference, 6-10, 11-15 and 16 and more), number of livestock owned by the household, number of meals taken per day by the household, age of household head, presence of electricity in the house (indicator), gender of household head (indicator), literacy of household head (indicator).

iii) *Inequality measure*: The literature reports various measures of inequality including among others the Gini index, the generalized entropy index of Theil and Atkinson.[26] Although Gini index is the most widely used inequality index, for robustness purpose, we use these three measures of inequality. The inequality indexes are computed at village level.

Descriptive statistics of variables used in the welfare analysis are reported in Table 18. As outlined earlier, total expenditure is the sum of 9 components with the subsequent contribution of each to the total expenditure: food (73.76%); leisure (0.34%); clothing (3.5%); telephone (3.09%); water, electricity and gas (2.5%), transportation (4.27%), education (2.83%) and health (3%) and others (6.7%). Clearly, food expenditure represent the main consumption spending of household. On average, 0.37 children per household get the meals program, while 0.12 have the deworming and 0.05 have both. The average number of meals per day is about 3, but can go up to 6 which quite substantial. However, this is typical in rural areas where meals can be very fragmented. Another important item is the high number of livestock, with an average of 8.7 per household.

Include Table 18

Estimation results are reported in Table 19. The estimation is implemented by three stages least square which involves instrumental variables; the exogenous variables are taken to be instruments for the endogenous variable. The control variables: number of children receiving the meals program, the package (combination of meals and deworming), ownership of arable land, number of meals per day, presence of electricity in the house, literacy of household head have a significant and positive effect on households' welfare. The finding regarding the number of children receiving the meals and package can be explained in two ways. On the one hand, as we already know from the treatment effects, the implementation of school canteen and the package improves pupils' scores, promotion and dropout rates. Therefore the welfare of households having children beneficiaries is improved. On the other hand, in a context of poverty and vulnerability of households, if there are pupils who received school meals, other household members will have relatively more food than usual. In addition, we know that food expenditures are by far the largest share of total spending (more than 70%). As a result, households with children benefiting from the school feeding will spend less on food which directly contributes to improving their well-being. It is also important to note that the deworming program alone does not contribute significantly to improving households' welfare. The coefficient of this control is positive but not significant. However, the number of children receiving the combination of both programs increases welfare more than the number of children benefiting from meals program alone. This finding supports the complementarity nature of the package.

Include Table 19

[26] See e.g., Atkinson (1970) and Deaton (2013).

In view of this result and the finding presented in the previous section, it appears that school meals and the package not only have a positive effect on improving students' achievement but also contribute to enhance households' welfare. In terms of economic policy if policymakers agree on the objective of improving educational outcomes and households' well-being as well, the school meals program or the combination of school meals and deworming can serve as lever to achieve this goal. This result is complemented by that on the number of meals taken per day which shows that increasing the number of meals improves households' well-being. In addition, the control ownership of arable land (area between 11 and 15 ha and 16 ha and more) has a positive and significant effect on welfare compared to the area between 0 and 5 ha which is the reference. This result provides some interesting insights into the economic behavior of households. Indeed, assets such as land, equipment and real estate are well known factors that may contribute to improving welfare thanks to their potential sources of revenue. This result shows the positive value that households give to their property. The result also suggests that the effect of arable land becomes significant only after a sizable surface, here 6 ha.

The presence of electricity in the house also has a positive effect on welfare. Indeed, in rural areas, having power connection is not only an indicator of a certain ease, but also it allows the household to use a number of electrical equipment (TV, fridge etc.) that evidently may improve daily life. The literacy of the head of household is conducive to welfare. A similar result was found by Glewwe et al. (2001) in the case of Ivory Coast. The results also indicate a nonlinear relationship between the age of household head and welfare. Recall that in our sample, the age of household head ranges between 18 and 98 years old. This variable displays a U-shaped curve with a threshold around 54 years old. This finding is somewhat surprising at first sight. However, it can be explained by the context of our study. Indeed, in rural areas, it is not uncommon to have relatively young household heads. The majority of families live from agriculture, livestock and also remittances. Young household heads may face difficulties to provide for their family. To avoid heavy debts, some of them are constrained to live with their grandparents. In that case, family decisions can be shared with grandparents. When becoming more mature, the household head becomes empowered and has likely accumulated sufficient assets enabling him to enhance the welfare of his/her household.

The household composition has a negative effect on welfare, meaning that welfare deteriorates gradually as households expand. Indeed, it is intuitive that spending increases with household size. As regard the inequality measure, recall that the economic theory reported a negative relationship between inequality and welfare. In our analysis we find no evidence of inequality on welfare. Lastly, whatever the inequality measure used, our results point to the same direction.

9. Conclusion

Thanks to a unique observational data set, we are able to assess the impact of deworming and school meals as a true *package* on pupils' achievement in rural Senegal. In that, our approach is new and can be distinguished from previous contributions in which deworming and school feeding are implemented and studied separately as single programs or a single joint program. From our field experience and in conducting this analysis, several comments come to our mind regarding to contribute to the debate regarding the role of such interventions.

Let us first highlight the pressing issues and reflections raised by school meals and deworming programs. Several school meals programs were initiated in developing countries. The impact of these programs on pupils' performance is often contradictory. Over the last decade a heated debate has taken place over the ability of these programs to actually attract and retain pupils at school as well as increase pupils' performance. Therefore, doubts were expressed about the objectives of these programs to improve educational outcomes. These criticisms point out that in the context of acute poverty, school meals programs contribute more to reduce food poverty. In other words, school meals would be a palliative of food poverty. Indeed, some parents send their children to schools where these programs are implemented so that they can receive food rations. Reducing food poverty is by itself a noble goal. The issue comes when the analyst eventually seeks to measure the program's effect on an outcome that ultimately would not be the most relevant. However, the choice of the targeted outcome is made (before survey design) by policymakers and those who administer the programs. Economic theory provides some understanding of the underlying mechanisms. For example, the neo-classical framework has been widely used to predict the effects of food assistance on household consumption and welfare. Indeed, according to Engel's Law poorer households spend a greater share of their expenditure on food.[27] As a result, the propensity to consume food from food programs may be larger in the poorest households compared to relatively better off ones.

Another issue regarding the role of school meals is their ability to reduce child labor. Child labor is widely practiced in rural communities. This allows some families to generate additional income for the household. As food costs constitute a significant share of households' spending in rural areas, it is likely that some parents send their children to school in the hope of thereby reducing their food expenditures. Therefore one pathway from food assistance programs to decreased child labor supply is through an income effect. A second pathway to decreased labor child supply is through food assistance triggering dependency by crowding out pre-existing safety nets like remittances which is a very widespread practice in Senegal given the large Senegalese diaspora in the world, or community gifts as these communities are very welded and support each other.

Regarding deworwing programs, it is worthwhile noticing that the perception of families about this intervention is mixed or even negative. Several families have fairly serious reservations due to side effects of deworming drugs. It is therefore quite possible that the outcome of this program is contrary to what is expected. A major effort of information and education must be done to convince families and also children of the merits of such interventions. All these considerations should lead analysts to be cautious about the conclusions of impact assessments. As we pointed out, the novelty of the interventions that we seek to evaluate in this study is to combine them as a package. Intuitively, deworming and meals are complementary so that both programs could reinforce each other. Moreover, the sequence with which the programs are administered makes sense and can have an impact on the outcomes. This study aims to provide answers to these questions.

Several challenging research perspectives may deserve attention. Empirically, a multiple outcome framework seems promising. In this study, we have considered separately six outcomes (aggregate, French and math scores; enrollment, promotion and dropout rates). It would be interesting to consider the improvement of all these outcome jointly. Evidently, these outcomes are related. For example, in order to record good scores, one needs to be enrolled and not to dropout. Moreover, being successful in terms of academic achievements may also imply a high probability to be promoted. Another challenge consists in extending the double-index selection process to the case of M-selections. This is not only a methodological challenge, but represents a real empirical interest. Indeed, many food and nutrition programs involve the implementation of many treatments that are interdependent (fresh fruit and vegetable taking to combat childhood obesity, vitamins supplementation to improve child survival, special milk, etc). However, this does not go without methodological difficulties. Yet in this study, the likelihood maximization procedure is complex. As for the Roy model, the main difficulty is that the procedure is data consuming. Indeed, all the parameters have to be estimated for each regime. As a result, the problem of parameter inflation is likely. In this sense, the two-stage estimation and the IV approaches provide a more manageable alternative without arbitrary distribution assumption. Lastly, an immediate extension of this study would be to provide statistical criteria for choosing between the DISM and the Roy model for each of outcomes. At the time of writing, none of these issues have been addressed in the literature. We speculate that these are promising research avenues.

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[27]Proposed by Engel (1857), Engel's Law is based on empirical facts. It states that as income rises, the share of income allocated to food expenditures (the so-called Engel coefficient) falls, even if actual expenditure on food rises. In other words, the income elasticity of demand for food lies between 0 and 1. According to Houthakker (1957), among all the empirical relations observed from economic data, Engel's Law is likely the most established.

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Table 1: Summary descriptive statistics

Variable	Deworming (T_1) Mean	Deworming (T_1) St.Dev.	Meal (T_2) Mean	Meal (T_2) St.Dev.	Package (T_1T_2)[a] Mean	Package (T_1T_2)[a] St.Dev.	Untreated Mean	Untreated St.Dev.	t-test $p>\|t\|^1$	$p>\|t\|^2$	$p>\|t\|^3$	$p>\|t\|^4$	$p>\|t\|^5$	$p>\|t\|^6$
Aggregate score	36.694	16.561	41.771	18.992	47.663	14.266	37.687	19.306	0.000***	0.000***	0.405	0.000***	0.000***	0.000***
French score	35.366	19.817	40.742	21.028	45.242	17.885	38.413	21.071	0.000***	0.007***	0.020**	0.000***	0.019**	0.000***
Math score	37.627	17.687	42.678	21.204	50.084	16.699	36.965	21.121	0.000***	0.000***	0.611	0.000***	0.000***	0.000***
Enrollment rate	-32.281	34.715	7.631	37.574	-20.358	51.624	-31.404	60.005	0.036**	0.000***	0.808	0.005***	0.000***	0.000***
Promotion rate	73.345	14.798	78.760	11.740	81.887	6.760	79.152	12.959	0.015**	0.451	0.000***	0.000***	0.002***	0.000***
Dropout rate	15.181	12.400	15.072	9.302	10.191	0.950	16.603	12.989	0.000***	0.002***	0.079*	0.000***	0.000***	0.877
Temporary shelters	1.800	0.920	1.625	1.292	0.777	0.852	1.522	1.169	0.000***	0.037**	0.000***	0.000***	0.000***	0.035**
School manual	0.819	0.860	0.833	0.555	0.589	0.476	1.069	1.050	0.000***	0.000***	0.000***	0.003***	0.000***	0.747
Total pupils	231.818	171.293	187.302	128.113	289.496	200.752	191.256	121.595	0.000***	0.435	0.000***	0.002***	0.000***	0.000***
Class size	32.884	10.113	27.882	12.378	36.274	18.061	36.560	14.824	0.829	0.000***	0.000***	0.014***	0.000**	0.000***
Teacher's age	34.545	5.296	32.389	5.805	31.325	6.014	31.143	5.570	0.713	0.000***	0.000***	0.050***	0.000*	0.000***
Pupil's age	9.513	1.778	9.662	1.699	9.281	1.586	9.885	1.790	0.000***	0.002***	0.001***	0.196	0.015**	0.211
Total expenditure[b]	11.490	0.508	11.501	0.525	11.393	0.532	11.450	0.540	0.236	0.021**	0.233	0.073*	0.028**	0.771
Education expenditure[b]	8.001	0.878	7.606	1.159	7.580	1.333	7.524	1.402	0.651	0.136	0.000***	0.000***	0.811	0.000***
Health expenditure[b]	7.265	2.274	7.763	1.674	7.848	1.630	7.407	2.138	0.018**	0.000***	0.295	0.007***	0.585	0.000***
Livestock	6.965	11.075	9.788	25.884	21.629	85.703	12.664	23.151	0.000***	0.003***	0.000***	0.004***	0.001***	0.074*
Primary schools	1	0	1.305	0.773	1.274	0.447	1.209	0.479	0.130	0.000***	0.000***	0.000***	0.644	0.000***
Distance to school	0.898		0.813		0.785		0.776		0.820	0.029**	0.000***	0.001***	0.438	0.000***
Management committee	0.751		0.653		0.459		0.532		0.096*	0.000***	0.000***	0.000***	0.000***	0.002***
Association of parents	1		0.953		1		0.964		0.026**	0.162	0.001***	-	0.010**	0.000***
Association of mothers	0.384		0.430		0.496		0.150		0.000***	0.000***	0.000***	0.030**	0.154	0.177
Cooperative school	0.755		0.685		0.733		0.668		0.120	0.374	0.003***	0.629	0.269	0.027**
Council grant	0.723		0.926		0.770		0.616		0.000***	0.000***	0.000***	0.310	0.000***	0.000***
Water point	0.639		0.450		0.770		0.395		0.000***	0.006***	0.000***	0.007***	0.000***	0.000***
Storage	0.402		0.441		0.496		0.176		0.000***	0.000***	0.000***	0.068*	0.239	0.245
Medicine box	0		0.080		0.229		0.141		0.004***	0.000***	0.000***	0.000***	0.000***	0.000***
Toilets	0.639		0.635		1		0.558		0.000***	0.000***	0.009***	0.000***	0.000***	0.902
Hands washing	0		0.080		0		0.099		0.000***	0.103	0.000***	-	0.000***	0.000***
Disturbed courses	0.737		0.893		0.733		0.701		0.429	0.000***	0.203	0.923	0.000***	0.000***
Meals near school	0.227		0.342		0.496		0.277		0.000***	0.000***	0.069*	0.000***	0.000***	0.000***
School cost	0.527		0.627		0.274		0.514		0.000***	0.000***	0.674	0.000***	0.000***	0.003***
Gender of teacher	0.874		0.812		0.718		0.835		0.000***	0.133	0.093*	0.000***	0.012**	0.017**
No profes. diploma	0.171		0.220		0.125		0.301		0.000***	0.000***	0.000***	0.232	0.012**	0.079*
Profes. diploma CAP	0.430		0.143		0.251		0.157		0.003***	0.377	0.000***	0.000***	0.001***	0.000***
Profes. diploma CEAP	0.132		0.352		0.237		0.203		0.353	0.000***	0.004***	0.007***	0.008***	0.000***
Other profes. diploma	0.265		0.282		0.385		0.337		0.260	0.004***	0.014**	0.012**	0.016**	0.579
Acad. diploma bacplus	0.622		0.415		0.762		0.436		0.000***	0.308	0.000***	0.004***	0.000***	0.000***
Acad. diploma brevet	0.377		0.584		0.237		0.563		0.000***	0.308	0.000***	0.004***	0.000***	0.000***
Continuing training	0.353		0.451		0.733		0.655		0.065*	0.000***	0.000***	0.000***	0.000***	0.003***
Absenteeism	0.125		0.071		0.266		0.083		0.000***	0.281	0.016**	0.000***	0.000***	0.004***
Gender of pupil	0.489		0.495		0.444		0.509		0.142	0.500	0.524	0.388	0.271	0.859
Grade	0.498		0.489		0.481		0.489		0.861	0.664	0.991	0.878	0.720	0.802
Deworming at home	0.157		0.214		0.311		0.202		0.002***	0.470	0.073*	0.000***	0.012**	0.039**
Koranic school	0.146		0.309		0.214		0.310		0.018**	0.922	0.000***	0.082*	0.026**	0.000***
Early childhood inst.	0.143		0.033		0.081		0.072		0.706	0.000***	0.000***	0.072*	0.009***	0.000***
Snack	0.083		0.077		0.111		0.107		0.899	0.014**	0.217	0.370	0.190	0.734
Sick last 3 months	0.269		0.297		0.333		0.298		0.387	0.986	0.311	0.176	0.407	0.360
Pupils eat at fill	0.895		0.888		0.933		0.887		0.101	0.959	0.717	0.207	0.117	0.763
Gender of house head	0.863		0.926		0.911		0.897		0.604	0.016**	0.082*	0.164	0.542	0.001***
Lit. of house head	0.206		0.170		0.111		0.170		0.071*	0.974	0.135	0.016**	0.084*	0.173
Married	0.951		0.958		0.962		0.955		0.696	0.737	0.709	0.583	0.816	0585
Land	0.972		0.939		0.970		0.944		0.195	0.636	0.048**	0.924	0.153	0.035**
Parents school	0.472		0.488		0.725		0.509		0.000***	0.298	0.232	0.000***	0.000***	0.640
Koranic school com.	0.132		0.645		0.274		0.419		0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
College	0.125		0.138		0.274		0.234		0.295	0.000***	0.000***	0.000***	0.000***	0.580
Diourbel	0		0		0		0.068		0.001***	0.000***	0.000***	-	-	-
Fatick	0.779		0.634		0.770		0.434		0.000***	0.000***	0.000***	0.830	0.002***	0.000***
Kolda	0.220		0.214		0.229		0.453		0.000***	0.000***	0.000***	0.830	0.684	0.825
Sedhiou	0		0.151		0		0.044		0.012**	0.000***	0.000***	-	0.000***	0.000***
# Observations														

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Variable	Deworming(T_1)		Meal (T_2)		Package ($T_1 T_2$)[a]		Untreated		t-test					
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	$p > \|t\|^1$	$p > \|t\|^2$	$p > \|t\|^3$	$p > \|t\|^4$	$p > \|t\|^5$	$p > \|t\|^6$
Total	286		799		135		2267							
%	8.2		22.9		3.9		65							

Notes:[a]: Package of meal and deworming programs [b]: In log; 1=Untreated vs. package; 2=Untreated vs. Meal; 3=Untreated vs. Deworming; 4=Deworming vs. Package
5=Meal vs. Package; 6=Deworming vs. Meal
Significance levels: $*$: 10% $**$: 5% $***$: 1%

Table 2: Average treatment effects in the double endogenous model

Parameter	Definition	Treatment effect
Exclusive effect of T_1, $\text{EATE}_{T_1}(\mathbf{x})$	$\mathbb{E}(y\|T_1=1,T_2=0,\mathbf{x})-\mathbb{E}(y\|T_1=0,T_2=0,\mathbf{x})$ $=\delta_1+\mathbb{E}(\varepsilon\|\mu_1>-\boldsymbol{\gamma}_1'\mathbf{w}_1,\mu_2\leq-\boldsymbol{\gamma}_2'\mathbf{w}_2,\mathbf{x})$ $-\mathbb{E}(\varepsilon\|\mu_1\leq-\boldsymbol{\gamma}_1'\mathbf{w}_1,\mu_2\leq-\boldsymbol{\gamma}_2'\mathbf{w}_2,\mathbf{x})$	$\delta_1+\sigma_\varepsilon\rho_{\mu_1\varepsilon}(\lambda_1^{+-}+\lambda_1^{--})$ $+\sigma_\varepsilon\rho_{\mu_2\varepsilon}(\lambda_2^{--}-\lambda_2^{+-})$
Exclusive effect of T_2, $\text{EATE}_{T_2}(\mathbf{x})$	$\mathbb{E}(y\|T_1=0,T_2=1,\mathbf{x})-\mathbb{E}(y\|T_1=0,T_2=0,\mathbf{x})$ $=\delta_2+\mathbb{E}(\varepsilon\|\mu_1\leq-\boldsymbol{\gamma}_1'\mathbf{w}_1,\mu_2>-\boldsymbol{\gamma}_2'\mathbf{w}_2,\mathbf{x})$ $-\mathbb{E}(\varepsilon\|\mu_1\leq-\boldsymbol{\gamma}_1'\mathbf{w}_1,\mu_2\leq-\boldsymbol{\gamma}_2'\mathbf{w}_2,\mathbf{x})$	$\delta_2+\sigma_\varepsilon\rho_{\mu_1\varepsilon}(\lambda_1^{--}-\lambda_1^{-+})$ $+\sigma_\varepsilon\rho_{\mu_2\varepsilon}(\lambda_2^{-+}+\lambda_2^{--})$
Global effect (of T_1,T_2), $\text{GATE}(\mathbf{x})$	$\mathbb{E}(y\|T_1=1,T_2=1,\mathbf{x})-\mathbb{E}(y\|T_1=0,T_2=0,\mathbf{x})$ $=\delta_1+\delta_2+\theta+E(\varepsilon\|\mu_1>-\boldsymbol{\gamma}_1'\mathbf{w}_1,\mu_2>-\boldsymbol{\gamma}_2'\mathbf{w}_2,\mathbf{x})$ $-\mathbb{E}(\varepsilon\|\mu_1\leq-\boldsymbol{\gamma}_1'\mathbf{w}_1,\mu_2\leq-\boldsymbol{\gamma}_2'\mathbf{w}_2,\mathbf{x})$	$\delta_1+\delta_2+\theta+\sigma_\varepsilon\rho_{\mu_1\varepsilon}(\lambda_1^{++}+\lambda_1^{--})$ $+\sigma_\varepsilon\rho_{\mu_2\varepsilon}(\lambda_2^{++}+\lambda_2^{--})$
Additional effect, $\text{AATE}(\mathbf{x})$	$\text{GATE}(\mathbf{x})$-$\text{EATE}_{T_1}(\mathbf{x})$-$\text{EATE}_{T_2}(\mathbf{x})$ $=\mathbb{E}(y\|T_1=1,T_2=1,\mathbf{x})-\mathbb{E}(y\|T_1=1,T_2=0,\mathbf{x})$ $-\mathbb{E}(y\|T_1=0,T_2=1,\mathbf{x})+\mathbb{E}(y\|T_1=0,T_2=0,\mathbf{x})$	$\theta+\sigma_\varepsilon\rho_{\mu_1\varepsilon}(\lambda_1^{++}-\lambda_1^{+-}+\lambda_1^{-+}-\lambda_1^{--})$ $+\sigma_\varepsilon\rho_{\mu_2\varepsilon}(\lambda_2^{++}+\lambda_2^{+-}-\lambda_2^{-+}-\lambda_2^{--})$
Relative effect of (T_1,T_2) vs. T_1, $\text{RATE}_{T_1}(\mathbf{x})$	$\text{GATE}(\mathbf{x})$-$\text{EATE}_{T_1}(\mathbf{x})$ $=\mathbb{E}(y\|T_1=1,T_2=1,\mathbf{x})-\mathbb{E}(y\|T_1=1,T_2=0,\mathbf{x})$	$\delta_2+\theta+\sigma_\varepsilon\rho_{\mu_1\varepsilon}\left(\lambda_1^{++}-\lambda_1^{+-}\right)$ $+\sigma_\varepsilon\rho_{\mu_2\varepsilon}(\lambda_2^{++}+\lambda_2^{+-})$
Relative effect of (T_1,T_2) vs. T_2, $\text{RATE}_{T_2}(\mathbf{x})$	$\text{GATE}(\mathbf{x})$-$\text{EATE}_{T_2}(\mathbf{x})$ $=\mathbb{E}(y\|T_1=1,T_2=1,\mathbf{x})-\mathbb{E}(y\|T_1=0,T_2=1,\mathbf{x})$	$\delta_1+\theta+\sigma_\varepsilon\rho_{\mu_1\varepsilon}(\lambda_1^{++}+\lambda_1^{-+})$ $+\sigma_\varepsilon\rho_{\mu_2\varepsilon}(\lambda_2^{++}-\lambda_2^{-+})$
Relative effect of T_1 vs. T_2, $\text{RATE}_{T_1,T_2}(\mathbf{x})$	$\text{EATE}_{T_1}(\mathbf{x})$ - $\text{EATE}_{T_2}(\mathbf{x})$ $=\mathbb{E}(y\|T_1=1,T_2=0,\mathbf{x})-\mathbb{E}(y\|T_1=0,T_2=1,\mathbf{x})$	$\delta_1-\delta_2+\sigma_\varepsilon\rho_{\mu_1\varepsilon}(\lambda_1^{+-}+\lambda_1^{-+})$ $+\sigma_\varepsilon\rho_{\mu_2\varepsilon}(-\lambda_2^{+-}-\lambda_2^{-+})$

Table 3: Treatment effects in the generalized Roy model

Parameter	Definition	Treatment effect
Average treatment effect		
Exclusive effect of T_1, $\text{EATE}_{T_1}(\mathbf{x})$	$\mathbb{E}(y_{i10} - y_{i00}\|\mathbf{x})$	$\mathbf{x}_i(\boldsymbol{\beta}'_{10} - \boldsymbol{\beta}'_{00}) := \vartheta^{00}_{10}(\mathbf{x})$
Exclusive effect of T_1, $\text{EATE}_{T_2}(\mathbf{x})$	$\mathbb{E}(y_{i01} - y_{i00}\|\mathbf{x})$	$\mathbf{x}_i(\boldsymbol{\beta}'_{01} - \boldsymbol{\beta}'_{00}) := \vartheta^{00}_{01}(\mathbf{x})$
Global effect of (T_1, T_2), $\text{GATE}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i00}\|\mathbf{x})$	$\mathbf{x}_i(\boldsymbol{\beta}'_{11} - \boldsymbol{\beta}'_{00}) := \vartheta^{00}_{11}(\mathbf{x})$
Additional effect, $\text{AATE}(\mathbf{x})$	$\text{GATE}(\mathbf{x})$ - $\text{EATE}_{T_1}(\mathbf{x})$ - $\text{EATE}_{T_2}(\mathbf{x})$	$\mathbf{x}_i(\boldsymbol{\beta}'_{11} - \boldsymbol{\beta}'_{10} - \boldsymbol{\beta}'_{01} + \boldsymbol{\beta}'_{00}) := \vartheta^{10.01}_{11.00}(\mathbf{x})$
Relative effect of (T_1, T_2) vs. T_1, $\text{RATE}_{T_1}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i10}\|\mathbf{x})$	$\mathbf{x}_i(\boldsymbol{\beta}'_{11} - \boldsymbol{\beta}'_{10}) := \vartheta^{10}_{11}(\mathbf{x})$
Relative effect of (T_1, T_2) vs. T_2, $\text{RATE}_{T_1}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i01}\|\mathbf{x})$	$\mathbf{x}_i(\boldsymbol{\beta}'_{11} - \boldsymbol{\beta}'_{01}) := \vartheta^{01}_{11}(\mathbf{x})$
Relative effect of T_1 vs. T_2, $\text{RATE}_{T_1,T_2}(\mathbf{x})$	$\text{EATE}_{T_1}(\mathbf{x})$ - $\text{EATE}_{T_2}(\mathbf{x})$	$\mathbf{x}_i(\boldsymbol{\beta}'_{10} - \boldsymbol{\beta}'_{01}) := \vartheta^{01}_{10}(\mathbf{x})$
Treatment effect on the treated		
Exclusive effect of T_1, $\text{EATET}_{T_1}(\mathbf{x})$	$\mathbb{E}(y_{i10} - y_{i00}\|T_1 = 1, T_2 = 0, \mathbf{x})$	$\vartheta^{00}_{10}(\mathbf{x}) + \lambda_1^{+-}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$ $+\lambda_2^{+-}(\sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$
Exclusive effect of T_2, $\text{EATET}_{T_2}(\mathbf{x})$	$\mathbb{E}(y_{i01} - y_{i00}\|T_1 = 0, T_2 = 1, \mathbf{x})$	$\vartheta^{00}_{01}(\mathbf{x}) + \lambda_1^{-+}(\sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$ $+\lambda_2^{-+}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$
Global effect of (T_1, T_2), $\text{GATET}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i00}\|T_1 = 1, T_2 = 1, \mathbf{x})$	$\vartheta^{00}_{11}(\mathbf{x}) + \lambda_1^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$ $+\lambda_2^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$
Additional effect, $\text{AATET}(\mathbf{x})$	$\text{GATET}(\mathbf{x})$ - $\text{EATET}_{T_1}(\mathbf{x})$ - $\text{EATET}_{T_2}(\mathbf{x})$	$\vartheta^{10.01}_{11.00}(\mathbf{x}) + \lambda_1^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$ $+\lambda_2^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$ $-\lambda_1^{+-}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$ $-\lambda_2^{+-}(\sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$ $-\lambda_1^{-+}(\sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$ $-\lambda_2^{-+}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$
Relative effect of (T_1, T_2) vs. T_1, $\text{RATET}_{T_1}(\mathbf{x})$	$\text{GATET}(\mathbf{x})$ - $\text{EATET}_{T_1}(\mathbf{x})$	$\vartheta^{10}_{11}(\mathbf{x}) + \lambda_1^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$ $+\lambda_2^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$ $-\lambda_1^{+-}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$ $-\lambda_2^{+-}(\sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$
Relative effect of (T_1, T_2) vs. T_2, $\text{RATET}_{T_2}(\mathbf{x})$	$\text{GATET}(\mathbf{x})$ - $\text{EATET}_{T_2}(\mathbf{x})$	$\vartheta^{01}_{11}(\mathbf{x}) + \lambda_1^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$ $+\lambda_2^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$ $-\lambda_1^{-+}(\sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$ $-\lambda_2^{-+}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$
Relative effect of T_1 vs. T_2, $\text{RATET}_{T_1,T_2}(\mathbf{x})$	$\text{EATET}_{T_1}(\mathbf{x})$ - $\text{EATET}_{T_2}(\mathbf{x})$	$\vartheta^{01}_{10}(\mathbf{x}) + \lambda_1^{+-}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$ $+\lambda_2^{+-}(\sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$

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Parameter	Definition	Treatment effect
		$-\lambda_1^{-+}(\sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$
		$-\lambda_2^{-+}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$
Sequential effect: (T_1, T_2), $\text{SeqATET}_{T_1,T_2}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i10} \mid T_1 = 1, T_2 = 1, \mathbf{x})$	$\vartheta_{11}^{10}(\mathbf{x}) + \lambda_1^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}} - \sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}})$
		$+\lambda_2^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$
Sequential effect: (T_2, T_1), $\text{SeqATET}_{T_2,T_1}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i01} \mid T_2 = 1, T_1 = 1, \mathbf{x})$	$\vartheta_{11}^{01}(\mathbf{x}) + \lambda_1^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$
		$+\lambda_2^{++}(\sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}} - \sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}})$
Substitution effect: (T_1, T_2), $\text{SubATET}_{T_1,T_2}(\mathbf{x})$	$\mathbb{E}(y_{i01} - y_{i10} \mid T_1 = 0, T_2 = 1, \mathbf{x})$	$-\vartheta_{10}^{01}(\mathbf{x}) + \lambda_1^{-+}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$
		$+\lambda_2^{-+}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$
Substitution effect: (T_2, T_1), $\text{SubATET}_{T_2,T_1}(\mathbf{x})$	$\mathbb{E}(y_{i10} - y_{i01} \mid T_2 = 0, T_1 = 1, \mathbf{x})$	$\vartheta_{10}^{01}(\mathbf{x}) + \lambda_1^{+-}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$
		$+\lambda_2^{+-}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$
Treatment effect on the untreated		
Exclusive effect of T_1, $\text{EATENT}_{T_1}(\mathbf{x})$	$\mathbb{E}(y_{i10} - y_{i00} \mid T_1 = 0, T_2 = 0, \mathbf{x})$	$\vartheta_{10}^{00}(\mathbf{x}) + \lambda_1^{--}(\sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}} - \sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}})$
		$+\lambda_2^{--}(\sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$
Exclusive effect of T_2, $\text{EATENT}_{T_2}(\mathbf{x})$	$\mathbb{E}(y_{i01} - y_{i00} \mid T_1 = 0, T_2 = 0, \mathbf{x})$	$\vartheta_{01}^{00}(\mathbf{x}) + \lambda_1^{--}(\sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$
		$+\lambda_2^{--}(\sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}} - \sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}})$
Global effect of (T_1, T_2), $\text{GATENT}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i00} \mid T_1 = 0, T_2 = 0, \mathbf{x})$	$\vartheta_{11}^{00}(\mathbf{x}) + \lambda_1^{--}(\sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}} - \sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}})$
		$+\lambda_2^{--}(\sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}} - \sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}})$
Additional effect, $\text{AATENT}(\mathbf{x})$	$\text{GATENT}(\mathbf{x})$ - $\text{EATENT}_{T_1}(\mathbf{x})$ - $\text{EATENT}_{T_2}(\mathbf{x})$	$\vartheta_{11.00}^{10.01}(\mathbf{x})$
		$+\lambda_1^{--}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} + \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}} - \sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_1\varepsilon_{00}})$
		$+\lambda_2^{--}(\sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}} + \sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}} - \sigma_{\varepsilon_{00}}\rho_{\mu_2\varepsilon_{00}})$
Relative effect of (T_1, T_2) vs. T_1, $\text{RATENT}_{T_1}(\mathbf{x})$	$\text{GATENT}(\mathbf{x})$ - $\text{EATENT}_{T_1}(\mathbf{x})$	$\vartheta_{11}^{10}(\mathbf{x}) + \lambda_1^{--}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} - \sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}})$
		$+\lambda_2^{--}(\sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}} - \sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}})$
Relative effect of (T_1, T_2) vs. T_2, $\text{RATENT}_{T_2}(\mathbf{x})$	$\text{GATENT}(\mathbf{x})$ - $\text{EATENT}_{T_2}(\mathbf{x})$	$\vartheta_{11}^{01}(\mathbf{x}) + \lambda_1^{--}(\sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}} - \sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}})$
		$+\lambda_2^{--}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}})$
Relative effect of T_1 vs. T_2, $\text{RATENT}_{T_1,T_2}(\mathbf{x})$	$\text{EATENT}_{T_1}(\mathbf{x})$ - $\text{EATENT}_{T_2}(\mathbf{x})$	$\vartheta_{10}^{01}(\mathbf{x}) + \lambda_1^{--}(\sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}} - \sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}})$
		$+\lambda_2^{--}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$
Sequential effect: (T_1, T_2), $\text{SeqATENT}_{T_1,T_2}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i10} \mid T_1 = 1, T_2 = 0, \mathbf{x})$	$\vartheta_{11}^{10}(\mathbf{x}) + \lambda_1^{+-}(\sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}} - \sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}})$
		$+\lambda_2^{+-}(\sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}} - \sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}})$
Sequential effect: (T_2, T_1), $\text{SeqATENT}_{T_2,T_1}(\mathbf{x})$	$\mathbb{E}(y_{i11} - y_{i01} \mid T_2 = 1, T_1 = 0, \mathbf{x})$	$\vartheta_{11}^{01}(\mathbf{x}) + \lambda_1^{-+}(\sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}} - \sigma_{\varepsilon_{11}}\rho_{\mu_1\varepsilon_{11}})$
		$+\lambda_2^{-+}(\sigma_{\varepsilon_{11}}\rho_{\mu_2\varepsilon_{11}} - \sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}})$
Substitution effect: (T_1, T_2), $\text{SubATENT}_{T_1,T_2}(\mathbf{x})$	$\mathbb{E}(y_{i01} - y_{i10} \mid T_1 = 0, T_2 = 0, \mathbf{x})$	$-\vartheta_{10}^{01}(\mathbf{x}) + \lambda_1^{--}(\sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}} - \sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}})$
		$+\lambda_2^{--}(\sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}} - \sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}})$
Substitution effect: (T_2, T_1), $\text{SubATENT}_{T_2,T_1}(\mathbf{x})$	$\mathbb{E}(y_{i10} - y_{i01} \mid T_2 = 0, T_1 = 0, \mathbf{x})$	$\vartheta_{10}^{01}(\mathbf{x}) + \lambda_1^{--}(\sigma_{\varepsilon_{01}}\rho_{\mu_1\varepsilon_{01}} - \sigma_{\varepsilon_{10}}\rho_{\mu_1\varepsilon_{10}})$

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Table 3 – continued

Parameter	Definition	Treatment effect
		$+\lambda_2^{--}(\sigma_{\varepsilon_{01}}\rho_{\mu_2\varepsilon_{01}} - \sigma_{\varepsilon_{10}}\rho_{\mu_2\varepsilon_{10}})$

Table 4: DISM[a] model: FIML[b]

Variable	Aggregate score Coef.	Aggregate score Std. Err.	French score Coef.	French score Std. Err.	Math score Coef.	Math score Std. Err.
Selection Eq. Deworming						
Total pupils	0.0005*	0.0002	0.0004**	0.0002	0.0006***	0.0002
Management committee	0.014	0.059	0.010	0.060	-0.026	0.060
Medicine box	-0.414***	0.090	-0.360***	0.091	-0.400***	0.092
Association of mothers	0.386***	0.059	0.363***	0.060	0.406***	0.060
Cooperative school	0.331***	0.068	0.296***	0.069	0.317***	0.069
Water point	0.441***	0.066	0.460***	0.067	0.439***	0.067
Gender of pupil	-0.043	0.055	-0.047	0.056	-0.048	0.056
Intercept	-1.823***	0.079	-1.792***	0.080	-1.812***	0.079
Selection Eq. Meal						
Total pupils	0.0004*	0.0002	0.0004**	0.0002	0.0004**	0.0002
Distance to school	0.022	0.061	0.028	0.062	0.021	0.061
Management committee	-0.041	0.055	-0.047	0.055	-0.044	0.054
Association of mothers	0.631***	0.057	0.646***	0.058	0.631***	0.057
Cooperative school	0.080	0.055	0.077	0.056	0.085	0.055
Rural council grant	0.717***	0.068	0.691***	0.068	0.738***	0.068
Water point	-0.009	0.062	0.003	0.062	-0.020	0.062
Disturbed courses	0.911***	0.072	0.917***	0.072	0.909***	0.072
Storage	0.831***	0.058	0.834***	0.058	0.817***	0.058
Gender of pupil	-0.060	0.050	-0.060	0.050	-0.061	0.049
Intercept	-2.435***	0.119	-2.430***	0.119	-2.436***	0.119
Performance Eq.						
Temporary shelters	0.342	0.316	0.367	0.338	0.189	0.355
School manual	3.150***	0.915	3.576***	0.979	2.944***	1.021
School manual squared	-0.096	0.159	-0.450***	0.170	0.240	0.177
Class size	-0.013	0.024	-0.025	0.026	-0.007	0.027
Teacher's age	-3.102***	0.528	-1.974***	0.562	-3.976***	0.588
Teacher's age square	0.048***	0.007	0.028***	0.008	0.064***	0.008
Pupil's age	0.833***	0.226	0.831***	0.244	0.811***	0.253
Education expenditure[c]	0.507**	0.244	0.729***	0.263	0.320	0.273
Health expenditure[c]	-0.052	0.150	0.029	0.162	-0.165	0.168
Livestock	-0.007	0.010	-0.011	0.011	-0.0004	0.011
Disturbed courses	-4.963***	0.918	-4.177***	0.988	-6.080***	1.020
Meals near school	0.124	0.727	-0.554	0.783	0.727	0.814
Toilets	2.787**	0.762	1.626**	0.820	3.791***	0.850
Hands washing	3.078**	1.219	4.058***	1.303	2.401*	1.358
Gender of teacher	-4.555***	0.913	-4.118***	0.986	-5.147***	1.023
No professional diploma	3.274***	0.870	2.400**	0.934	4.399***	0.971
Professional diploma CAP	-0.167	1.060	0.782	1.150	-0.819	1.186
Professional diploma CEAP	3.081***	0.919	1.265	0.990	4.594***	1.027
Academic diploma (bacplus)	0.661	0.721	-0.653	0.773	1.638**	0.803
Continuing training	-0.701	0.672	0.107	0.722	-1.643**	0.750
Absenteeism	-4.025***	1.135	-1.667	1.226	-6.371***	1.269
Gender of pupil	0.670	0.627	-0.291	0.662	1.543**	0.699
Grade	-11.209***	0.815	-17.697***	0.876	-4.605***	0.912
Deworming at home	-1.595**	0.749	-1.650**	0.807	-1.324	0.838
Koranic school	2.669***	0.676	2.561***	0.727	2.927***	0.756
Early childhood inst.	1.920	1.197	2.712**	1.295	1.207	1.344
Snack	-1.104	1.015	-1.094	1.094	-0.750	1.137
Sick last 3 months	0.005	0.655	0.251	0.705	-0.293	0.732
Pupils eat at fill	1.956**	0.990	1.944*	1.063	1.922*	1.107
Gender of household head	0.130	1.103	-0.486	1.190	0.581	1.235
Lit. of household head	-0.116	0.799	-0.080	0.861	-0.353	0.895

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Variable	Aggregate score Coef.	Std. Err.	French score Coef.	Std. Err.	Math score Coef.	Std. Err.
Married	1.654	1.568	2.753	1.691	0.588	1.754
Land	-1.949	1.358	-1.299	1.465	-2.417	1.519
Parents school	-2.047**	0.654	-2.802***	0.697	-1.221*	0.728
College	6.235***	0.905	4.496***	0.971	8.050***	1.016
Diourbel	4.484***	1.639	2.531	1.751	6.590***	1.828
Kolda	-3.818***	0.952	-4.474***	1.025	-2.870***	1.063
Sedhiou	-4.194*	1.530	-5.255***	1.633	-2.783	1.713
Deworming (T_1)	-17.155***	2.516	-18.719***	3.008	-15.190***	2.816
Meal (T_2)	3.488*	1.948	4.147**	2.076	2.966	2.048
T_1T_2	3.600*	2.097	5.868**	2.268	2.216	2.342
Intercept	82.369***	9.427	69.068***	10.037	92.011***	10.520
$\rho12$	-0.071*	0.039	-0.066*	0.039	-0.067*	0.039
$\rho13$	0.567***	0.058	0.494***	0.070	0.528***	0.060
$\rho23$	0.098	0.068	-0.010	0.068	0.181***	0.063
s_e3	18.383***	0.335	19.414***	0.358	20.500***	0.360
Log likelihood	-17710.647		-17970.804		-18098.279	
# Observations	3487		3487		3487	
Wald $\chi_2(7)$	210.25		191.39		209.36	
$P > \chi_2$	0.000		0.000		0.000	

Notes [a]: Double-Index Selection Model; [b]:Full Information Maximum Likelihood; [c]: In log.
Significance levels (bootstrap): $*$: 10% $**$: 5% $***$: 1%

Table 5: DISM[a] model: 2-step[b]

Variable	Aggregate score Coef.	Std. Err.	French score Coef.	Std. Err.	Math score Coef.	Std. Err.
Selection Eq. Deworming						
Total pupils	0.0003*	0.0001	0.0003*	0.0001	0.0003*	0.0001
Management committee	0.221***	0.056	0.221***	0.056	0.221***	0.056
Medicine box	-0.496***	0.089	-0.496***	0.089	-0.496***	0.089
Association of mothers	0.207***	0.052	0.207***	0.052	0.207***	0.052
Cooperative school	0.262***	0.055	0.262***	0.055	0.262***	0.055
Water point	0.582***	0.059	0.582***	0.059	0.582***	0.059
Gender of pupil	-0.029	0.047	-0.029	0.047	-0.029	0.047
Intercept	-1.942***	0.067	-1.942***	0.067	-1.942***	0.067
Selection Eq. Meal						
Total pupils	0.0005***	0.0001	0.0005***	0.0001	0.0005***	0.0001
Distance to school	0.193***	0.048	0.193***	0.048	0.193***	0.048
Management committee	-0.045	0.042	-0.0456	0.042	-0.045	0.042
Association of mothers	0.472***	0.043	0.472***	0.043	0.472***	0.043
Cooperative school	-0.169***	0.041	-0.169***	0.041	-0.169***	0.041
Rural council grant	0.569***	0.045	0.569***	0.045	0.569***	0.0457
Water point	0.156***	0.046	0.156***	0.046	0.156***	0.046
Disturbed courses	0.291***	0.044	0.291***	0.044	0.291***	0.044
Storage	0.390***	0.044	0.390***	0.044	0.390***	0.044
Gender of pupil	-0.041	0.037	-0.041	0.037	-0.041	0.037
Intercept	-1.482***	0.075	-1.482***	0.075	-1.482***	0.075
Performance Eq.						
Temporary shelters	0.374	0.306	0.369	0.343	0.297	0.358
School manual	3.273***	0.966	3.611***	1.011	2.939**	1.188

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Table 5 – continued

Variable	Aggregate score Coef.	Std. Err.	French score Coef.	Std. Err.	Math score Coef.	Std. Err.
School manual squared	-0.096	0.156	-0.450***	0.148	0.257	0.223
Class size	-0.015	0.024	-0.027	0.024	-0.025	0.031
Teacher's age	-2.979***	0.493	-1.912***	0.534	-3.935***	0.548
Teacher's age square	0.046***	0.007	0.027***	0.008	0.063***	0.008
Pupil's age	0.867***	0.240	0.836***	0.260	0.870***	0.269
Education expenditure[b]	0.544**	0.240	0.762**	0.298	0.348	0.257
Health expenditure[b]	-0.082	0.158	0.008	0.158	-0.182	0.186
Livestock	-0.001	0.015	-0.007	0.015	0.004	0.017
Disturbed courses	-5.787***	0.664	-4.392***	0.732	-7.295***	0.792
Meals near school	-0.049	0.791	-0.653	0.850	0.564	0.853
Toilets	2.984***	0.725	1.733**	0.773	4.147***	0.831
Hands washing	3.459***	1.172	4.337***	1.314	2.663**	1.244
Gender of teacher	-4.751***	0.936	-4.263***	1.028	-5.389***	1.021
No professional diploma	3.652***	0.837	2.565***	0.935	4.839***	0.911
Professional diploma CAP	-0.148	1.207	0.672	1.301	-0.664	1.254
Professional diploma CEAP	3.134***	1.023	1.269	1.145	4.762***	1.093
Academic diploma (bacplus)	0.616	0.693	-0.618	0.743	1.673**	0.850
Continuing training	-0.829	0.722	-0.015	0.754	-1.683**	0.836
Absenteeism	-4.13***	1.114	-1.989	1.239	-6.209***	1.132
Gender of pupil	0.809	0.578	-0.154	0.592	1.672**	0.688
Grade	-11.063***	0.806	-17.586***	0.913	-4.501***	0.874
Deworming at home	-1.564*	0.809	-1.626*	0.839	-1.348	0.918
Koranic school	2.799***	0.707	2.652***	0.702	3.103***	0.841
Early childhood inst.	2.172**	1.038	2.898**	1.125	1.432	1.206
Snack	-1.017	0.966	-1.029	0.994	-0.722	1.131
Sick last 3 months	0.053	0.672	0.287	0.746	-0.246	0.732
Pupils eat at fill	2.010*	1.052	1.947*	1.057	1.964	1.224
Gender of household head	0.042	0.941	-0.547	1.145	0.558	1.036
Lit. of household head	-0.143	0.823	-0.060	0.875	-0.383	0.936
Married	1.612	1.452	2.697	1.695	0.570	1.589
Land	-1.995	1.491	-1.330	1.600	-2.450	1.626
Parents school	-1.927***	0.621	-2.770***	0.724	-1.086	0.669
College	6.251***	1.039	4.575***	1.038	8.048***	1.188
Diourbel	4.561***	1.359	2.652*	1.571	6.481***	1.538
Kolda	-3.836***	0.959	-4.400***	0.975	-3.142***	1.152
Sedhiou	-4.149***	1.471	-5.324***	1.575	-2.825*	1.726
Deworming (T_1)	-18.845***	5.258	-19.479***	5.427	-19.717***	5.851
Meal (T_2)	4.266*	2.520	5.064*	2.635	3.397	2.903
T_1T_2	4.066*	2.087	6.098***	2.326	2.442	2.338
$h_1(T_1, T_2)$	11.161***	2.713	9.772***	2.855	13.181***	3.054
$h_2(T_1, T_2)$	1.418	1.622	-0.701	1.718	3.577*	1.861
Intercept	80.332***	8.341	67.714***	9.065	91.690***	9.416
# Observations	3487		3487		3487	
Wald $\chi_2(43)$	1395.70		1866.94		1243.89	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.166		0.203		0.145	

Notes [a]: Double-Index Selection Model; [b]: Two step; [c]: In log.

Significance levels (bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 6: Generalized Roy model: 2-step[a]

Variable	Aggregate score Coef.	Std. Err.	French score Coef.	Std. Err.	Math score Coef.	Std. Err.
Selection Eq. Deworming						
Total pupils	0.0003*	0.0001	0.0003*	0.0001	0.0003*	0.0001
Management committee	0.221***	0.056	0.221***	0.056	0.221***	0.056
Medicine box	-0.496***	0.089	-0.496***	0.089	-0.496***	0.089
Association of mothers	0.207***	0.052	0.207***	0.052	0.207***	0.052
Cooperative school	0.262***	0.055	0.262***	0.055	0.262***	0.055
Water point	0.582***	0.059	0.582***	0.059	0.582***	0.059
Gender of pupil	-0.029	0.047	-0.029	0.047	-0.029	0.047
Intercept	-1.942***	0.067	-1.942***	0.067	-1.942***	0.067
Selection Eq. Meal						
Total pupils	0.0005***	0.0001	0.0005***	0.0001	0.0005***	0.0001
Distance to school	0.193***	0.048	0.193***	0.048	0.193***	0.048
Management committee	-0.045	0.042	-0.0456	0.042	-0.045	0.042
Association of mothers	0.472***	0.043	0.472***	0.043	0.472***	0.043
Cooperative school	-0.169***	0.041	-0.169***	0.041	-0.169***	0.041
Rural council grant	0.569***	0.045	0.569***	0.045	0.569***	0.0457
Water point	0.156***	0.046	0.156***	0.046	0.156***	0.046
Disturbed courses	0.291***	0.044	0.291***	0.044	0.291***	0.044
Storage	0.390***	0.044	0.390***	0.044	0.390***	0.044
Gender of pupil	-0.041	0.037	-0.041	0.037	-0.041	0.037
Intercept	-1.482***	0.075	-1.482***	0.075	-1.482***	0.075
Performance Eq. Deworming						
Temporary shelters	-3.374**	1.479	-3.232*	1.917	-4.523***	1.741
Class size	-0.321**	0.154	-0.495***	0.167	-0.195	0.161
Teacher's age	-8.972***	2.039	-10.737***	2.416	-7.080***	2.427
Teacher's age square	0.125***	0.029	0.141***	0.035	0.106***	0.033
Pupil's age	1.594**	0.602	2.361***	0.705	0.733	0.637
Academic diploma (bacplus)	8.193***	2.615	10.269***	2.958	7.295**	2.839
Absenteeism	4.796	5.956	3.182	6.778	11.155*	5.952
Gender of pupil	-0.917	1.439	-0.884	1.706	0.101	1.824
Grade	-16.738***	2.343	-25.852***	2.818	-7.910***	2.528
Deworming at home	-3.087	2.211	-0.425	2.626	-2.631	3.083
Koranic school	-0.064	2.038	1.593	2.701	0.418	2.508
Early childhood inst.	-2.572	2.821	-2.322	2.786	-4.188	3.342
Snack	-3.450	3.166	-1.729	3.580	-2.574	3.731
Pupils eat at fill	6.722***	2.498	9.624***	2.834	3.494	3.008
Gender of household head	2.225	2.829	0.573	3.116	2.107	3.688
Lit. of household head	1.075	1.999	1.938	2.011	1.396	2.369
Married	2.795	4.993	0.393	5.960	2.584	6.012
λ_1^{+-}	24.389*	13.036	18.653	15.745	38.823***	13.657
λ_2^{+-}	4.648	6.433	7.436	7.489	5.561	6.661
Intercept	146.152***	49.514	195.332***	60.408	86.224**	54.921
# Observations	320		320		320	
Wald $\chi_2(19)$	244.51		298.29		135.96	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.356		0.401		0.227	
Performance Eq. Meal						
Temporary shelters	-0.576	0.579	-0.333	0.573	-0.953	0.661
Class size	0.377***	0.043	0.368***	0.051	0.405***	0.051
Teacher's age	1.068	1.347	1.315	1.467	1.180	1.362
Teacher's age square	-0.005	0.020	-0.010	0.022	-0.005	0.021
Pupil's age	-0.256	0.431	-0.453	0.501	-0.152	0.455
Academic diploma (bacplus)	-2.768**	1.289	-3.568***	1.335	-1.976	1.434

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Table 6 – continued

Variable	Aggregate score Coef.	Aggregate score Std. Err.	French score Coef.	French score Std. Err.	Math score Coef.	Math score Std. Err.
Absenteeism	5.027*	3.058	-0.043	3.140	10.013***	3.261
Gender of pupil	1.396	1.238	-0.710	1.324	2.866**	1.391
Grade	-4.917***	1.454	-9.533***	1.660	-0.122	1.614
Deworming at home	-3.531**	1.717	-4.292**	1.813	-2.743	1.886
Koranic school	-6.009***	1.181	-7.180***	1.321	-4.715***	1.413
Early childhood inst.	4.712	3.445	5.665	4.023	3.260	3.616
Snack	-4.253*	2.277	-2.717	2.635	-4.379*	2.618
Pupils eat at fill	7.617***	1.568	7.492***	1.667	7.586***	1.854
Gender of household head	1.271	2.524	-1.371	3.162	4.352*	2.550
Lit. of household head	0.031	1.772	-1.396	1.901	0.884	1.981
Married	-2.955	2.871	2.301	3.371	-8.175**	3.684
λ_1^{-+}	15.248***	5.588	16.141***	5.917	13.537**	6.754
λ_2^{-+}	5.570**	2.265	5.468**	2.449	5.903**	2.700
Intercept	-1.559	21.626	-1.500	24.074	-7.209	21.917
# Observations	915		915		915	
Wald $\chi_2(19)$	326.95		277.05		291.21	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.170		0.168		0.153	
Performance Eq. Package						
Temporary shelters	5.109***	1.588	4.772***	1.809	5.447***	1.925
Class size	1.094***	0.167	0.918***	0.184	1.270***	0.189
Teacher's age	-45.806***	7.100	-41.943***	8.370	-49.670***	8.188
Teacher's age square	0.662***	0.099	0.605***	0.120	0.718***	0.114
Pupil's age	-2.376*	1.239	-2.580*	1.390	-2.171	1.334
Academic diploma (bacplus)	-18.169***	4.026	-21.428***	4.280	-14.911***	4.606
Absenteeism	-28.398***	9.427	-18.943*	10.260	-37.853***	11.122
Gender of pupil	-1.522	2.410	-2.182	2.674	-0.862	2.848
Grade	-4.743	5.163	-8.657	5.915	-0.830	5.300
Deworming at home	-5.012*	2.752	-4.619	3.328	-5.405	3.366
Koranic school	1.816	3.682	1.069	3.938	2.563	4.386
Early childhood inst.	-14.486**	6.811	-10.298	6.825	-18.675**	9.133
Snack	1.302	5.644	1.527	5.840	1.077	7.072
Pupils eat at fill	-0.029	4.594	1.950	4.358	-2.009	6.155
Gender of household head	-2.709	4.383	-2.363	4.686	-3.054	4.773
Lit. of household head	-3.546	3.994	-5.005	3.866	-2.087	4.795
Married	-4.312	6.624	-4.114	7.045	-4.510	6.797
λ_1^{++}	80.384***	18.355	68.143***	20.381	92.624***	22.789
λ_2^{++}	-47.396*	27.553	-49.361	31.404	-45.432	32.294
Intercept	731.730***	105.850	695.734***	127.702	767.727***	123.242
# Observations	168		168		168	
Wald $\chi_2(19)$	299.54		410.47		219.96	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.476		0.507		0.373	
Performance Eq. Untreated						
Temporary shelters	-0.601*	0.313	-0.571*	0.319	-0.636*	0.356
Class size	-0.036	0.026	-0.080***	0.026	0.007	0.031
Teacher's age	-0.471	0.526	-0.555	0.511	-0.384	0.620
Teacher's age square	0.005	0.007	0.005	0.007	0.005	0.009
Pupil's age	0.656**	0.298	0.522*	0.311	0.789**	0.322
Academic diploma (bacplus)	0.874	0.694	0.128	0.695	1.627*	0.819
Absenteeism	-3.556***	1.261	-0.128	1.353	-7.001***	1.353
Gender of pupil	1.130	0.728	0.254	0.705	2.003**	0.855
Grade	-13.060***	0.959	-18.900***	1.012	-7.215***	1.113
Deworming at home	-1.965*	1.022	-1.535	1.063	-2.389**	1.098
Koranic school	2.252***	0.780	1.864**	0.810	2.640**	0.909

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Variable	Aggregate score Coef.	Std. Err.	French score Coef.	Std. Err.	Math score Coef.	Std. Err.
Early childhood inst.	5.931***	1.531	6.724***	1.568	5.154***	1.729
Snack	-2.311*	1.258	-1.879	1.411	-2.728**	1.335
Pupils eat at fill	4.699***	1.309	3.382**	1.339	6.016***	1.418
Gender of household head	-3.243**	1.373	-3.234**	1.384	-3.261**	1.646
Lit. of household head	2.260**	1.030	3.086***	1.031	1.440	1.168
Married	0.879	1.813	1.202	1.769	0.570	2.187
λ_1^{--}	14.650***	3.452	15.842***	3.285	13.511***	4.162
λ_2^{--}	-5.559***	1.936	-4.644**	2.101	-6.439***	2.111
Intercept	46.542***	9.254	55.706***	9.063	37.308***	10.935
# Observations	2572		2572		2572	
Wald $\chi_2(19)$	518.10		872.91		232.47	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.114		0.192		0.051	

Notes [a]:Two-step; [b] In log.

Significance levels (bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 7: DISM[a] model (2-step[b])

Variable	Enrollment rate Coef.	Std. Err.	Promotion rate Coef.	Std. Err.	Dropout rate Coef.	Std. Err.
Selection Eq. Deworming						
Total pupils	0.0003*	0.0001	0.0003*	0.0001	0.0003*	0.0001
Management committee	0.221***	0.056	0.221***	0.056	0.221***	0.056
Medicine box	-0.496***	0.089	-0.496***	0.089	-0.496***	0.089
Association of mothers	0.207***	0.052	0.207***	0.052	0.207***	0.052
Cooperative school	0.262***	0.055	0.262***	0.055	0.262***	0.055
Water point	0.582***	0.059	0.582***	0.059	0.582***	0.059
Gender of pupil	-0.029	0.047	-0.029	0.047	-0.029	0.047
Intercept	-1.942***	0.067	-1.942***	0.067	-1.942***	0.067
Selection Eq. Meal						
Total pupils	0.0005***	0.0001	0.0005***	0.0001	0.0005***	0.0001
Distance to school	0.193***	0.048	0.193***	0.048	0.193***	0.048
Management committee	-0.045	0.042	-0.0456	0.042	-0.045	0.042
Association of mothers	0.472***	0.043	0.472***	0.043	0.472***	0.043
Cooperative school	-0.169***	0.041	-0.169***	0.041	-0.169***	0.041
Rural council grant	0.569***	0.045	0.569***	0.045	0.569***	0.0457
Water point	0.156***	0.046	0.156***	0.046	0.156***	0.046
Disturbed courses	0.291***	0.044	0.291***	0.044	0.291***	0.044
Storage	0.390***	0.044	0.390***	0.044	0.390***	0.044
Gender of pupil	-0.041	0.037	-0.041	0.037	-0.041	0.037
Intercept	-1.482***	0.075	-1.482***	0.075	-1.482***	0.075
Performance Eq.						
Temporary shelters	6.700***	0.669	1.041***	0.161	-0.928***	0.158
Class size	-0.451***	0.050	0.015	0.013	-0.021*	0.013
Teacher's age	-3.893***	1.056	-1.341***	0.343	0.354	0.314
Teacher's age square	0.061***	0.015	0.017***	0.004	-0.005	0.004
Pupil's age	0.268	0.342	0.202*	0.119	-0.207**	0.103
Education expenditure[c]	-0.109	0.556	0.016	0.142	0.147	0.119
Health expenditure[c]	-1.165***	0.333	-0.213**	0.087	0.144*	0.075
Livestock	-0.019	0.022	-0.019***	0.006	0.011*	0.006

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Table 7 – continued

Variable	Enrollment rate Coef.	Std. Err.	Promotion rate Coef.	Std. Err.	Dropout rate Coef.	Std. Err.
Primary schools	0.241	0.982	-	-	-	-
Distance to school	-7.556***	2.038	3.995***	0.477	-2.959***	0.470
Association of parents	10.440***	2.377	6.021***	0.787	-3.703***	0.468
Disturbed courses	-4.018**	1.630	-4.573***	0.485	5.258***	0.411
Meals near school	1.121	1.325	-0.598	0.385	-0.529	0.406
Gender of teacher	-6.145***	2.114	3.749***	0.495	-1.203***	0.453
Continuing training	-	-	1.315***	0.459	-1.090**	0.423
Absenteeism	-0.113	3.067	-1.761***	0.578	-0.155	0.606
Gender of pupil	1.159	1.144	0.416	0.403	-0.535	0.356
Koranic school	2.991**	1.251	1.405***	0.394	-0.983**	0.394
Early childhood inst.	-3.321	2.120	1.913***	0.696	-2.313***	0.609
Snack	4.155**	1.843	0.277	0.683	-0.143	0.715
Sick last 3 months			-0.525	0.378	0.416	0.374
Pupils eat at fill	5.852***	2.042	2.307***	0.799	-3.261***	0.788
Gender of household head	-3.988	2.741	0.790	0.657	0.884*	0.499
Lit. of household head	10.834***	1.614	-0.524	0.497	1.009**	0.453
Married	-0.213	3.435	-0.627	0.870	-0.243	0.823
Land	-4.760*	2.424	1.643**	0.744	-1.459*	0.797
School cost	-3.771**	1.462				
Koranic school com.	1.030	1.432			1.167***	0.431
College			-0.260	0.623	-1.213**	0.586
Diourbel	13.551***	3.995	5.728***	0.890	-4.680***	0.858
Kolda	-76.376***	1.858	-5.258***	0.509	5.558***	0.534
Sedhiou	-18.183***	2.721	9.914***	0.740	-6.079***	0.815
Deworming (T_1)	-8.007	10.196	7.548**	2.917	-9.645***	2.887
Meal (T_2)	58.966***	5.924	-18.048***	1.646	13.065***	1.608
T_1T_2	1.623	3.601	9.494***	1.339	-2.799***	1.001
$h_1(T_1,T_2)$	-9.007*	5.140	-6.171***	1.486	3.943***	1.438
$h_2(T_1,T_2)$	-28.215***	3.804	12.224***	1.059	-10.518***	1.009
Intercept	65.993***	20.599	93.063***	5.516	14.921***	5.268
# Observations	3428		3487		3487	
Wald $\chi_2(d.o.f)$	19968.66 (34)		2534.05(34)		3453.24 (35)	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.602		0.250		0.249	

Notes [a]: Double-Index Selection Model; [b]: Two step; [c]: In log.
Significance levels (bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 8: Generalized Roy model (2-step[a])

Variable	Enrollment rate Coef.	Std. Err.	Promotion rate Coef.	Std. Err.	Dropout rate Coef.	Std. Err.
Selection Eq. Deworming						
Total pupils	0.0003*	0.0001	0.0003*	0.0001	0.0003*	0.0001
Management committee	0.221***	0.056	0.221***	0.056	0.221***	0.056
Medicine box	-0.496***	0.089	-0.496***	0.089	-0.496***	0.089
Association of mothers	0.207***	0.052	0.207***	0.052	0.207***	0.052
Cooperative school	0.262***	0.055	0.262***	0.055	0.262***	0.055
Water point	0.582***	0.059	0.582***	0.059	0.582***	0.059
Gender of pupil	-0.029	0.047	-0.029	0.047	-0.029	0.047
Intercept	-1.942***	0.067	-1.942***	0.067	-1.942***	0.067

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Variable	Enrollment rate Coef.	Std. Err.	Promotion rate Coef.	Std. Err.	Dropout rate Coef.	Std. Err.
Selection Eq. Meal						
Total pupils	0.0005***	0.0001	0.0005***	0.0001	0.0005***	0.0001
Distance to school	0.193***	0.048	0.193***	0.048	0.193***	0.048
Management committee	-0.045	0.042	-0.0456	0.042	-0.045	0.042
Association of mothers	0.472***	0.043	0.472***	0.043	0.472***	0.043
Cooperative school	-0.169***	0.041	-0.169***	0.041	-0.169***	0.041
Rural council grant	0.569***	0.045	0.569***	0.045	0.569***	0.0457
Water point	0.156***	0.046	0.156***	0.046	0.156***	0.046
Disturbed courses	0.291***	0.044	0.291***	0.044	0.291***	0.044
Storage	0.390***	0.044	0.390***	0.044	0.390***	0.044
Gender of pupil	-0.041	0.037	-0.041	0.037	-0.041	0.037
Intercept	-1.482***	0.075	-1.482***	0.075	-1.482***	0.075
Performance Eq. Deworming						
Temporary shelters	-17.718***	1.372	-4.563***	0.832	3.877***	0.560
Class size	-1.833***	0.180	-0.191	0.120	0.375***	0.078
Pupil's age	-0.802	0.562	-0.471	0.361	0.507**	0.239
Education expenditure[b]	6.397***	1.258	3.490***	0.941	-2.114***	0.619
Health expenditure[b]	-0.322	0.328	-0.201	0.237	0.178	0.159
Livestock	-0.129*	0.077	-0.038	0.069	0.044	0.049
Distance to school	14.758***	2.762	5.703***	2.191	-1.429	1.410
Gender of teacher	21.138***	3.323	11.811***	1.792	-11.421***	1.419
Continuing training			-3.469**	1.620		
Gender of pupil	2.710	2.052	1.385	1.296	-1.721**	0.858
Koranic school	6.191***	2.337	4.217**	1.651	-2.940**	1.139
Early childhood inst.	1.763	2.816	-2.447	1.688	1.849*	1.122
Snack	5.863*	3.286	3.731*	2.002	-2.670**	1.273
Sick last 3 months			-0.805	1.075	0.277	0.725
Pupils eat at fill	28.923***	3.800	15.421***	2.141	-10.674***	1.595
Gender of household head	2.794	3.136	2.558	1.988	-1.799	1.376
Lit. of household head	3.206	2.482	1.500	1.773	-0.470	1.275
Married	-4.358	5.155	-1.001	3.477	0.673	2.356
Land	-4.573	3.032	-4.560**	1.837	2.547*	1.464
λ_1^{+-}	-65.351***	8.487	-3.835	6.480	23.827***	4.441
λ_2^{+-}	-38.792***	4.391	8.434***	2.998	-3.129	2.201
Intercept	95.461***	27.436	40.598*	21.126	-9.200	14.720
# Observations	288		286		286	
Wald $\chi_2(d.o.f)$	2276.27 (19)		1213.66(21)		2028.79(20)	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.790		0.528		0.696	
Performance Eq. Meal						
Temporary shelters	5.558***	0.577	2.835***	0.321	-0.994***	0.259
Class size	-0.773***	0.100	0.143***	0.026	-0.242***	0.027
Pupil's age	0.193	0.762	-0.173	0.220	-0.236	0.164
Education expenditure[b]	-2.202*	1.152	-0.033	0.370	-0.056	0.305
Health expenditure[b]	-0.351	0.565	-0.733***	0.219	0.498***	0.178
Livestock	-0.101	0.087	-0.012	0.016	-0.024	0.023
Distance to school	-4.514	3.076	2.597**	1.077	-0.873	1.049
Gender of teacher	-34.665***	4.519	6.140***	1.028	-1.204	0.782
Continuing training			-1.240	0.940		
Gender of pupil	1.057	1.926	-0.492	0.700	0.556	0.582
Koranic school	3.015	2.301	1.302	0.827	0.765	0.726
Early childhood inst.	-14.563***	4.928	2.457	2.100	-4.149***	1.562
Snack	-14.347***	3.786	-2.507*	1.318	1.587	1.175
Sick last 3 months			-0.930	0.848	0.948	0.673
Pupils eat at fill	2.785	3.002	-2.704**	1.207	0.653	0.885

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Table 8 – continued

Variable	Enrollment rate Coef.	Std. Err.	Promotion rate Coef.	Std. Err.	Dropout rate Coef.	Std. Err.
Gender of household head	13.535*	6.919	0.829	1.775	1.815	1.179
Lit. of household head	14.765***	3.149	2.875***	0.831	-0.282	0.736
Married	-0.469	6.573	-1.701	1.784	-1.243	1.878
Land	-3.955	5.090	1.093	1.395	1.562	1.186
λ_1^{-+}	42.324***	7.314	-11.011***	2.738	7.086***	2.395
λ_2^{-+}	-25.219***	4.571	15.937***	1.547	-9.221***	1.220
Intercept	70.729***	16.113	60.811***	5.263	27.725***	4.447
# Observations	827		822		822	
Wald $\chi_2(d.o.f)$	379.93 (19)		273.15(21)		212.57 (20)	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.271		0.222		0.172	
Performance Eq. Package						
Temporary shelters	-13.834***	0.584	5.512***	0.182	-0.868***	0.014
Class size	-0.013	0.024	0.004	0.007	-0.0004	0.0006
Pupil's age	-0.047	0.040	0.032**	0.015	-0.001	0.001
Education expenditure[b]	0.001	0.068	0.003	0.023	-0.0004	0.001
Health expenditure[b]	0.021	0.063	-0.011	0.022	0.0009	0.001
Livestock	0.0006**	0.0003	-0.0002	0.0001	0.00002	0.00001
Distance to school	9.046***	0.340	-2.847***	0.106	0.237***	0.008
Gender of teacher	0.554*	0.335	-0.232*	0.118	0.015	0.008
Continuing training			-0.123	0.085		
Gender of pupil	1.784***	0.094	0.700***	0.031	-0.079***	0.002
Koranic school	-0.502***	0.149	0.158***	0.048	-0.012***	0.004
Early childhood inst.	-0.387	0.255	0.106	0.074	-0.010*	0.006
Snack	-0.226	0.200	0.068	0.052	-0.006	0.004
Sick last 3 months			0.017	0.025	-0.0005	0.002
Pupils eat at fill	0.340	0.250	-0.107	0.094	0.006	0.007
Gender of household head	-0.209	0.142	0.061	0.048	-0.005	0.004
Lit. of household head	-0.053	0.140	0.020	0.046	-0.002	0.003
Married	0.117	0.186	-0.054	0.062	0.004	0.005
Land	-0.187	0.292	0.042	0.083	-0.006	0.007
λ_1^{++}	-167.168***	0.797	-1.094	0.264	0.989***	0.021
λ_2^{++}	72.112***	2.696	-23.553***	0.827	1.983***	0.069
Intercept	191.992***	1.855	101.787***	0.540	7.386***	0.047
# Observations	135		135		135	
Wald $\chi_2(d.o.f)$	3.66e+06 (19)		327065.53		1.09e+06(20)	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.99		0.99		0.99	
Performance Eq. Untreated						
Temporary shelters	2.571***	0.843	0.599***	0.194	-0.828***	0.171
Class size	-0.449***	0.070	-0.027*	0.015	0.014	0.015
Pupil's age	-0.899	0.594	0.133	0.140	-0.233*	0.134
Education expenditure[b]	4.867***	0.917	0.067	0.173	-0.131	0.177
Health expenditure[b]	-3.649***	0.585	-0.367***	0.105	0.346***	0.102
Livestock	-0.413***	0.044	-0.074***	0.010	0.089***	0.010
Distance to school	-12.540***	3.487	4.037***	0.629	-4.219***	0.608
Gender of teacher	-20.712***	2.761	1.542**	0.684	0.722	0.665
Continuing training			2.225***	0.549		
Gender of pupil	0.149	2.072	0.733	0.539	-0.741	0.528
Koranic school	0.865	2.351	1.985***	0.474	-1.364***	0.447
Early childhood inst.	4.222	3.705	2.277***	0.708	-2.908***	0.624
Snack	1.371	3.371	-0.387	0.829	-0.380	0.899
Sick last 3 months			0.332	0.517	-0.222	0.496
Pupils eat at fill	31.105***	2.854	4.286***	0.966	-6.112***	1.044
Gender of household head	-20.150***	4.069	1.075	0.866	0.434	0.696

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Variable	Enrollment rate Coef.	Std. Err.	Promotion rate Coef.	Std. Err.	Dropout rate Coef.	Std. Err.
Lit. of household head	17.791***	3.112	-0.466	0.659	-0.081	0.652
Married	-4.055	7.092	-1.591	1.104	1.900*	1.039
Land	-7.900**	3.738	3.034***	1.068	-3.034***	1.076
λ_1^{--}	107.293***	10.615	20.796***	2.161	-22.859***	2.143
λ_2^{--}	23.885***	6.695	-20.390***	1.233	19.688***	1.195
Intercept	-19.412	13.954	73.448***	2.788	22.035***	2.870
# Observations	2312		2299		2299	
Wald $\chi_2(d.o.f)$	1727.77(19)		812.10(21)		1033.09(20)	
$P > \chi_2$	0.000		0.000		0.000	
Adj R-squared	0.283		0.154		0.184	

Notes [a]:Two-step; [b] In log.
Significance levels (bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 9: Average Treatment Effects: DISM[a]

	FIML[b] Aggregate	French	Math	Two step Aggregate	French	Math
Excusif: deworming	3.434***	0.055*	6.264***	3.700***	0.302***	6.866***
Excusif: meal	7.197***	4.103***	10.158***	6.560***	3.779***	9.329***
Global	15.097***	10.674***	19.578***	14.099***	9.997***	18.353***
Additionnal	4.465***	6.515***	3.155***	3.838***	5.915***	2.157***
Relative: package vs. deworming	11.663***	10.618***	13.313***	10.399***	9.694***	11.486***
Relative: package vs. meal	7.900***	6.571***	9.420***	7.538***	6.218***	8.023***
Relative: deworming vs. meal	-3.763***	-4.047***	-3.893***	-2.860***	-3.476***	-2.462***

Notes [a]: Double-Index Selection Model; [b]=Full Information Maximum Likelihood
Significance levels (Bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 10: Treatment Effects: Generalized Roy model[a]

	Population (ATE)			Treated (ATET)			Untreated (ATENT)		
	Aggregate	French	Math	Aggregate	French	Math	Aggregate	French	Math
Exclusive: deworming	5.357***	3.7520***	8.832***	17.295***	2.002***	48.124***	-2.192***	-3.426***	-2.838***
Exclusive: meal	7.470***	5.659***	9.347***	20.124***	17.209***	23.515***	1.259***	0.064	2.587***
Global	18.176***	11.793***	24.552***	89.231***	55.548***	122.773***	27.817***	25.718***	29.938***
Additional	5.348***	2.382***	6.371***	51.811***	36.336***	51.133***	28.750***	29.080***	30.189***
Relative: package vs. deworming	12.819***	8.041***	15.719***	71.936***	53.545***	74.649***	30.010***	29.144***	32.777***
Relative: package vs. meal	10.705***	6.134***	15.204***	69.107***	38.339***	99.258***	26.557***	25.654***	27.350***
Relative: deworming vs. meal	-2.113***	-1.907***	-0.514	-2.829***	-15.206***	24.609***	-3.452***	-3.490***	-5.426***

Notes [a]: Two step estimation.

Significance levels (Bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 11: Substitution and Sequential Effects: Generalized Roy model[a]

	Treated (ATET)			Untreated (ATENT)		
	Aggregate	French	Math	Aggregate	French	Math
Sequential: (T_1, T_2)	54.999***	33.247***	55.144***	144.436***	130.512***	142.742***
Sequential: (T_2, T_1)	68.244***	38.043***	99.576***	-63.891***	-67.825***	-60.469***
Substitution: (T_1, T_2)	5.104***	0.178***	6.254***	3.452***	3.490***	5.426***
Substitution: (T_2, T_1)	15.066***	1.550***	45.748***	-3.452***	-3.490***	-5.426***

Notes [a]: Two step estimation.

Significance levels (Bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 12: Average Treatment Effects

	DISM[a]			Roy[b]		
	Enrollment	Promotion	Dropout	Enrollment	Promotion	Dropout
Exclusive: deworming	-25.619***	-5.198***	-1.443***	-19.642***	-8.290***	-1.263***
Exclusive: meal	11.177***	2.727***	-4.797***	19.644***	5.021***	-5.430***
Global	-12.400***	7.040***	-9.029***	-14.415***	2.547***	-8.100***
Additional	2.041***	9.511***	-2.788***	2.735***	5.815***	-3.680***
Relative: package vs. deworming	13.219***	12.239***	-7.585***	17.675***	10.837***	-9.436***
Relative: package vs. meal	-23.578***	4.313***	-4.231***	-20.740***	1.768***	-2.111***
Relative: deworming vs. meal	36.797***	7.925***	-3.353***	1.550***	2.381***	-1.660***

Notes [a]: Double-Index Selection Model, two-step estimations; [b]: Roy model, two-step estimations.

Significance levels (Bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 13: Treatment Effects: Generalized Roy[a]

	Treated (ATET)			Untreated (ATENT)		
	Enrollment	Promotion	Dropout	Enrollment	Promotion	Dropout
Exclusive: deworming	-251.724***	-59.885***	89.095***	80.410***	-11.976***	-0.995***
Exclusive: meal	-37.906***	41.619***	-38.952***	45.890***	-17.996***	9.014***
Global	-381.663***	-31.793***	14.529***	58.663***	14.644***	-1.869***
Additional	-92.032***	-13.527***	-35.613***	-67.636***	44.617***	-9.889***
Relative: package vs. deworming	-129.938***	28.091***	-74.565***	-21.746***	26.621***	-0.874***
Relative: package vs. meal	-343.757***	-73.413***	53.482***	12.773***	32.641***	-10.884***
Relative: deworming vs. meal	-213.818***	-101.504***	128.048***	34.520***	6.020***	-10.010***

Notes [a]: Two step estimation.

Significance levels (Bootstrap -100 replications-): $*$: 10% $**$: 5% $***$: 1%

Table 14: Program cost per year: Deworming

	Quantity	Currency (CFA)	Number of pupils	Cost per pupil (in CFA)
Deworming				
Drugs	400,000	6,400,000	200,000	
Advocacy Mission	1	3,734,280		
Transport	1	200,000		
Supervision	1	4,496,000		
Total deworming		14,830,280	200,000	74.151

Table 15: Program cost per year: Meal

	Quantity	Currency (CFA)	Number of pupils	Cost per pupil (CFA)
Meal				
Food	16,900	7,165,413,861	560,000	
Other costs[a]	1	170,566,943	560,000	
Total meal		7,335,980,804	560,000	13,099.966

Note: [a] Strengthening capacities and resources of the DCS, responsible of canteens and school management committees.

Table 16: Cost effectiveness analysis

	DISM[a]			Roy [b]		
	Aggregate	French	Math	Aggregate	French	Math
Cost deworming only	74.151	74.151	74.151	74.151	74.151	74.151
Cost meal only	13,099.966	13,099.966	13,099.966	13,099.966	13,099.966	13,099.966
Cost deworming and meal	13,174.117	13,174.117	13,174.117	13,174.117	13,174.117	13,174.117
Percentage of additional score						
ATE						
Exclusive: deworming	3.700	0.302	6.866	5.357	3.752	8.832
Exclusive: meal	6.560	3.779	9.329	7.470	5.659	9.347
Global	14.099	9.997	18.353	18.176	11.793	24.552
ATET						
Exclusive: deworming				17.295	2.002	48.124
Exclusive: meal				20.124	17.209	23.515
Global				89.231	55.548	122.773
Sequential: (T1,T2)				54.999	33.247	55.144
Sequential: (T2,T1)				68.244	38.043	99.576
Substitution: (T1,T2)				5.104	0.178	6.254
Substitution: (T2,T1)				15.066	1.550	45.748
Cost per percentage of additional score						
ATE						
Exclusive: deworming	20.040	245.533	10.799	13.841	19.763	8.395
Exclusive: meal	1996.946	3466.516	1404.219	1753.676	2314.890	1401.515
Global	934.400	1317.807	717.818	724.808	1117.113	536.580
ATET						
Exclusive: deworming				4.287	37.038	1.540
Exclusive: meal				650.962	761.227	557.089
Global package				147.640	237.166	107.304
Sequential: (T1,T2)				239.533	396.249	238.903
Sequential: (T2,T1)				193.044	346.295	132.302
Substitution: (T1,T2)				2581.135	74011.893	2106.510
Substitution: (T2,T1)				874.426	8499.430	287.971

Notes [a]: Dummy Index-Selection Model, two-step estimations; [b]: Generalized Roy model, two-step estimations.

Table 17: Cost effectiveness analysis

	DISM[a]			Roy [b]		
	Enrollment	Promotion	Dropout	Enrollment	Promotion	Dropout
Cost deworming only	74.151	74.151	74.151	74.151	74.151	74.151
Cost meal only	13,099.966	13,099.966	13,099.966	13,099.966	13,099.966	13,099.966
Cost deworming and meal	13,174.117	13,174.117	13,174.117	13,174.117	13,174.117	13,174.117
Percentage of additional score						
Exclusive: deworming			-1.443			-1.263
Exclusive: meal	11.177	2.727	-4.797	19.644	5.021	-5.430
Global of the package		7.040	-9.029		2.547	-8.100
Cost per percentage of additional score						
Exclusive: deworming			51.386			58.710
Exclusive: meal	1172.046	4803.801	2730.866	666.868	2609.035	2412.516
Global		1871.323	1459.089		5172.405	1626.434

Notes [a]: Dummy Index-Selection Model, two-step estimations; [b]: Generalized Roy model, two-step estimations.

Table 18: Welfare analysis: Descriptive statistics

Variable	Mean	St.Dev.	Min	Max
Total expenditure[a]	11.961	0.474	10.020	13.670
Gini inequality index	0.240	0.066	0.141	0.415
Atkinson inequality index	0.052	0.030	0.016	0.151
Entropy inequality index	0.106	0.064	0.033	0.318
# Children having deworming	0.124	0.414	0	4
# Children having meals	0.368	0.731	0	7
# Children having package	0.053	0.274	0	3
# Children 0-5 years	2.754	2.301	0	19
# Children 6-14 years	4.616	3.092	0	40
# Adults (15 years and more)	6.713	3.982	2	32
# Livestock owned	8.697	12.469	0	502
# Meals per day	2.983	0.183	1	6
Age of household head	51.670	12.988	18	98
Electricity[b]	0.152			
Gender of household head[b]	0.875			
Literacy of household head[b]	0.180			
Area of arable land (in hectare) 0-5[b]	0.597			
Area of arable land (in hectare) 6-10[b]	0.307			
Area of arable land (in hectare) 11-15[b]	0.044			
Area of arable land (in hectare) 16 and more[b]	0.051			
# Observations (households)		1153		

Note: [a] Expenditure per adult equivalent in log.
Note: [b] binary variables.

Table 19: Welfare analysis: Three-stage least square estimation (dependent variable: log of total expenditure)[a]

	Gini		Atkinson		Entropy	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Welfare Equation						
Treatment status						
# Children dewormed	0.023	0.043	0.022	0.052	0.024	0.051
# Children meals	0.100***	0.019	0.098***	0.018	0.098***	0.018
# Children package	0.194***	0.060	0.191***	0.064	0.189***	0.065
Household characteristics						
Household composition						
# Children 0-5 years	-0.036***	0.006	-0.036***	0.007	-0.036***	0.007
# Children 6-14 years	-0.014***	0.005	-0.014***	0.005	-0.014***	0.005
# Adults (15 years and more)	-0.030***	0.004	-0.030***	0.004	-0.030***	0.004
Arable land (in ha)						
Area 6-10	0.038	0.027	0.038	0.027	0.038	0.027
Area 11-15	0.218***	0.063	0.218***	0.064	0.222***	0.062
Area 16 and more	0.292***	0.068	0.295***	0.080	0.295***	0.084
# Livestock owned	0.09**	0.04	0.09**	0.04	0.09**	0.04
# Meals per day	0.135**	0.067	0.137**	0.070	0.137**	0.070
Age of household head	-0.013**	0.006	-0.013**	0.006	-0.014**	0.006
Age of household head square	0.01**	0.005	0.01**	0.005	0.01**	0.005
Electricity	0.165***	0.038	0.160***	0.047	0.163***	0.044
Gender of household head	-0.054	0.039	-0.054	0.040	-0.055	0.040
Literacy of household head	0.122***	0.033	0.121***	0.033	0.120***	0.032

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Table 19 – continued

Variable	Gini Coef.	Gini Std. Err.	Atkinson Coef.	Atkinson Std. Err.	Entropy Coef.	Entropy Std. Err.
Inequality index	0.299	1.265	0.708	4.039	0.347	1.720
Intercept	12.103***	0.321	12.136***	0.263	12.143***	0.259
Inequality Equation						
Expenditure distribution	4.213***	0.682	1.519***	0.309	3.451***	0.659
Intercept	0.233***	0.002	0.049***	0.001	0.100***	0.002
R-square	0.2459		0.2466		0.2470	
χ_2	388.52		380.24		385.65	
$P > \chi_2$	0.000		0.000		0.000	
# Observations (households)	1153		1153		1153	

Notes [a]: Three-stage least squares estimations.

Significance levels: $*$: 10% $**$: 5% $***$: 1%

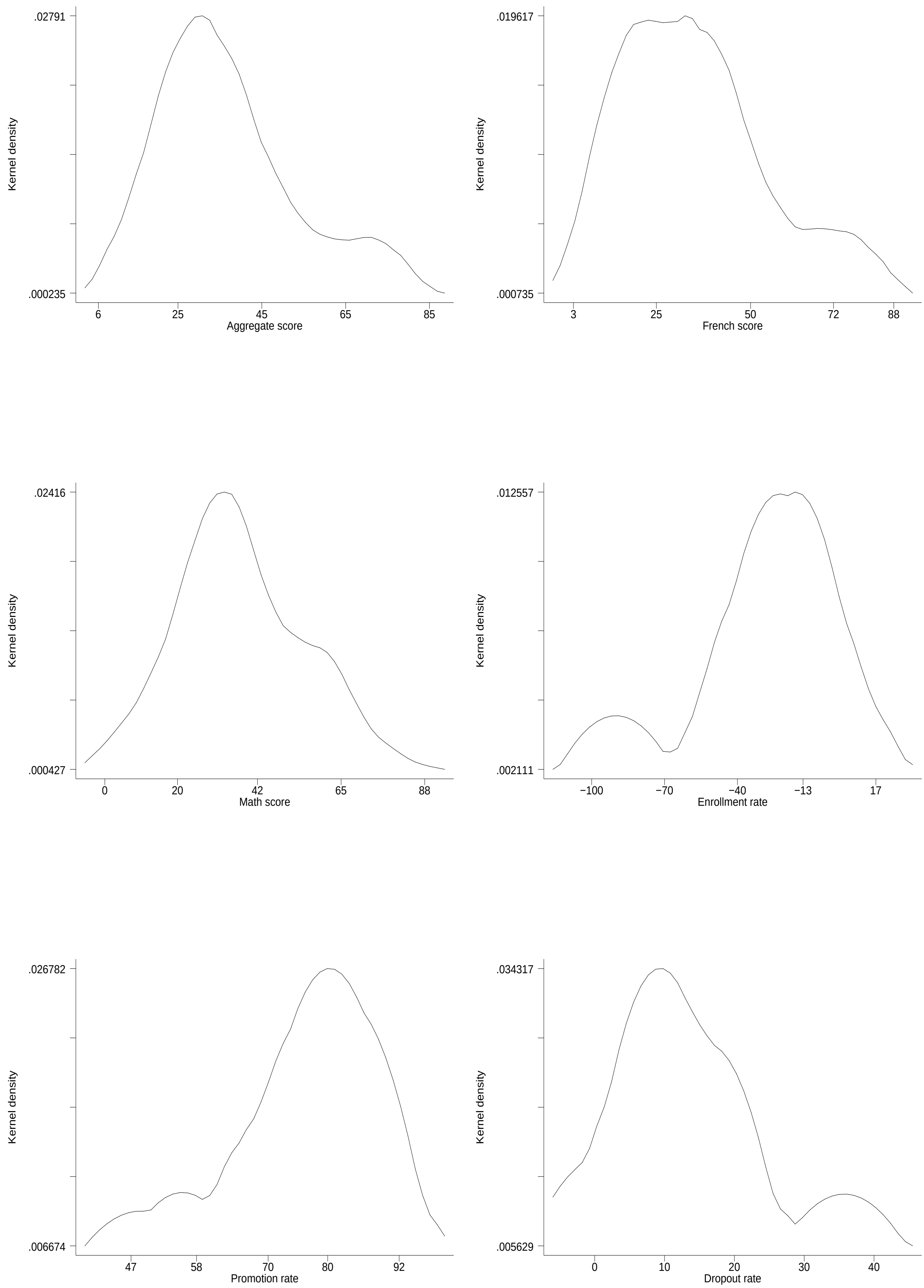

Figure 1: Kernel (Epanechnikov) density estimate: Distribution of outcomes (scores: aggregate, French and Maths; enrollment, promotion and dropout rates) for pupils having only the deworming program

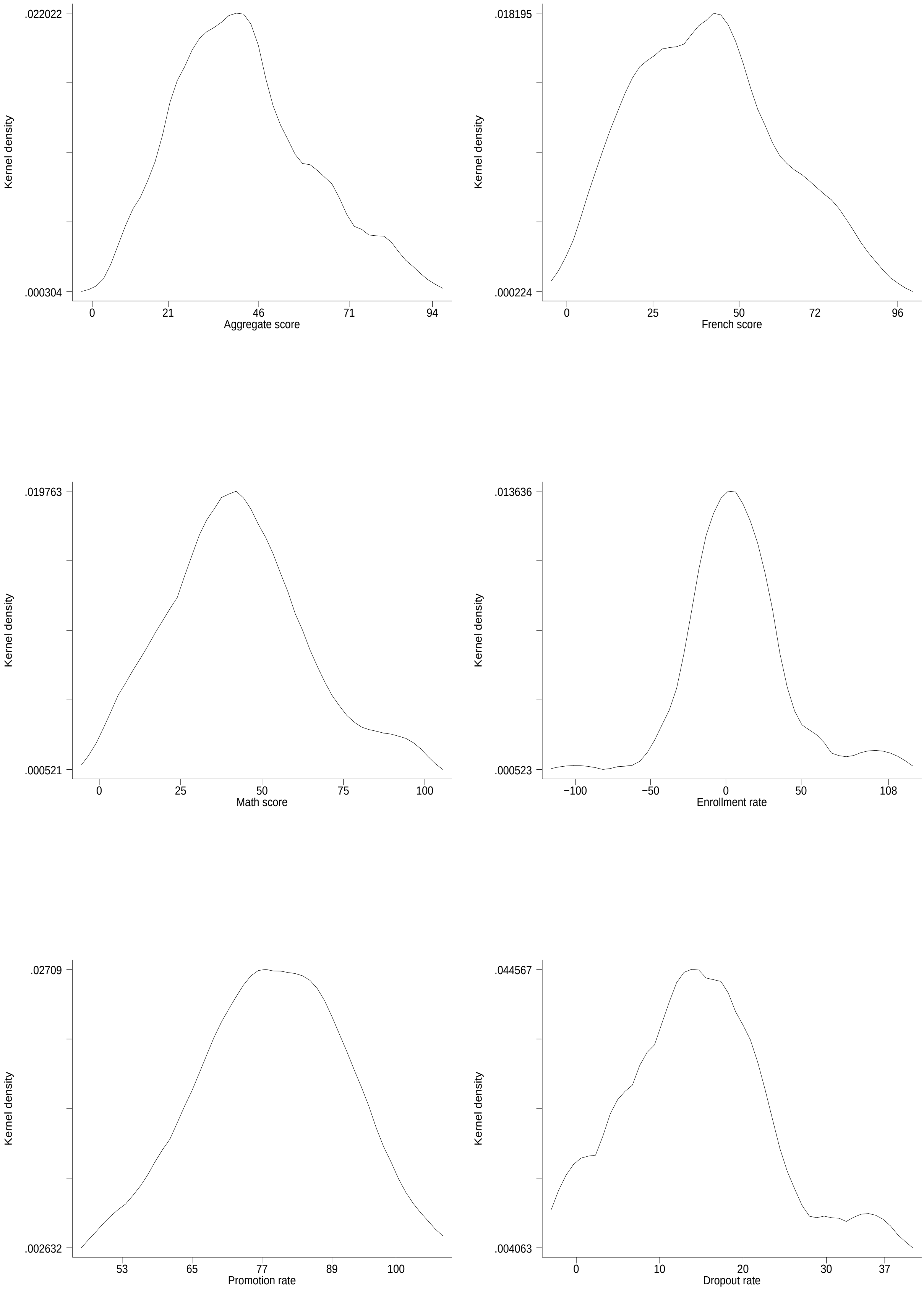

Figure 2: Kernel (Epanechnikov) density estimate: Distribution of outcomes (scores: aggregate, French and Maths; enrollment, promotion and dropout rates) for pupils having only meals program

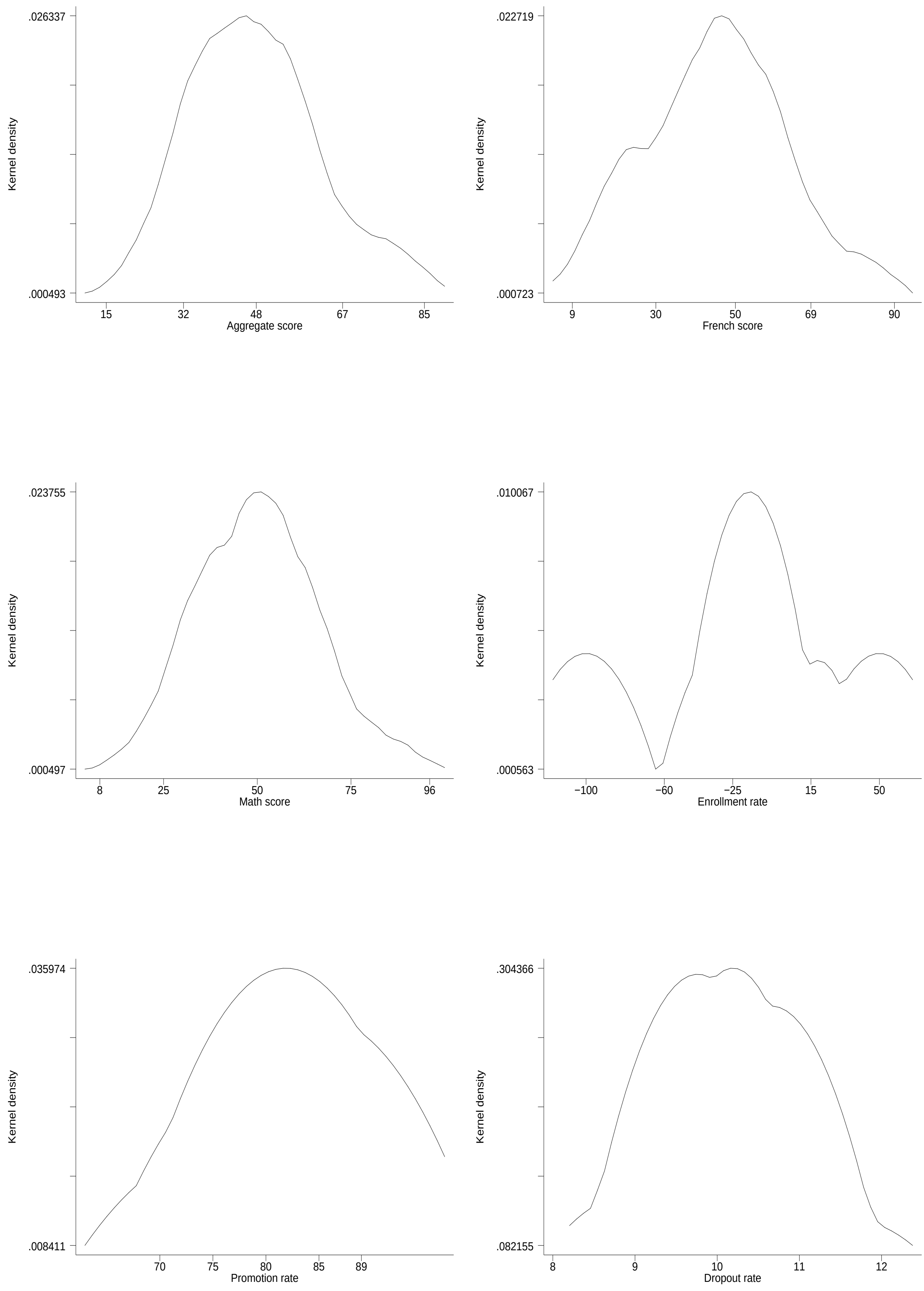

Figure 3: Kernel (Epanechnikov) density estimate: Distribution of outcomes (scores: aggregate, French and Maths; enrollment, promotion and dropout rates) for pupils having both programs (deworming and meals)

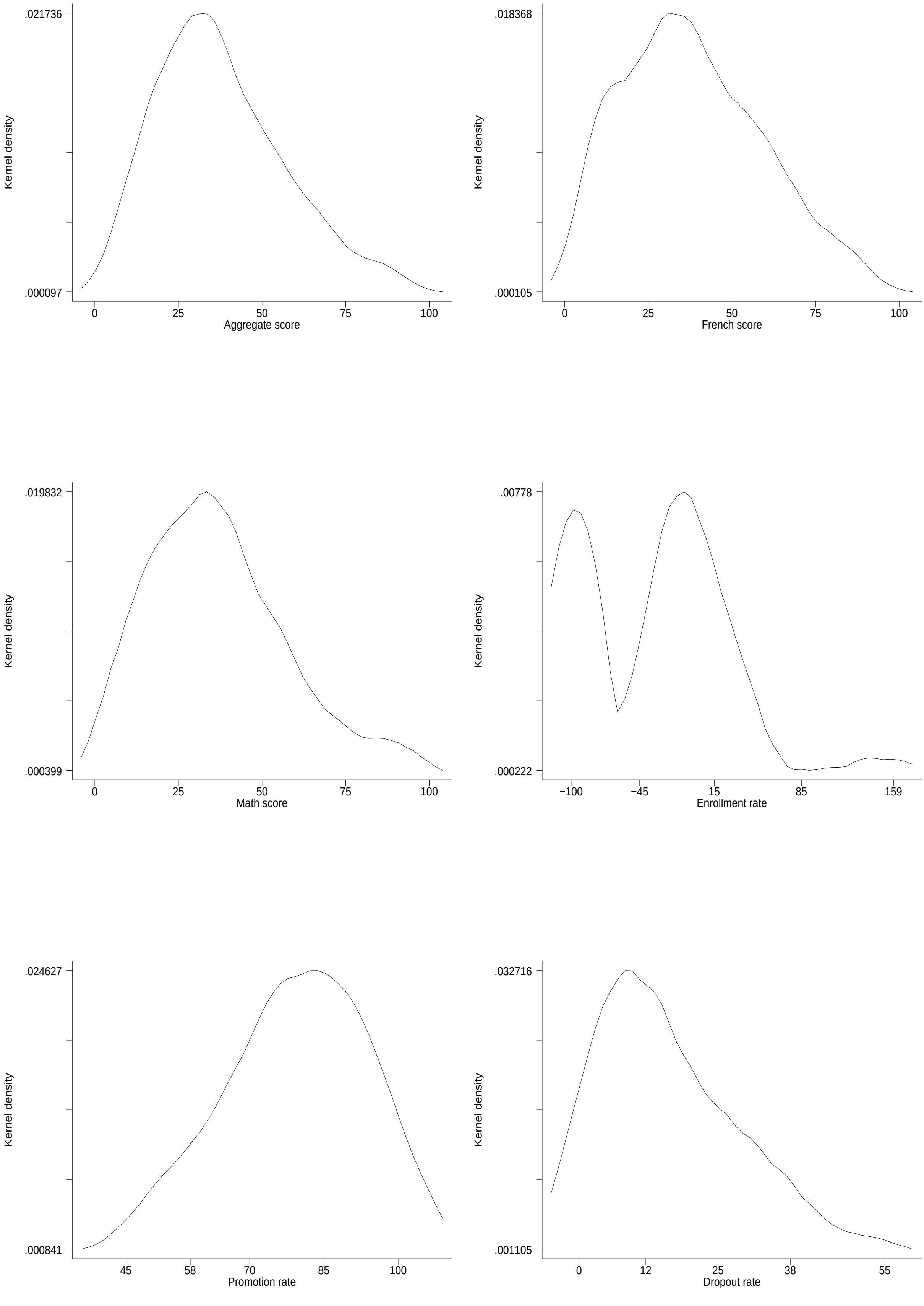

Figure 4: Kernel (Epanechnikov) density estimate: Distribution of outcomes (scores: aggregate, French and Maths; enrollment, promotion and dropout rates) for pupils who received no programs

List and definition of variables

Table 20: Table A1. Definition of variables

Variable name	Definition	Nature
Outcomes		
Aggregate score	Aggregate test scores in French and Mathematics	continuous
French score	Test scores in French	continuous
Math score	Test scores in Mathematics	continuous
Enrollment rate	Enrollment rate of the school	continuous
Promotion rate	Promotion rate of the school	continuous
Dropout rate	Dropout rate of the school	continuous
Treatment indicators		
Meal	Meal program indicator	binary (yes=1)
Deworming	Deworming program indicator	binary (yes=1)
Schools & teachers		
Temporary shelters	Number of classes in temporary shelters	continuous
School manual [a]	Number of pupils per manual in the school	continuous
Total pupils	Total number of pupils per school	continuous
Class size	Number of pupils by class	continuous
Teacher's age	Age of the teacher (in year)	continuous
Distance to school	Distance between school and pupils's home (less than 1 km)	binary (yes=1)
Gender of teacher	Gender of the teacher	binary (male=1)
No professional diploma	Teachers without professional diploma	binary (yes=1)
Professional diploma CAP	Teachers with a 'Certificat d'Aptitude Pédagogique' as professional diploma	binary (yes=1)
Professional diploma CEAP	Teachers with a 'Certificat Elémentaire d'Aptitude Pédagogique' as professional diploma	binary (yes=1)
Other professional diploma	Teachers with other professional diploma	binary (yes=1)
Academic diploma (bacplus)	Teachers having as academic diploma: baccalaureate or undergraduate or bachelor	binary (yes=1)
Academic diploma (brevet)	Teachers having as academic diploma: certificate 'brevet'	binary (yes=1)
Continuing training	Teachers have received continuing training	binary (yes=1)
Absenteeism	Indicates whether the teachers of the schools are often absent or not	binary (yes=1)
Medicine box	Existence of a medicine box in the school	binary (yes=1)
Toilets	Existence of separate toilets in the school	binary (yes=1)
Management committee	Existence of a management committee in the school	binary (yes=1)
Cooperative school	Existence of a cooperative school in the school	binary (yes=1)
Association of parents	Existence of a Association of pupil's parents in the school	binary (yes=1)
Association of mothers	Existence of a Association of pupil's mothers in the school	binary (yes=1)
Rural council grant	School receives a grant from the rural council	binary (yes=1)
Water point	Existence of a water point in the school	binary (yes=1)
Disturbed courses	Disturbances that caused delay of the start courses	binary (yes=1)
Storage	Existence of a storage -warehouse- in the school	binary (yes=1)
Meals near school	Opportunity of the pupils to have meal near school	binary (yes=1)
Hands washing	Existence of a hands washing device in the school	binary (yes=1)
School cost	School where school expenses are too high for households	binary (yes=1)

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Variable name	Definition	Nature
Pupils		
Pupil's age	Age of the pupil (in year)	continuous
Gender of pupil	Gender of the pupil	binary (boy=1)
Grade	Education level of the pupil	binary (CE2=1)
Deworming at home	Pupils who dewormed at home	binary (yes=1)
Koranic school	Pupils who attended a Koranic school	binary (yes=1)
Early childhood inst.	Pupils who attended an early child institution	binary (yes=1)
Sick in last 3 months	Pupils who have been sick in the last 3 months	binary (yes=1)
Pupils eat at fill	Pupils who eat at their fill at home	binary (yes=1)
Snack	Child who brings a snack to school	binary (yes=1)
Households		
Total expenditure	Monthly total expenditure of household per adult equivalent[b] (in log, CFA[c])	continuous
Health expenditure	Annual health expenditure of household (in log, CFA[c])	continuous
Education expenditure	Annual education expenditure of household (in log, CFA[c])	continuous
Livestock	Number of head of livestock that the household owns	continuous
Gender of household head	Gender of the household head	binary (male=1)
Lit. of household head	Head of household is literate in French	binary (yes=1)
Married	Married people	binary (yes=1)
Land	Possession of cultivable land owned by the household	binary (yes=1)
Communities		
Primary schools	Number of primary schools in the community	continuous
College	Existence of a college in the school's village	binary (yes=1)
Parents school	Child living in a community where parents are not interested in school	binary (yes=1)
Koranic school com.	Child living in a community where attending Koranic school prevent children from going to school	binary (yes=1)
Locations		
Diourbel	Region Diourbel	binary (yes=1)
Fatick	Region Fatick	binary (yes=1)
Kolda	Region Kolda	binary (yes=1)
Sedhiou	Region Sedhiou	binary (yes=1)

Note [a]: This variable is created using total pupils and number of school manuals.
Note [b]: Ratio between total expenditure and household size per adult equivalent based on Oxford A scales.
Note [c]: Currency of the French colonies in Africa.

Supplementary appendix to:

'The Harmony of Programs Package: Quasi-experimental Evidence on Deworming and Canteen Interventions in Rural Senegal'

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APPENDIX

A. Methods: General framework for mean of trivariate truncated normal distributions

Let x, y and z denote three random variables following a trivariate normal distribution with mean $\boldsymbol{\mu}$ and covariance matrix $\boldsymbol{\Sigma}$, i.e.,

$$(x, y, z) \sim N\left[\begin{pmatrix} \mu_x \\ \mu_y \\ \mu_z \end{pmatrix}, \begin{pmatrix} \sigma_x^2 & & \\ \rho_{xy}\sigma_x\sigma_y & \sigma_y^2 & \\ \rho_{xz}\sigma_x\sigma_z & \rho_{yz}\sigma_y\sigma_z & \sigma_z^2 \end{pmatrix}\right].$$

In this appendix, we establish various neat relations regarding the mean of trivariate truncated normal distribution. These relations are used in the estimation strategies of the paper and also proved particularly useful in deriving treatment effects. The formulas we get also have the advantage of being easy to write in terms of code for most statistical and econometric software. Before proceeding, let's briefly recall the well-known formulae for the mean of univariate and bivariate truncation.

A.1. Univariate truncation

The conditional expectation $\mathbb{E}(x \mid x > a)$ involving the ***univariate*** truncated normal distribution is given by

$$\mathbb{E}(x \mid x > a) = \mu_x + \sigma_x \lambda_{x_a}\left[\left(\frac{a-\mu_x}{\sigma_x}\right)\right] \tag{A-1}$$

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where $\lambda_{x_a} = \dfrac{\phi_1\left(\frac{a-\mu_x}{\sigma_x}\right)}{1-\Phi_1\left(\frac{a-\mu_x}{\sigma_x}\right)}$ denotes the ***inverse Mill's ratio*** with ϕ_1 and Φ_1 denoting respectively the probability distribution function (pdf) and the cumulative distribution function (cdf) of the ***univariate*** standard normal distribution. Similarly, the conditional expectation involving the univariate truncated (from above) normal distribution is given by

$$\mathbb{E}(x \mid x \leq b) = \mu_x - \sigma_x \lambda_{x_b}\left[\left(\frac{b-\mu_x}{\sigma_x}\right)\right] \tag{A-2}$$

where $\lambda_{x_b} = \dfrac{\phi_1\left(\frac{b-\mu_x}{\sigma_x}\right)}{1-\Phi_1\left(\frac{b-\mu_x}{\sigma_x}\right)}$.

A.2. Bivariate truncation

The conditional expectation $E(x|y > a)$ involving the ***bivariate*** truncated (from below) normal distribution is written as

$$\begin{aligned}\mathbb{E}(x|y > a) &= \mu_x + \frac{cov(x,y)}{\sigma_y}\lambda_{y_a} \\ &= \mu_x + \frac{\rho_{xy}\sigma_x\sigma_y}{\sigma_y}\lambda_{y_a} \\ &= \mu_x + \rho_{xy}\sigma_x\lambda_{y_a},\end{aligned} \tag{A-3}$$

where $cov(x,y) = \rho_{xy}\sigma_x\sigma_y$ and $\lambda_{y_a} = \dfrac{\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)}{1-\Phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)}$. Similarly, we can show that

$$\mathbb{E}(x|y \leq b) = \mu_x - \frac{cov(x,y)}{\sigma_y}\lambda_{y_b}, \tag{A-4}$$

where $\lambda_{y_b} = \dfrac{\phi_1\left(\frac{b-\mu_y}{\sigma_y}\right)}{1-\Phi_1\left(\frac{b-\mu_y}{\sigma_y}\right)}$. In what follows, we establish the analogue formulae for the case of trivariate truncation.

A.3. Trivariate truncation

We are interested in the expressions of $\mathbb{E}(x|y > a, z > b)$, $\mathbb{E}(x|y \leq a, z \leq b)$, $\mathbb{E}(x|y > a, z \leq b)$ and $\mathbb{E}(x|y \leq a, z > b)$. These conditional expectations involve the ***trivariate*** truncated normal distribution. More specifically, we make use of the conditional distribution of $x|y,z$. The mean of that distribution is given by

$$\mathbb{E}(x|y,z) = \mu_x + \frac{\sigma_x\rho_{xy.z}}{\sigma_y}(y-\mu_y) + \frac{\sigma_x\rho_{xz.y}}{\sigma_z}(z-\mu_z), \tag{A-5}$$

where $\rho_{xy.z}$ and $\rho_{xz.y}$ are *derived* from and *related* to the ***partial correlations,*** and are given by

$$\rho_{xy.z} = \frac{\rho_{xy}-\rho_{xz}\rho_{yz}}{1-\rho_{yz}^2};\ \rho_{xz.y} = \frac{\rho_{xz}-\rho_{xy}\rho_{yz}}{1-\rho_{yz}^2}. \tag{A-6}$$

A.3.a. Expression of $\mathbb{E}(x|y > a, z > b)$

We can derive $\mathbb{E}(x|y > a, z > b)$ by using equation (A-5). Hence,

$$\begin{aligned}
\mathbb{E}(x|y > a, z > b) &= \mu_x + \frac{\sigma_x \rho_{xy.z}}{\sigma_y}\mathbb{E}(y - \mu_y|y > a, z > b) + \frac{\sigma_x \rho_{xz.y}}{\sigma_z}\mathbb{E}(z - \mu_z|y > a, z > b) \\
&= \mu_x + \frac{\sigma_x \rho_{xy.z}}{\sigma_y}\left[\mathbb{E}(y|y > a, z > b) - \mu_y\right] + \frac{\sigma_x \rho_{xz.y}}{\sigma_z}\left[\mathbb{E}(z|y > a, z > b) - \mu_z\right]. \qquad \text{(A-7)}
\end{aligned}$$

Thus, we need to derive the expressions of $\mathbb{E}(y|y > a, z > b)$ and $\mathbb{E}(z|y > a, z > b)$.

i) *Computation of* $\mathbb{E}(y|y > a, z > b)$

Since

$$f_1(y|y > a, z > b) = \frac{f_2(y,z)}{\underbrace{\mathbb{P}[y > a, z > b]}_{\equiv \Gamma}},^{1} \qquad \text{(A-8)}$$

the conditional expectation can be written as

$$\begin{aligned}
\mathbb{E}(y|y > a, z > b) &= \mathbb{E}(yz^0|y > a, z > b) \\
&= \Gamma^{-1}\int_a^\infty \int_b^\infty y f(y,z) dy dz. \qquad \text{(A-9)}
\end{aligned}$$

By making the variable changes $Y = \frac{y-\mu_y}{\sigma_y}$ and $Z = \frac{z-\mu_z}{\sigma_z}$ so that $dy = \sigma_y dY$ and $dz = \sigma_z dZ$, the expectation can be written as

$$\begin{aligned}
\mathbb{E}(y|y > a, z > b) &= \underbrace{\Phi_2^{-1}\left[\frac{\mu_y - a}{\sigma_y}, \frac{\mu_z - b}{\sigma_z}, \rho_{yz}\right]}_{\equiv \Phi_2^{-1}} \int_{\frac{a-\mu_y}{\sigma_y}}^\infty \int_{\frac{b-\mu_z}{\sigma_z}}^\infty (\sigma_y Y + \mu_y)\frac{\phi_2(Y,Z)}{\sigma_y \sigma_z}\sigma_y \sigma_z dY dZ \\
&= \sigma_y \Phi_2^{-1}\int_{\frac{a-\mu_y}{\sigma_y}}^\infty \int_{\frac{b-\mu_z}{\sigma_z}}^\infty Y\phi_2(Y,Z) dY dZ + \mu_y \Phi_2^{-1}\underbrace{\int_{\frac{a-\mu_y}{\sigma_y}}^\infty \int_{\frac{b-\mu_z}{\sigma_z}}^\infty \phi_2(Y,Z) dY dZ}_{\equiv \Phi_2} \qquad \text{(A-10)} \\
&= \sigma_y \underbrace{\Phi_2^{-1}\int_{\frac{a-\mu_y}{\sigma_y}}^\infty \int_{\frac{b-\mu_z}{\sigma_z}}^\infty Y\phi_2(Y,Z) dY dZ}_{\mathbb{E}\left(Y|Y > \frac{a-\mu_y}{\sigma_y}, Z > \frac{b-\mu_z}{\sigma_z}\right)} + \mu_y.
\end{aligned}$$

Since Y and Z have a bivariate standard normal distribution, we can use the results of Rosenbaum (1961) or, more generally, the moment generating function approach of Muthén (1990) alongside the iterative ***incomplete normal moment*** results from Elandt (1961) to show that:

$$\begin{aligned}
\mathbb{E}\left(Y|Y > \frac{a-\mu_y}{\sigma_y}, Z > \frac{b-\mu_z}{\sigma_z}\right) &= \Phi_2^{-1}\left[\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\rho_{yz}\frac{a-\mu_y}{\sigma_y} - \frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right. \\
&\quad \left. + \rho_{yz}\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\rho_{yz}\frac{b-\mu_z}{\sigma_z} - \frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right]. \qquad \text{(A-11)}
\end{aligned}$$

[1] The subscripts 1 and 2 denote respectively the univariate and the bivariate pdf of cdf of the normal or standard normal distribution.

Hence,

$$\mathbb{E}(y|y>a,z>b) = \sigma_y \Phi_2^{-1}\left[\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\rho_{yz}\frac{a-\mu_y}{\sigma_y}-\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right.$$

$$\text{(A-12)} \qquad \left. + \rho_{yz}\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\rho_{yz}\frac{b-\mu_z}{\sigma_z}-\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right] + \mu_y.$$

ii) *Computation of* $\mathbb{E}(z|y>a,z>b)$

Similarly, we can derive $\mathbb{E}(z|y>a,z>b)$ as

$$\mathbb{E}(z|y>a,z>b) = \sigma_z \Phi_2^{-1}\left[\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\rho_{yz}\frac{b-\mu_z}{\sigma_z}-\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right.$$

$$\text{(A-13)} \qquad \left. + \rho_{yz}\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\rho_{yz}\frac{a-\mu_y}{\sigma_y}-\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right] + \mu_z.$$

For notational convenience, let us define Λ_1 and Λ_2 as

$$\text{(A-14a)} \qquad \Lambda_1 \equiv \phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\rho_{yz}\frac{a-\mu_y}{\sigma_y}-\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)$$

$$\text{(A-14b)} \qquad \Lambda_2 \equiv \phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\rho_{yz}\frac{b-\mu_z}{\sigma_z}-\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right).$$

Hence, $\mathbb{E}(x|y>a,z>b)$ can be written as

$$\mathbb{E}(x|y>a,z>b) = \mu_x + \frac{\sigma_x\rho_{xy.z}}{\sigma_y}\left[\sigma_y\Phi_2^{-1}\left(\Lambda_1+\rho_{yz}\Lambda_2\right)+\mu_y-\mu_y\right]$$

$$\text{(A-15)} \qquad + \frac{\sigma_x\rho_{xz.y}}{\sigma_z}\left[\sigma_z\Phi_2^{-1}\left(\Lambda_2+\rho_{yz}\Lambda_1\right)+\mu_z-\mu_z\right].$$

Replacing $\rho_{xy.z}$ and $\rho_{xz.y}$ by their expressions, and simplifying the previous expression yield

$$\mathbb{E}(x|y>a,z>b) = \mu_x + \frac{\sigma_x\left(\rho_{xy}-\rho_{xz}\rho_{yz}\right)}{1-\rho_{yz}^2}\Phi_2^{-1}\left(\Lambda_1+\rho_{yz}\Lambda_2\right)$$

$$\text{(A-16)} \qquad + \frac{\sigma_x\left(\rho_{xz}-\rho_{xy}\rho_{yz}\right)}{1-\rho_{yz}^2}\Phi_2^{-1}\left(\Lambda_2+\rho_{yz}\Lambda_1\right).$$

Factorizing yields

$$\mathbb{E}(x|y>a,z>b) = \mu_x + \frac{\sigma_x\Phi_2^{-1}}{1-\rho_{yz}^2}\Lambda_1\left[\rho_{xy}-\rho_{xz}\rho_{yz}+\rho_{xz}\rho_{yz}-\rho_{xy}\rho_{yz}^2\right]$$

$$\text{(A-17)} \qquad + \frac{\sigma_x\Phi_2^{-1}}{1-\rho_{yz}^2}\Lambda_2\left[\rho_{xz}-\rho_{xy}\rho_{yz}+\rho_{xy}\rho_{yz}-\rho_{xz}\rho_{yz}^2\right]$$

which can also be written as

$$\mathbb{E}(x|y>a,z>b) = \mu_x + \frac{\sigma_x\Phi_2^{-1}}{1-\rho_{yz}^2}\Lambda_1\rho_{xy}(1-\rho_{yz}^2) + \frac{\sigma_x\Phi_2^{-1}}{1-\rho_{yz}^2}\Lambda_2\rho_{xz}(1-\rho_{yz}^2)$$

$$\text{(A-18)} \qquad = \mu_x + \sigma_x\Phi_2^{-1}\Lambda_1\rho_{xy} + \sigma_x\Phi_2^{-1}\Lambda_2\rho_{xz}.$$

The final expression of $\mathbb{E}(x|y > a, z > b)$ is given by

$$\mathbb{E}(x|y > a, z > b) = \mu_x + \frac{\sigma_x \rho_{xy} \phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)}{\Phi_2\left[\frac{\mu_y - a}{\sigma_y}, \frac{\mu_z - b}{\sigma_z}, \rho_{yz}\right]} \Phi_1\left(\frac{\rho_{yz}\frac{a-\mu_y}{\sigma_y} - \frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)$$

$$+ \frac{\sigma_x \rho_{xz} \phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)}{\Phi_2\left[\frac{\mu_y - a}{\sigma_y}, \frac{\mu_z - b}{\sigma_z}, \rho_{yz}\right]} \Phi_1\left(\frac{\rho_{yz}\frac{b-\mu_z}{\sigma_z} - \frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right). \quad \text{(A-19)}$$

A.3.b. Expression of $\mathbb{E}(x|y \le a, z \le b)$

In this case, $\mathbb{E}(y|y > a, z > b)$ and $\mathbb{E}(z|y > a, z > b)$ are replaced by $\mathbb{E}(y|y \le a, z \le b)$ and $\mathbb{E}(z|y \le a, z \le b)$ in equation (A-7). Hence, we need to derive $\mathbb{E}(y|y \le a, z \le b)$ and $\mathbb{E}(z|y \le a, z \le b)$. Equation (A-8) is now written as

$$f_1(y|y \le a, z \le b) = \frac{f_2(y, z)}{\mathbb{P}[y \le a, z \le b]}. \quad \text{(A-20)}$$

Using similar derivations as previously and results from Muthén (1990), $\mathbb{E}(y|y \le a, z \le b)$ is given by

$$\mathbb{E}(y|y \le a, z \le b) = \sigma_y \Phi_2^{-1}\left[\frac{a-\mu_y}{\sigma_y}, \frac{b-\mu_z}{\sigma_z}, \rho_{yz}\right]\left[-\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\frac{b-\mu_z}{\sigma_z} - \rho_{yz}\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right.$$

$$\left. -\rho_{yz}\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\frac{a-\mu_y}{\sigma_y} - \rho_{yz}\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right] + \mu_y. \quad \text{(A-21)}$$

Similarly, $\mathbb{E}(z|y \le a, z \le b)$ is derived as

$$\mathbb{E}(z|y \le a, z \le b) = \sigma_z \Phi_2^{-1}\left[\frac{a-\mu_y}{\sigma_y}, \frac{b-\mu_z}{\sigma_z}, \rho_{yz}\right]\left[-\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\frac{a-\mu_y}{\sigma_y} - \rho_{yz}\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right.$$

$$\left. -\rho_{yz}\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\frac{b-\mu_z}{\sigma_z} - \rho_{yz}\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right] + \mu_z. \quad \text{(A-22)}$$

Using similar calculations as previously, $\mathbb{E}(x|y \le a, z \le b)$ is derived as

$$\mathbb{E}(x|y \le a, z \le b) = \mu_x - \frac{\sigma_x \rho_{xy} \phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)}{\Phi_2\left[\frac{a-\mu_y}{\sigma_y}, \frac{b-\mu_z}{\sigma_z}, \rho_{yz}\right]} \Phi_1\left(\frac{\frac{b-\mu_z}{\sigma_z} - \rho_{yz}\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)$$

$$- \frac{\sigma_x \rho_{xz} \phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)}{\Phi_2\left[\frac{a-\mu_y}{\sigma_y}, \frac{b-\mu_z}{\sigma_z}, \rho_{yz}\right]} \Phi_1\left(\frac{\frac{a-\mu_y}{\sigma_y} - \rho_{yz}\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right). \quad \text{(A-23)}$$

A.3.c. Expression of $\mathbb{E}(x|y > a, z \le b)$

The calculation of $\mathbb{E}(x|y > a, z \le b)$ involves $\mathbb{E}(y|y > a, z \le b)$ and $\mathbb{E}(z|y > a, z \le b)$ in equation (A-7). The latter two expectations are given by

$$\mathbb{E}(y|y > a, z \le b) = \sigma_y \Phi_2^{-1}\left[\frac{\mu_y - a}{\sigma_y}, \frac{b-\mu_z}{\sigma_z}, -\rho_{yz}\right]\left[\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\frac{b-\mu_z}{\sigma_z} - \rho_{yz}\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right.$$

$$\left. -\rho_{yz}\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\rho_{yz}\frac{b-\mu_z}{\sigma_z} - \frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right] + \mu_y \quad \text{(A-24)}$$

and

$$\mathbb{E}(z|y>a,z\leq b)=\sigma_z\Phi_2^{-1}\left[\frac{\mu_y-a}{\sigma_y},\frac{b-\mu_z}{\sigma_z},-\rho_{yz}\right]\left[-\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\rho_{yz}\frac{b-\mu_z}{\sigma_z}-\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right.$$

$$\left.+\rho_{yz}\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\frac{b-\mu_z}{\sigma_z}-\rho_{yz}\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)\right]+\mu_z. \tag{A-25}$$

Hence, $\mathbb{E}(x|y>a,z\leq b)$ is given by

$$\mathbb{E}(x|y>a,z\leq b)=\mu_x+\frac{\sigma_x\rho_{xy}\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)}{\Phi_2\left[\frac{\mu_y-a}{\sigma_y},\frac{b-\mu_z}{\sigma_z},-\rho_{yz}\right]}\Phi_1\left(\frac{\frac{b-\mu_z}{\sigma_z}-\rho_{yz}\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right)$$

$$-\frac{\sigma_x\rho_{xz}\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)}{\Phi_2\left[\frac{\mu_y-a}{\sigma_y},\frac{b-\mu_z}{\sigma_z},-\rho_{yz}\right]}\Phi_1\left(\frac{\rho_{yz}\frac{b-\mu_z}{\sigma_z}-\frac{a-\mu_y}{\sigma_y}}{\sqrt{1-\rho_{yz}^2}}\right). \tag{A-26}$$

A.3.d. Expression of $\mathbb{E}(x|y\leq a,z>b)$

Finally, the calculation of $\mathbb{E}(x|y\leq a,z>b)$ involves $\mathbb{E}(y|y\leq a,z>b)$ and $\mathbb{E}(z|y\leq a,z>b)$ in equation (A-7), the expressions of which are given by

$$\mathbb{E}(y|y\leq a,z>b)=\sigma_y\Phi_2^{-1}\left[\frac{a-\mu_y}{\sigma_y},\frac{\mu_z-b}{\sigma_z},-\rho_{yz}\right]\left[-\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\rho_{yz}\frac{a-\mu_y}{\sigma_y}-\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right.$$

$$\left.+\rho_{yz}\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\frac{a-\mu_y}{\sigma_y}-\rho_{yz}\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right]+\mu_y \tag{A-27}$$

and

$$\mathbb{E}(z|y\leq a,z>b)=\sigma_z\Phi_2^{-1}\left[\frac{a-\mu_y}{\sigma_y},\frac{\mu_z-b}{\sigma_z},-\rho_{yz}\right]\left[\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)\Phi_1\left(\frac{\frac{a-\mu_y}{\sigma_y}-\rho_{yz}\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right.$$

$$\left.-\rho_{yz}\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)\Phi_1\left(\frac{\rho_{yz}\frac{a-\mu_y}{\sigma_y}-\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)\right]+\mu_z. \tag{A-28}$$

Hence, $\mathbb{E}(x|y\leq a,z>b)$ is given by

$$\mathbb{E}(x|y\leq a,z>b)=\mu_x-\frac{\sigma_x\rho_{xy}\phi_1\left(\frac{a-\mu_y}{\sigma_y}\right)}{\Phi_2\left[\frac{a-\mu_y}{\sigma_y},\frac{\mu_z-b}{\sigma_z},-\rho_{yz}\right]}\Phi_1\left(\frac{\rho_{yz}\frac{a-\mu_y}{\sigma_y}-\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right)$$

$$+\frac{\sigma_x\rho_{xz}\phi_1\left(\frac{b-\mu_z}{\sigma_z}\right)}{\Phi_2\left[\frac{a-\mu_y}{\sigma_y},\frac{\mu_z-b}{\sigma_z},-\rho_{yz}\right]}\Phi_1\left(\frac{\frac{a-\mu_y}{\sigma_y}-\rho_{yz}\frac{b-\mu_z}{\sigma_z}}{\sqrt{1-\rho_{yz}^2}}\right). \tag{A-29}$$

B. Further results: Treatment effect heterogeneity

Average Treatment Effects are obtained by taking the average either over the entire sample (this is the case for the average treatment effect) or over two sub-populations leading to the Average Treatment Effect on the Treated (ATET) and the Average Treatment Effect on the Non-Treated (ATENT). All these effects are based on a hypothesis of homogeneity though the ATET and ATENT can be viewed as heterogenous. In other words, the average effects obtained are extrapolated to the population considered. In this supplement, we propose to study the variation in treatment effects across populations.

Treatment effect heterogeneity is an outstanding issue in many impact evaluation studies. As pointed out by Imai and Strauss (2011), the study of heterogeneous treatment effects is relevant from a policy perspective as it enables to identify subgroups of populations for which treatments are effective.[2] Treatment effect is heterogenous if some pupils experience larger treatment effects than others while the treatment is identical for all. This may follow from the characteristics of pupils and likely some unobserved factors.

B.1. Scores

The distribution of the treatments effects for the scores outcomes are plotted in Figures 1, 2, 3, 4 and 5. Two salient pictures can be observed. On one hand, the exclusive ATE effect for meals program has a strong uni-modal distribution which is concentrated around the average. At the same time, the distribution of the exclusive effect of deworming is more heterogeneous, less concentrated and slightly shifted to the right. In other words, there is a more heterogeneous population that experiences the effect of deworming while the effect of meals is more homogeneous. As a result the distribution of the exclusive effect of deworming is more dispersed than the effect of meals. This implies that the second order moment of the exclusive deworming effect is greater than that of the meals effect. On the other hand the distributions of global and additional effects are closely related except for the ATET of Maths score. The distribution of the sequential and substitution effects show similar pictures with strong uni-modality.

Include Figures 1, 2, 3, 4, 5

B.2. Enrollment, promotion and dropout

Figures 6, 7, 8, 9 and 10 display the plots of the distributions of treatment effects for the enrollment, promotion and dropout rates. The outstanding findings concern the enrollment rate and the distribution of sequential and substitution effects. Regarding enrollment rate, we observe a bi-modal distribution of the additional ATE with the largest mode having negative values of the treatment effects and a second less pronounced mode which displays positive values of treatment effects. This result indicates a double heterogeneity: one related to the sign of the treatment effects and the other to the multiple modality. Indeed, whereas a significant proportion of pupils experiment an additional negative effect, another small proportion of pupils experiment an additional positive effect.

The other distributions on the Figure display uni-modal patterns. Figure 6 (left) shows the effects of treatment on the treated, the exclusive and additional effects of deworming have a bi-modal distribution with different signs for each modality. We deduce that the heterogeneity picture is more pronounced than in the previous case. An interesting phenomenon appears in Figure 9 (left). Indeed, we observe a mirror-like distribution between the two substitution effects for the promotion rate. While the uni-modality T_2T_1 is displayed around negative treatment effect values, the substitution T_1T_2 reflects the same shape but with a reverse tail and a main mode around positive values of treatment effects.

[2] It is worthwhile to notice that we are not conducting a statistical inference on causal heterogeneity. Readers interested in this aspect can refer to the study of Angrist (2004), Horiuchi et al. (2007), Imai and Strauss (2011) and Imai and Ratkovic (2013).

Include Figures 6, 7, 8, 9, 10

The main conclusion we draw from the study of the distributions is that while some effects are homogeneous (e.g, exclusive ATE for meals and substitution effects for treated and untreated for the scores), other effects are clearly heterogeneous (mainly though some effects on enrollment rate, sequential and substitution effects). In other words, pupils react differently to the same intervention.

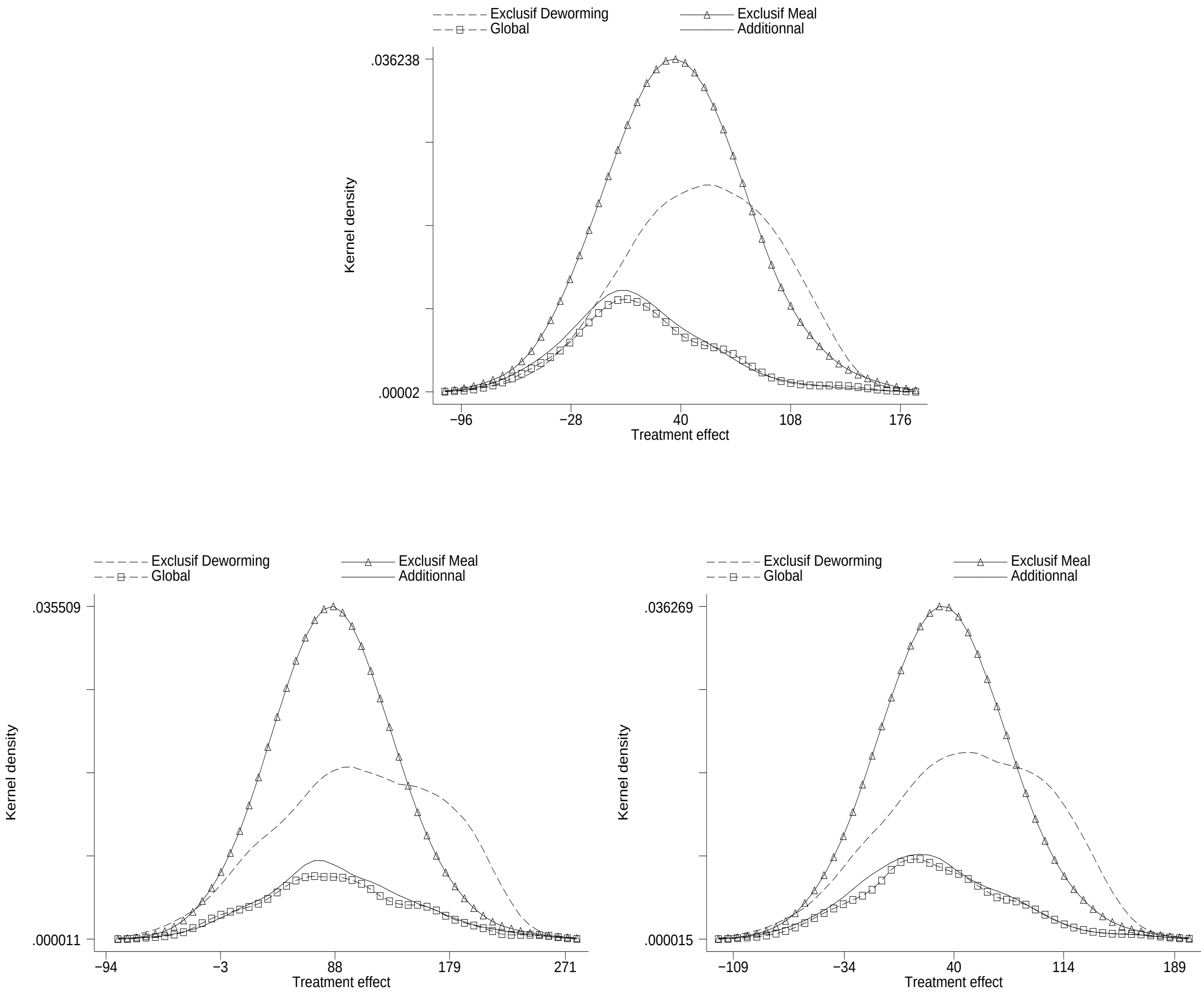

Figure 1: Distribution of treatment effects for aggregate score. [Top]: Average Treatment Effect (ATE) [Bottom-left]: Average Treatment Effect on the Treated (ATET). [Bottom-right]: Average Treatment Effect on the Nontreated (ATENT)

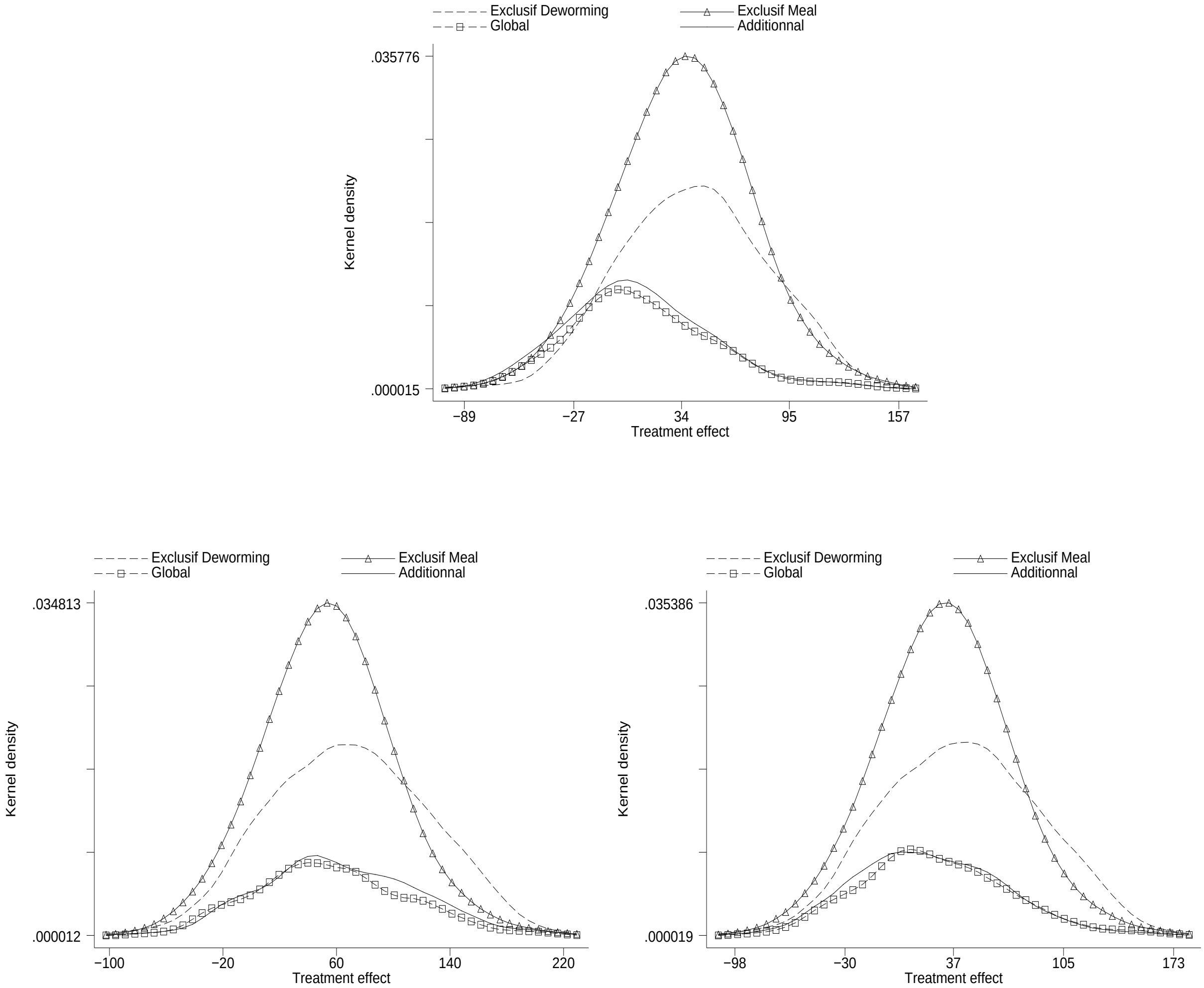

Figure 2: Distribution of treatment effects for French score. [Top]: Average Treatment Effect (ATE) [Bottom-left]: Average Treatment Effect on the Treated (ATET). [Bottom-right]: Average Treatment Effect on the Nontreated (ATENT)

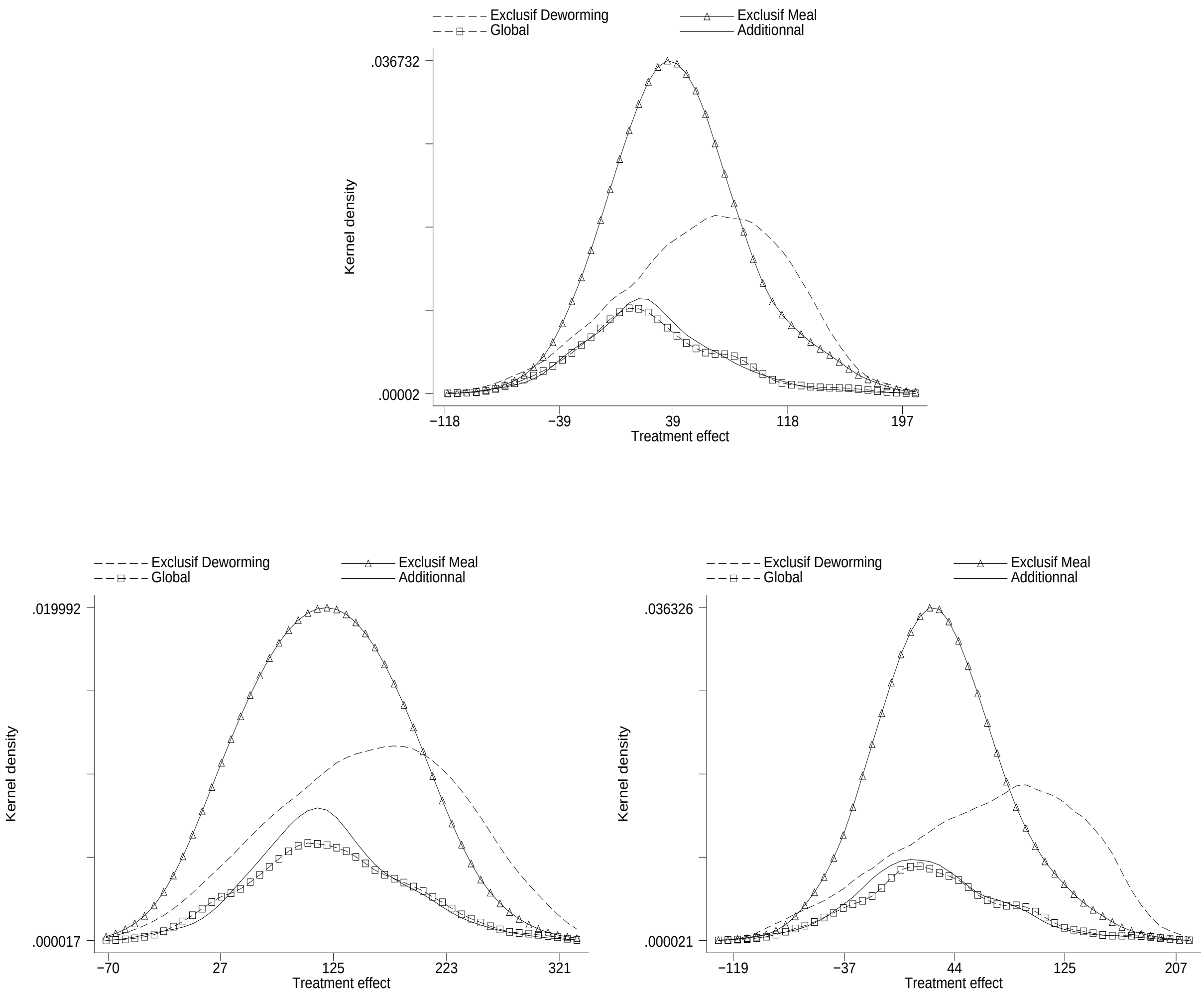

Figure 3: Distribution of treatment effects for math score. [Top]: Average Treatment Effect (ATE) [Bottom-left]: Average Treatment Effect on the Treated (ATET). [Bottom-right]: Average Treatment Effect on the Nontreated (ATENT)

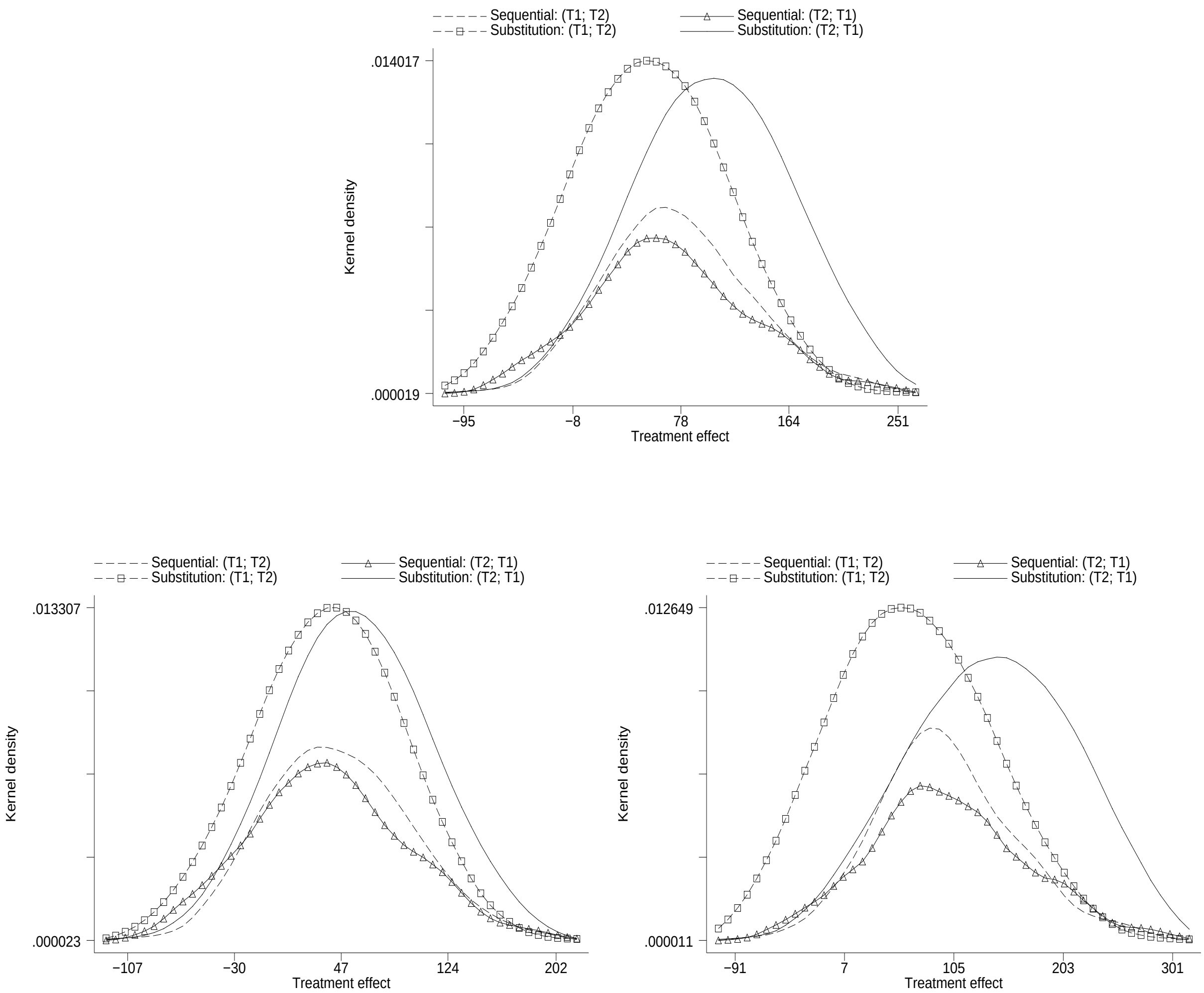

Figure 4: Distribution of sequential and substitution effect on the treated. [Top]: Aggregate score [Bottom-left]: French score. [Bottom-right]: Math score

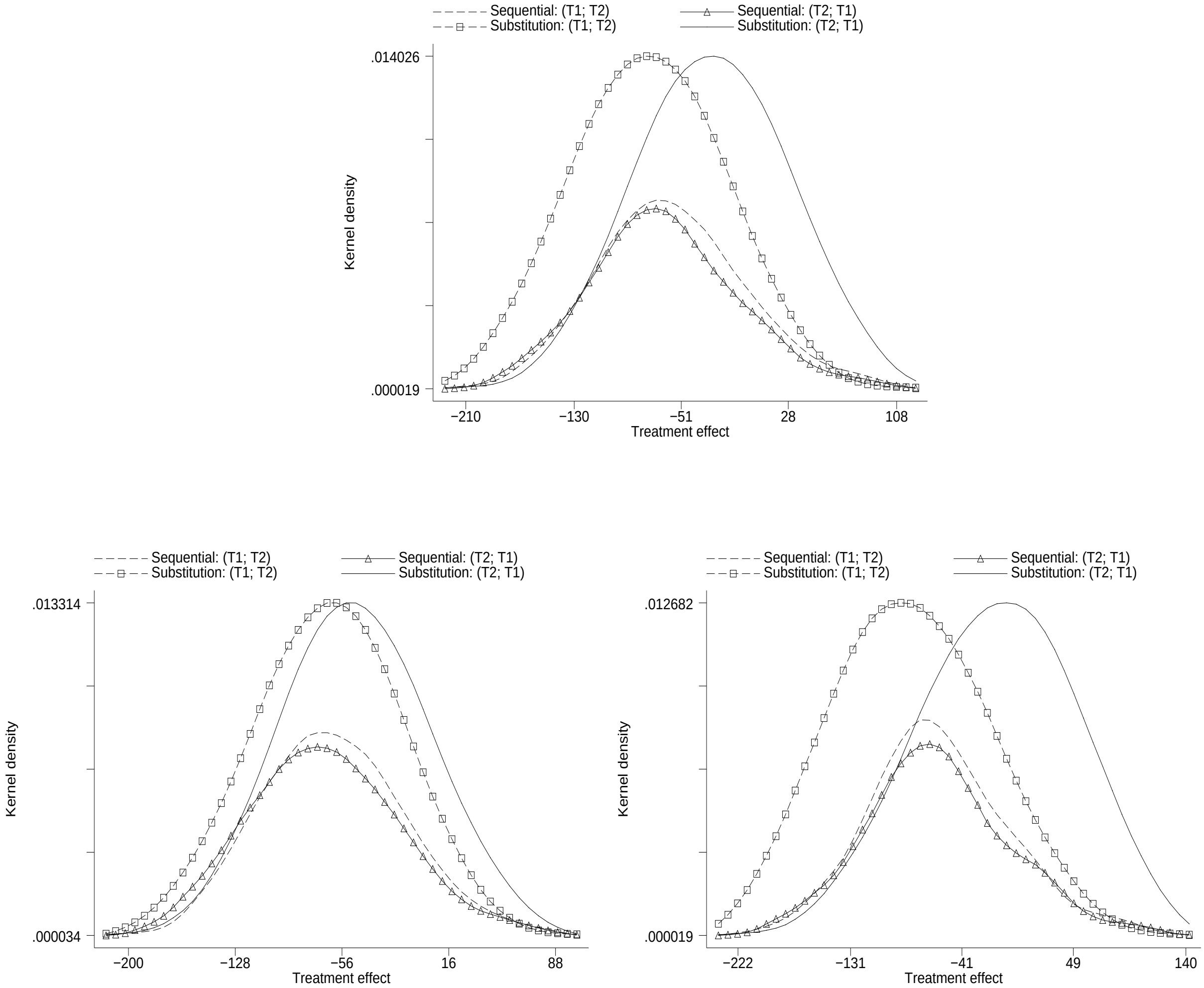

Figure 5: Distribution of sequential and substitution effect on the nontreated. [Top]: Aggregate score [Bottom-left]: French score. [Bottom-right]: Math score

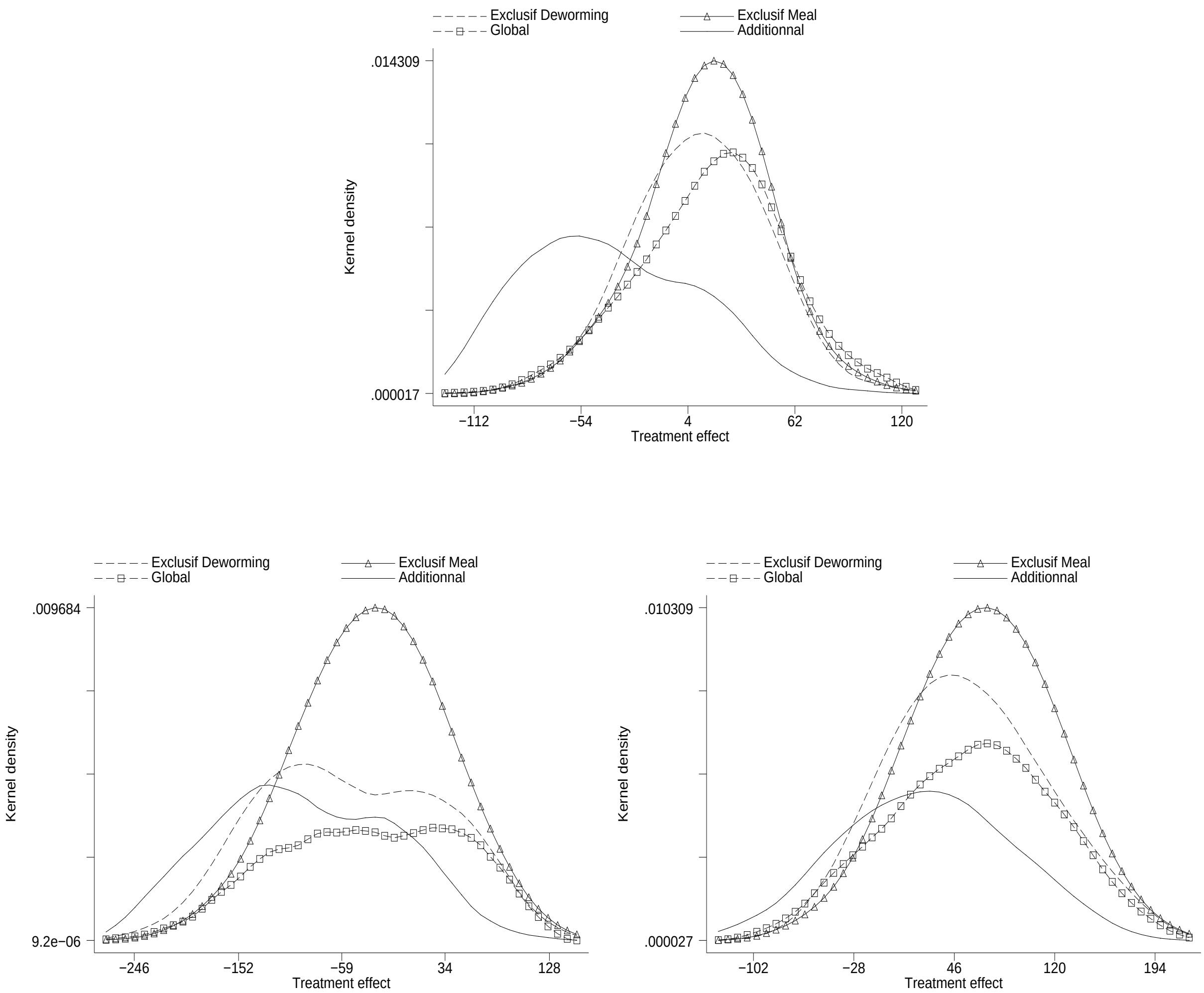

Figure 6: Distribution of treatment effects for enrollment rate. [Top]: Average Treatment Effect (ATE) [Bottom-left]: Average Treatment Effect on the Treated (ATET). [Bottom-right]: Average Treatment Effect on the Nontreated (ATENT)

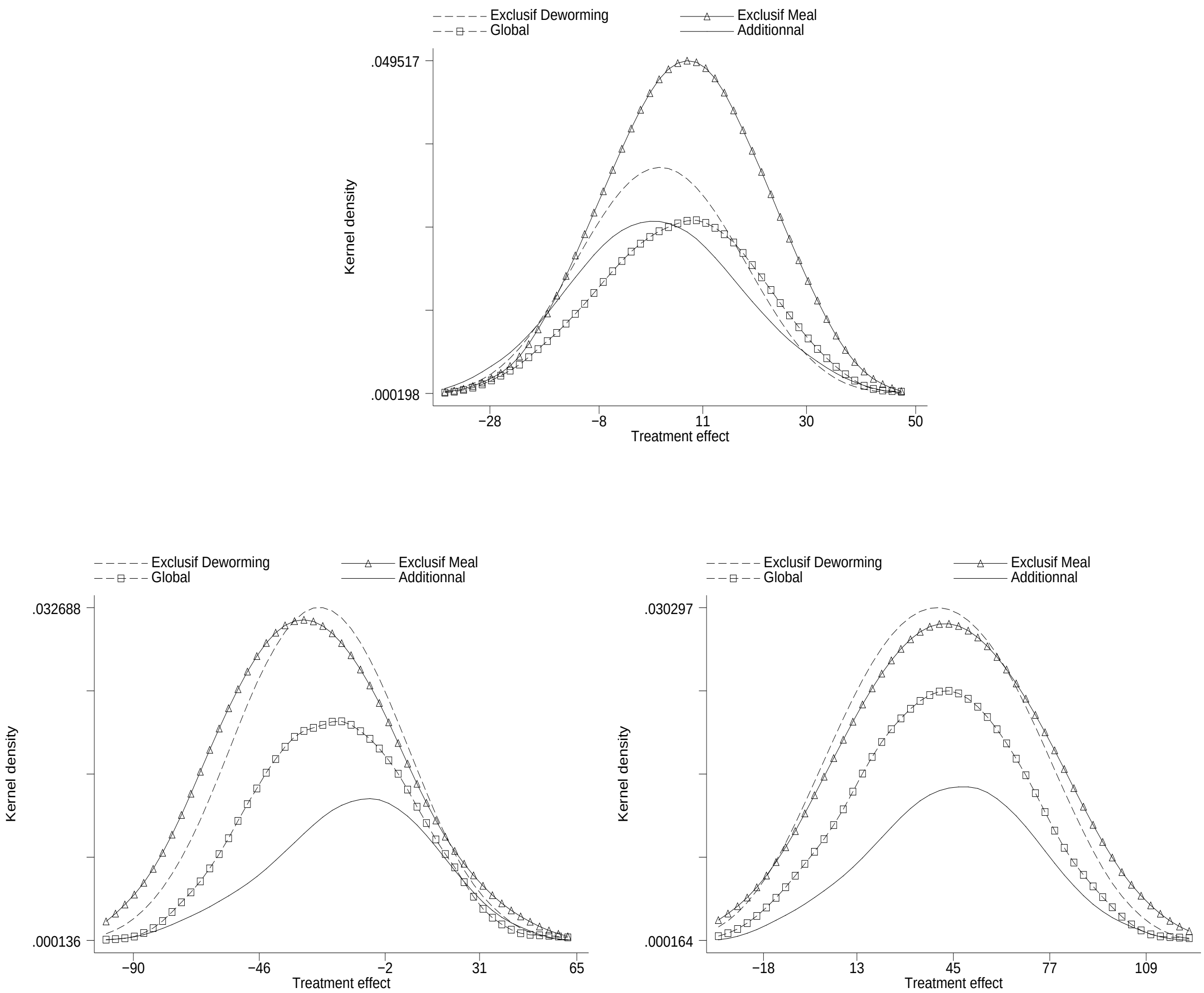

Figure 7: Distribution of treatment effects for promotion rate. [Top]: Average Treatment Effect (ATE) [Bottom-left]: Average Treatment Effect on the Treated (ATET). [Bottom-right]: Average Treatment Effect on the Nontreated (ATENT)

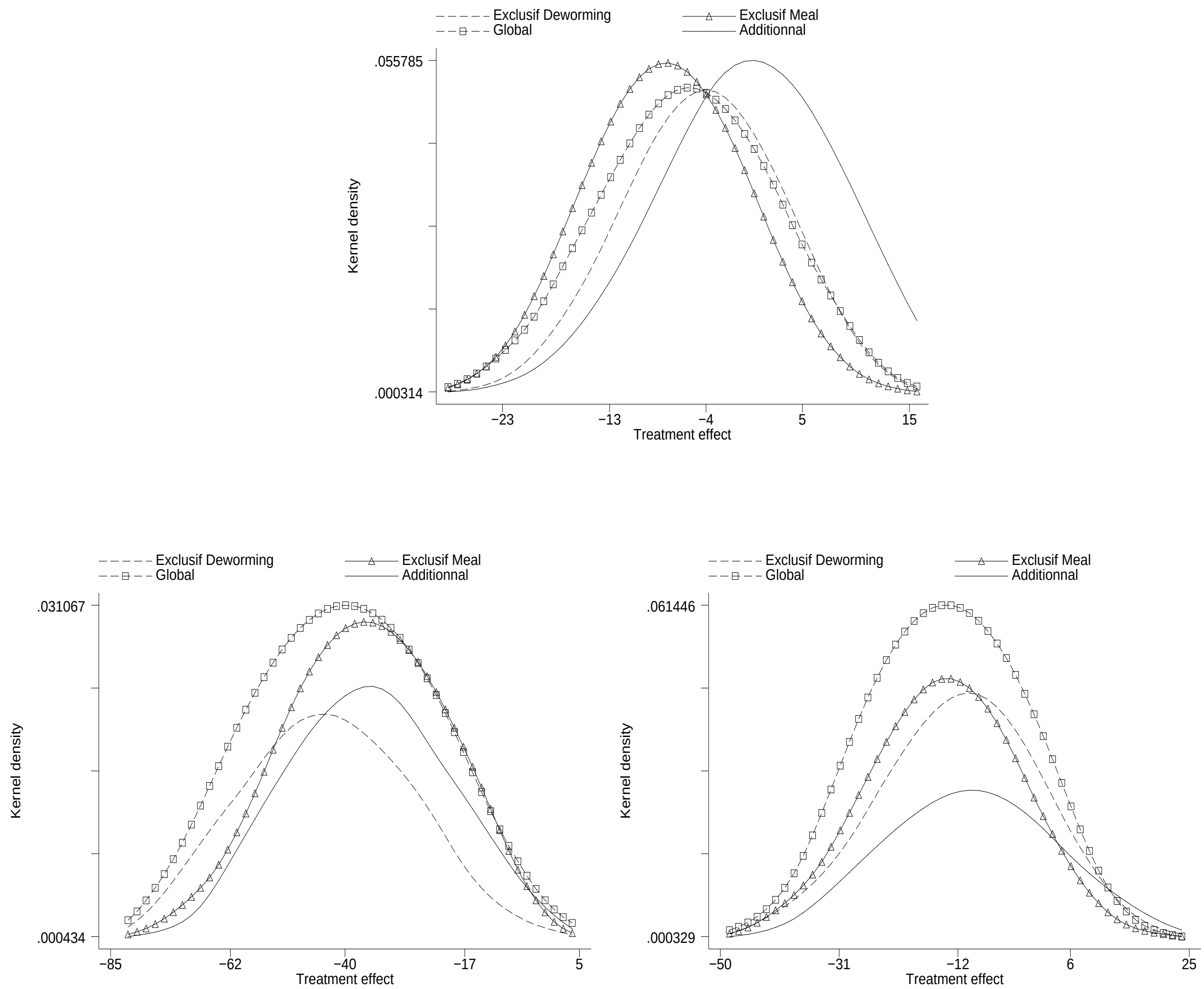

Figure 8: Distribution of treatment effects for dropout rate. [Top]: Average Treatment Effect (ATE) [Bottom-left]: Average Treatment Effect on the Treated (ATET). [Bottom-right]: Average Treatment Effect on the Nontreated (ATENT)

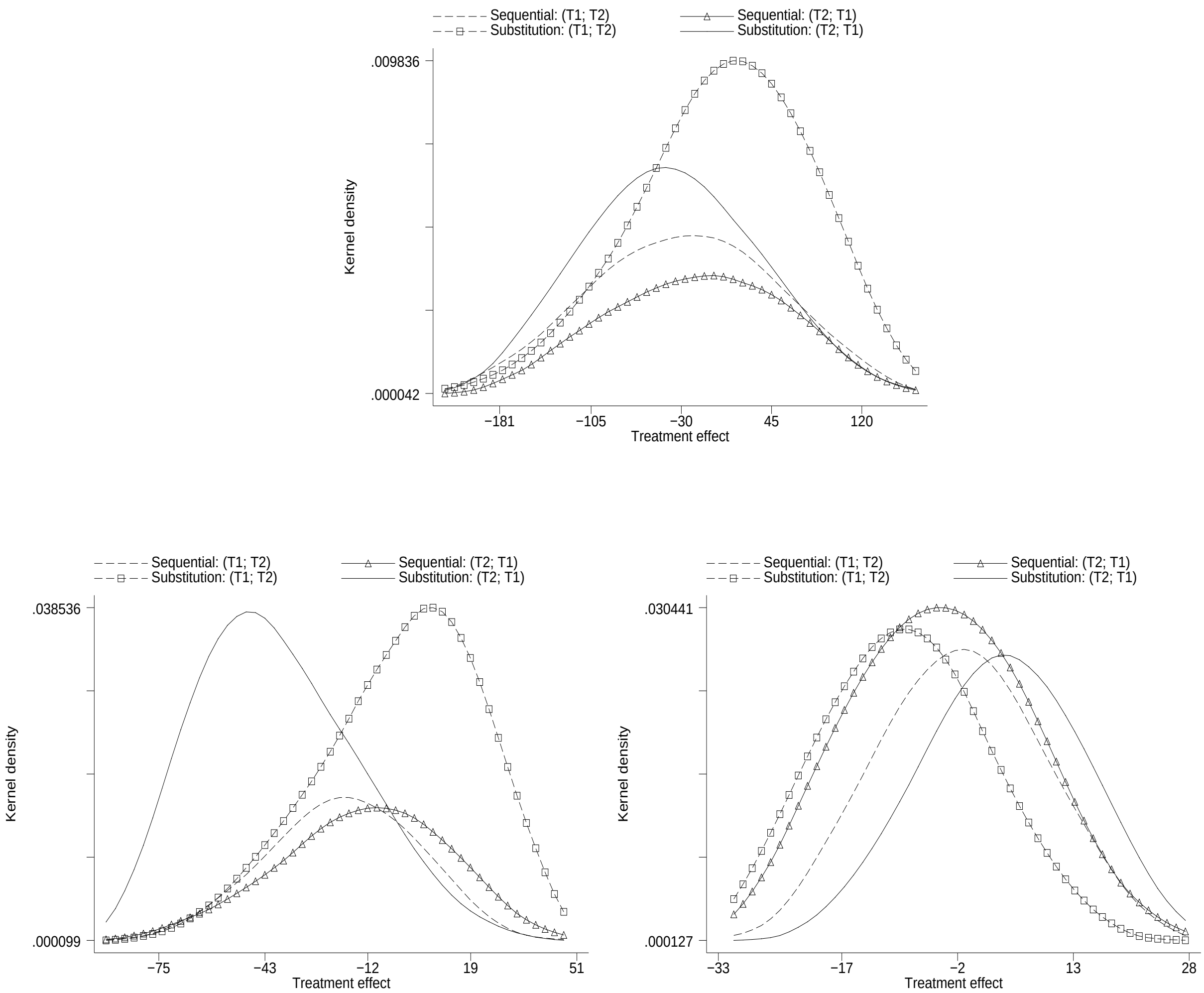

Figure 9: Distribution of sequential and substitution effect on the treated. [Top]: Enrollment rate [Bottom-left]: Promotion rate. [Bottom-right]: Dropout rate

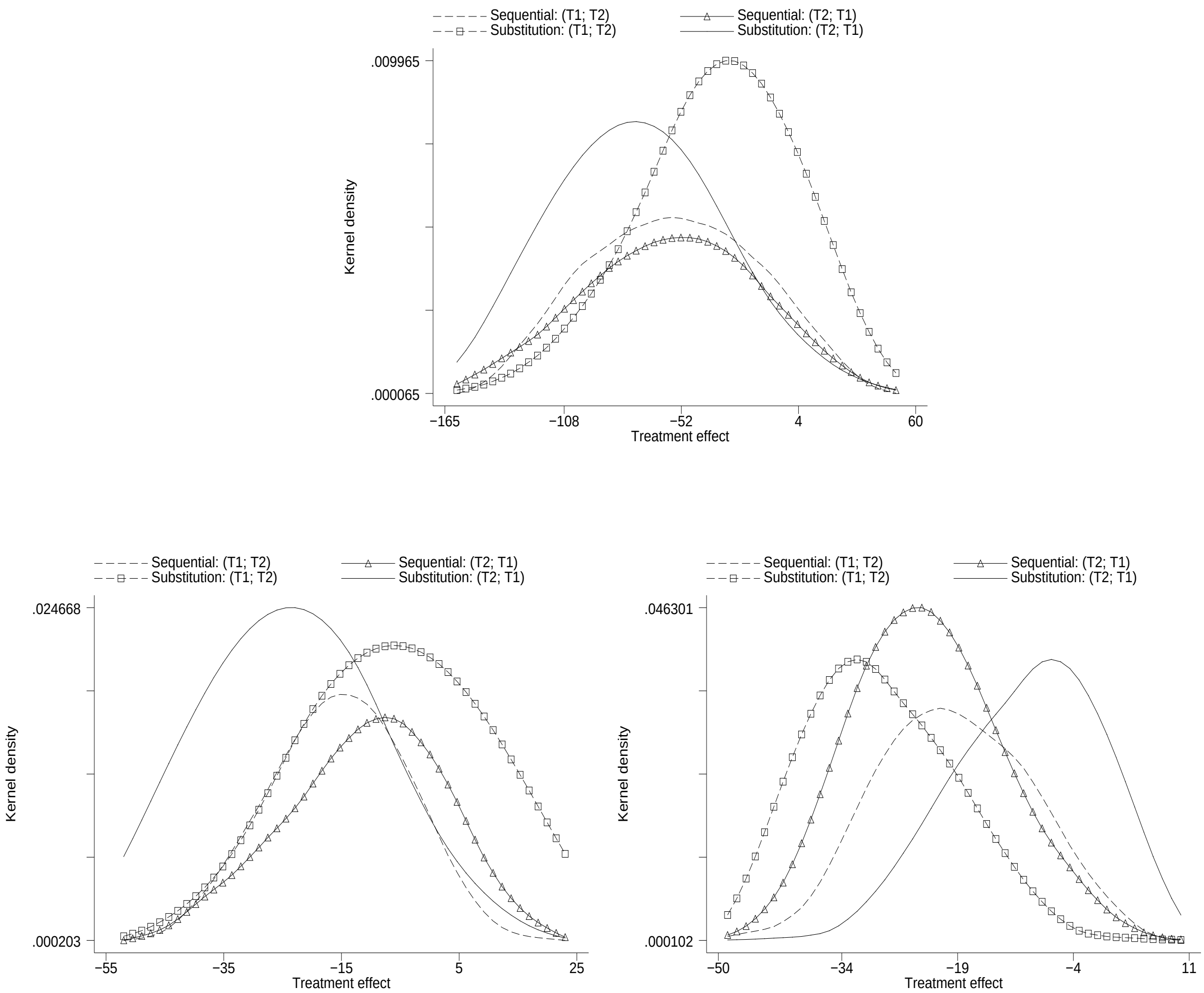

Figure 10: Distribution of sequential and substitution effect on the nontreated. [Top]: Enrollment rate [Bottom-left]: Promotion rate. [Bottom-right]: Dropout rate

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