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DISCUSSION PAPER

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# Peer effects and textbooks in primary education: evidence from francophone sub-Saharan Africa

**ABSTRACT**

As opposed to many other school inputs, textbooks have frequently been demonstrated to significantly foster student achievement. Using the rich data set provided by the 'Program on the Analysis of Education Systems' (PASEC) for five francophone, sub-Saharan African countries, this paper goes beyond the estimation of direct effects of textbooks on students' learning and focuses on peer effects resulting from textbooks owned by students' classmates. Applying and extending nonparametric estimation methods from the treatment evaluation literature we separate the direct effect of textbooks from their peer effect. The latter clearly dominates but depends upon the initial level of textbook availability.

**Key words:** primary education, student achievement, evaluation, nonparametric estimation

**JEL-Classifications:** C14, C21, O15

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# 1 Introduction

Improving the quality of primary education in developing countries belongs to the central development objectives put forward by the international community in the context of the 'Education for All' initiative and the 'Millennium Development Goals' (UNESCO 2000, World Bank 2003). In Francophone sub-Saharan Africa, this challenge seems to be greater than anywhere else in the world. Identifying effective measures for improving education quality has proven difficult. The impacts of class size reductions or increases in teacher salaries, for example, were often found to be insignificant and small, particularly when contrasted with the rather high costs.[1] *Textbooks*, on the other hand, appear to be an effective and rather inexpensive means to improve cognitive development and educational achievement.[2] While Glewwe, Kremer, and Moulin (2000) and Glewwe, Kremer, Moulin, and Zitzewitz (2004) have argued that these effects may be overestimated due to omitted variable bias, we suggest that they may also be underestimated because of neglected peer-effects. At the same time, the existence of peer effects may help to explain why books are underprovided.

Using data from the 'Program on the Analysis of Education Systems' (PASEC)[3] for 5th grade students in Burkina Faso, Cameroon, Cote d'Ivoire, Madagascar and Senegal, we estimate separately the direct effect of a student having a textbook, and the effect of his or her classmates having textbooks. The latter will be considered as a peer effect or externality. Moreover, we take into account that if resources are insufficient to provide textbooks to all children, the impact of textbooks might depend on the *allocation* of

[1] See e.g. Hoxby (1996), Hanushek (1998), Pritchett and Filmer (1999), Wößmann and West (2002) and Hanushek and Luque (2003).

[2] See e.g. Lockheed and Verspoor (1991), Fuller and Clarke (1994), Tan, Lane, and Coustère (1997), Michaelowa (2001), UNESCO (2004, p. 48) for textbooks, or OECD and UNESCO-UIS (2003), and Mullis et. al. (2000) for the impact of the general availability of books.

[3] Original French title: "Programme d'analyse des systèmes éducatifs de la CONFEMEN", whereby CONFEMEN stands for the Conference of Francophone Education Ministers ("Conférence des ministres de l'éducation des pays ayant le français en partage"). Data and initial evaluations are available on CD ROM (CONFEMEN 2002). To obtain the data, contact pasec@sentoo.sn.

books within and between schools.

To estimate the direct effect of textbooks and their externalities, we use nonparametric estimation techniques from the treatment evaluation literature. These nonparametric techniques avoid the restrictive functional form assumptions that were made in the empirical literature on textbooks so far. In other words, we do not restrict the effects of textbooks to be linear or quadratic or of any other particular shape. These estimation techniques have been successfully used in labour economics.[4] In contrast to other studies, however, nonparametric regression proceeds here on a large set of covariates and this paper therefore represents one of the first applications of high-dimensional nonparametric regression. Moreover, as opposed to most earlier studies, our analysis includes two simultaneous treatment variables one of which is continuous.

Identification is based on controlling for all confounding variables. In contrast to most other data sets, which often contain only very limited information on important variables such as ability (Glewwe, Kremer, Moulin, and Zitzewitz 2004), the PASEC data set includes exceptionally comprehensive information about student ability, family background, teachers, school principals, classrooms and schools. Achievement data are available for the two central subjects mathematics and French and collected both at the beginning *and* at the end of the academic year. Measures of ability at the beginning of the year are particularly relevant since they enable us to follow an added value approach (Hanushek 1986) and to measure the effect of textbooks on learning within a given year, rather than on the overall level of cognitive skills which may be related to a variety of variables that would have had to be measured in earlier years, prior to the sampling, and are therefore unavailable in the data set. The availability of pre-test information at the beginning of the year is therefore a major advantage of the PASEC data, not only

[4]See e.g. Heckman, Ichimura, and Todd (1997, 1998), Angrist (1998), Heckman, Ichimura, Smith, and Todd (1998), Angrist and Krueger (1999), Lechner (1999, 2004), Brodaty, Crépon, and Fougère (2001), Dearden, Ferri, and Meghir (2002), Gerfin and Lechner (2002), Black and Smith (2004), Frölich (2004), Imbens (2004), Moffitt (2004), Sianesi (2004), Smith and Todd (2004) and the Symposium on the Econometrics of Matching of the Review of Economics and Statistics (2004, 86:1).

over other data for developing countries,[5] but even over data from major international surveys on student achievement such as the OECD Programme on International Student Assessment (PISA) or the Third Mathematics and Science Study (TIMSS).

The estimation results provide some compelling evidence for the relevance of textbook externalities which may have important policy implications. In the francophone African countries considered here, textbooks are predominantly privately provided. Only about 13% of primary students in our sample obtained textbooks from their schools. Parents, however, will take their decision on buying a textbook merely on the grounds of their own children's anticipated benefits and will not take into account the positive externalities on other children. In other words, private purchasing of textbooks is likely to be socially suboptimal because only parts of the benefits accrue to parents. This calls for a subsidy on the price of textbooks or, potentially, for public provision, in particular if the impact of the textbooks depends upon their distribution.

Section 2 provides a detailed description of our methodological approach to identify the direct and indirect effect of textbooks as well as the effect of different allocations within and across schools. Section 3 discusses the PASEC data set used for the empirical analysis. Section 4 presents estimation and simulation results and section 5 concludes.

# 2 Textbooks and externalities

The availability of textbooks among classmates may affect one's own learning through a variety of channels. The conventional peer effects argument asserts that students with books learn faster and that these more knowledgeable peers are then beneficial for one's own learning because of enhanced motivation or competition or sharing of knowledge.

[5]Such data on primary student achievement similar to PASEC have been collected since the early 1990s by the "Southern African Consortium for Monitoring Education Quality" (SACMEQ) in anglophone Africa (see http://www.unesco.org/iiep/eng/networks/sacmeq/sacmeq.htm), the "Latin American Laboratory of the Quality of Education" (LLECE) in Latin America (see http://www.unesco.cl/09.htm), and the "Monitoring Learning Achievement" (MLA) program in various developing countries (see www.literacyonline.org/explorer/un_act.html).

This peer effect should increase with the share of classmates having books, and this increase could be more or less than proportional depending on whether homogeneous or heterogeneous classes provide a more efficient learning environment (Hoxby 2000).

In addition, there may be more direct channels through which one's classmates' textbooks can become effective. First, students may share books in class, e.g. two or three students may read from the same book. Unless reading from the same book is not disrupting them, educational achievement would increase with the number of books until all students have access to a book and would be flat from there onwards. If students benefit from taking the book home after class, the marginal benefit of a book will remain positive throughout, but saturation effects are to be expected well before all students of the class have a book at their disposal.

Second, the total number of books in a class is likely to change the instructional methods used by the teacher. This may lead to a non-linear relationship between textbook provision and student achievement. In a class where all students have books, the teacher can use pedagogical methods that require books. In a class without any textbooks, the teacher is forced to resort to alternative teaching methods. It is conceivable that there may be threshold effects, with textbooks remaining unused below a certain minimum provision. Similarly, teachers may increase the time spent on textbook based learning proportionally to the share of students possessing a book. In this case, the positive effect of additional textbooks should rise with the share of classmates already equipped. However, if only a fraction of the class has access to books, the teacher may find it hard to adapt his mode of instruction, addressing partly those with books and partly those without books. The overall educational achievement might then even be lower than in a class without books, leading to a U-shaped relationship between books and educational achievement.[6]

[6]If teachers are not used to teaching with books, it might take them some time until they develop the necessary skills. The *short-term* effects of giving more books to classes might therefore be small, as found in Glewwe, Kremer, and Moulin (2000). Nevertheless, they also found that teachers indeed adapt their methods of instruction, but it might take some years until they master sucessfully the new methods used.

Textbook externalities can have important policy consequences as they are likely to distort parents' decisions on buying textbooks for their children, leading to allocative inefficiency. In addition, nonlinearities in the peer effects affect the optimal allocation of books both within classes and between classes and schools. If the peer effect relationship is convex, an unequal distribution of books would be preferable to an equal distribution in terms of efficiency. On the other hand, a concave relationship would advocate an equal distribution of books within classes and/or between schools. Different policy instruments would then be appropriate. While with linear peer effects, subsidizing the price of books could provide the right incentives to parents for buying textbooks, a non-linear relationship would call for a more involved interaction, e.g. through the public provision of books, to achieve the optimal allocation of books within classes and between schools.

Given the above considerations, the functional form of the relationship between textbooks and educational achievement is not a priori obvious and we therefore follow a purely nonparametric approach to estimate the impact of textbooks and to disentangle direct and peer effects. For convenience of exposition, we adopt the potential outcomes framework frequently used in the treatment evaluation literature. Let $Y_i$ denote educational achievement at the end of a school year. Denote by $B_i$ the number of textbooks possessed by child $i$, and denote by $C_i$ the average number of textbooks among child $i$'s *classmates*. In PASEC surveys, each child is asked whether it has a French and/or a Math textbook, such that $B_i$ can take the values 0, 1 or 2.[7] Accordingly, the average number of books among classmates is $C_i \in [0, 2]$. Denote the potential outcomes as

$$Y_i^{b,c} \qquad \forall b \in \{0, 1, 2\} \qquad \text{and} \qquad 0 \leq c \leq 2.$$

$Y_i^{b,c}$ is the educational achievement that student $i$ would obtain if her number of books

[7] In Appendix E the effects of a French and a Math book are analyzed separately. Both types of books seem to have similar effects on French and Math proficiency, with most estimates being insignificant, though. Therefore, it appeared sensible to aggregate both books to the total number of books, on the one hand to simplify the exposition and interpretation of the results and, on the other hand, to obtain more precise estimates.

were hypothetically changed to $b$ and the number of books among her classmates were changed to $c$. The outcome $Y$ will be measured by the percentage of correct answers in an achievement test.

In the terminology of the evaluation literature, we have two treatment variables of which one is discrete and one is continuous (Rubin 1974). The outcome for a student who is *randomly* drawn from the population and for whom the number of books is set to $b$ and the number of books among classmates set to $c$ is

$$E[Y^{b,c}]. \tag{1}$$

Examining $E\left[Y^{b,c}\right]$ for different values of $b$ and $c$ traces the direct and the peer-effects of textbooks. Keeping $c$ constant, the difference

$$E[Y^{b'',c}] - E[Y^{b',c}]$$

gives the impact of increasing the number of own books from $b'$ to $b''$ for a randomly chosen student, without changing the number of books among her classmates. This captures the *direct* effect of books. The externality or peer effect of books can be characterized through

$$E[Y^{b,c''}] - E[Y^{b,c'}].$$

This represents the effect on the randomly chosen student if the books among her classmates are increased, without changing her own books $b$. This measures the externality of textbooks. A positive effect, for example, would indicate that a student benefits from classmates with many books. This peer effect may depend on the own number of books in that, for example, $E[Y^{0,c''}] - E[Y^{0,c'}]$ may differ from $E[Y^{1,c''}] - E[Y^{1,c'}]$. If externalities are relevant, the total effect of textbooks, i.e. the combination of direct and indirect effects, may differ substantially from the direct effect alone.

## 2.1 Identifying textbook externalities

To identify the potential outcomes $E\left[Y^{b,c}\right]$ from observational data, we need to take into account the non-random allocation of textbooks in the population. If we are able to

control for all confounding factors $X$ that influence $B$ or $C$ and the potential outcomes, then

$$Y^{b,c} \perp\!\!\!\perp B, C \mid X \qquad \forall b \in \{0,1,2\} \ , \ c \in [0,2].$$

With this selection on observables assumption (Heckman and Robb 1985) or conditional independence assumption (Lechner 1999), the potential outcomes given $X$ are identified by

$$E[Y^{b,c}|X] = E\left[Y|X, B=b, C=c\right]. \tag{2}$$

Directly assuming conditional mean independence is somewhat weaker than the (full) conditional independence assumption, but actually suffices in the context of our analysis. The conditional mean independence assumption (2) requires that all variables that simultaneously cause textbook possession $B_i$ and achievement $Y_i$, have to be included in $X_i$. In addition, all variables that simultaneously affect textbook availability among classmates $C_i$ and achievement $Y_i$ have to be included in $X_i$. Therefore, $X_i$ must include not only the relevant characteristics of student $i$ but also all relevant characteristics of her peer group since there might also be other peer effects operating e.g. through social background, which have to be separated from the textbook externality. This requires a rich data set, with detailed information about the student and its environment. The PASEC data set provides very comprehensive information about individual, family, teacher, school principal and school characteristics (as discussed in Section 3). In addition, it contains two measures of the student's ability before the treatment period since achievement tests in French and mathematics were handed out to the students at the beginning and at the end of the academic year. This pre-test information is highly relevant to control for otherwise unobserved cognitive differences between students.

With assumption (2), the potential outcomes $E\left[Y^{b,c}\right]$ are identified (using iterated expectations) as

$$E[Y^{b,c}] = \int m_{b,c}(X) \cdot dF_X, \tag{3}$$

where

$$m_{b,c}(x) = E\left[Y|X=x, B=b, C=c\right].$$

Identification further requires that $F_X$ and $F_{X|B,C}$ have the same support. In other words, the availability of textbooks $B$ and $C$ should not be fully determined by the characteristics $X$, but should entail some exogenous variation. Otherwise, we would be unable to distinguish the effect of textbooks from the effects of other background variables such as families' socioeconomic status. Regional differences in economic development and self-selection of peers could determine $B$ and $C$ jointly. Although the characteristics $X$ are indeed strongly related to $B$ and $C$ (as will be seen in Table 3.3), prediction is far from perfect. A variety of other factors affect textbook availability, such as national development strategies, promotion and marketing activities of book retailers, wholesalers and secondhand-book dealers, or activities of NGOs and programmes of bilateral donor agencies, which lead to more or less random variation.

A nonparametric matching estimator[8] of the mean potential outcome is

$$\hat{E}[Y^{b,c}] = \sum_i \hat{m}_{b,c}(X_i), \tag{4}$$

where $\hat{m}_{b,c}(x)$ is a nonparametric estimator of $m_{b,c}(x)$.

As an alternative to nonparametric regression on $X$, propensity score matching is frequently applied in the evaluation literature. In principle, propensity score matching allows to reduce the dimension of the nonparametric estimation problem.[9] We use nonparametric regression on $X$ instead of on the propensity score mainly for two reasons. First, matching on the propensity score is inefficient compared to matching on $X$. [10] Second, with $C$ being a continuous treatment variable, propensity score matching would require discretizing $C$. Apart from the small sample estimation problems that could occur with a finely discretized variable $C$, a discretization of $C$ could lead to more variable estimates if very small changes in $C$ are examined as, e.g., in Section 2.2.1.

The regression curve $m_{b,c}(x)$ is estimated by local linear regression with different bandwidths for the number of books $B$, the books among classmates $C$ and three different bandwidths for the $X$ variables. Details about the estimator are given in Appendix A.

[8] See Heckman, Ichimura, and Todd (1997, 1998) and Heckman, Ichimura, Smith, and Todd (1998).

[9] But does not improve upon the rate of convergence of the matching estimator.

[10] See e.g. Hahn (1998).

The PASEC data set contains data on five countries with essentially identical schooling systems inherited from the French colonial administration. Since we are interested in the effects of textbooks in the francophone African school system, the matching estimator (4) takes the average over all five countries. The estimation of $m_{b,c}(x)$, however, is carried out separately for each country.[11] This is to allow for different relationships between $X$ and cognitive development by country. In addition, some of the $X$ characteristics were measured differently in individual countries and are thus not comparable across countries. In particular, pre-test scores in Senegal have been obtained on the basis of a test different from the one administered in all other countries.

In the analysis two problems occur due to missing data. Some observations are missing for variables in $X$, and some observations are missing for the outcome variable $Y$. In the former case, missing data are imputed by linear regression and missing data indicators are included in the regression. This approach is not viable for missing data on the outcome variable $Y$. Achievement test scores are missing for about 10% of the observations for which data on $X$ is available. These observations are excluded from the estimation of $m_{b,c}(x)$ but are included in the matching estimator (4), i.e. we use only their information on $X$. Hence, the estimate of $m_{b,c}(x)$ in (3) may be biased. Nevertheless, this bias will cancel out when estimating treatment effects of the type

$$E[Y^{b'',c''}] - E[Y^{b',c'}] = \int (m_{b'',c''}(X) - m_{b',c'}(X)\ ) \cdot dF_X,$$

if the bias depends only on the student, family, teacher and school characteristics $X$ but not on the number of books $B$ or classmates' books $C$.

## 2.2 Effects of alternative allocations

Comparisons of the estimates of the potential outcomes $E\left[Y^{b,c}\right]$ for different values of $b$ and $c$ indicate the magnitudes of direct and peer effects for a randomly drawn student. They show the effects on a particular student if her environment was changed. Yet, they

[11] In other words, country is one of the variables in $X$ and its bandwidth is restricted to zero, hence no smoothing over countries takes place in the estimation of $m_{b,c}(x)$.

do not incorporate the effects these changes might entail on other students. For example, if student $i$ were to receive one additional book, this would increase $B_i$. At the same time, however, $i$'s classmates are affected by the externality since the number of books increases in their class. To examine the total effects, we consider three different types of changes in the allocation of books.

### 2.2.1 Adding one additional book

First, the impact of providing one additional book to a randomly drawn student is examined and decomposed into the direct effect and the indirect effect due to the textbook externality. This represents the marginal benefit of an additional book from a microeconomic perspective and is related to the decision problem of parents considering to buy a book for their child given their knowledge about the number of textbooks already available in the class. Suppose the population consists of $N$ (possibly infinite) students, let $\mathbf{B}$ be the $N \times 1$ column *vector* of the number of own textbooks $\mathbf{B} = (B_1, B_2, ...)'$, and let $\mathbf{C} = (C_1, C_2, ...)'$ be the $N \times 1$ column vector of textbooks among the respective classmates. $(\mathbf{B}, \mathbf{C})$ represents the actual allocation. Now, suppose a student $i$ (who does not already have two books) is given *one* additional book, and let $\mathbf{B}^{(i)}$, $\mathbf{C}^{(i)}$ denote the vectors corresponding to this new allocation. $\mathbf{B}^{(i)}$ differs from $\mathbf{B}$ only in the $i$-th element, which is $\mathbf{B}_i^{(i)} = \mathbf{B}_i + 1$. The vector $\mathbf{C}^{(i)}$ differs from $\mathbf{C}$ only in the elements corresponding to the classmates of $i$. Let $j$ be a classmate of $i$, the element $\mathbf{C}_j^{(i)}$ is then given by

$$\mathbf{C}_j^{(i)} = \frac{(n_{cl(j)} - 1) \cdot \mathbf{C}_j + 1}{n_{cl(j)} - 1},$$

where $n_{cl(j)}$ is the size of the class which student $i$ and $j$ attend. Summing over the $N$ students, the average outcome with this new allocation is

$$\frac{1}{N} \sum_{l=1}^{N} Y_l^{\mathbf{B}_l^{(i)}, \mathbf{C}_l^{(i)}}.$$

If the student $i$, who is given the additional book, is randomly drawn from all students

with less than 2 books, the population outcome is

$$\frac{1}{N_{<2}} \cdot \sum_{i:B_i<2}^{N} \left( \frac{1}{N} \sum_{l=1}^{N} Y_l^{\mathbf{B}_l^{(i)},\mathbf{C}_l^{(i)}} \right),$$

where $N_{<2}$ is the number of students with less than 2 books. Although the potential outcomes $Y_l^{\mathbf{B}_l^{(i)},\mathbf{C}_l^{(i)}}$ are unobservable by definition, their expected values can be identified by (2). Using

$$E[Y^{b,c}|X] = E\left[Y|X, B = b, C = c\right] = m_{b,c}(X),$$

the expected population outcome with one additional, randomly allocated book is

$$\frac{1}{N}\frac{1}{N_{<2}} \sum_{i:B_i<2}^{N} \sum_{l=1}^{N} m_{\mathbf{B}_l^{(i)},\mathbf{C}_l^{(i)}}(X_l).$$

The impact of one book is thus

$$\frac{1}{N}\frac{1}{N_{<2}} \sum_{i:B_i<2}^{N} \sum_{l=1}^{N} \left( m_{\mathbf{B}_l^{(i)},\mathbf{C}_l^{(i)}}(X_l) - m_{\mathbf{B}_l,\mathbf{C}_l}(X_l) \right),$$

which can be decomposed into the direct effect $\alpha_d$

$$\alpha_d = \frac{1}{N}\frac{1}{N_{<2}} \sum_{i:B_i<2}^{N} \sum_{l=1}^{N} \left( m_{\mathbf{B}_l^{(i)},\mathbf{C}_l}(X_l) - m_{\mathbf{B}_l,\mathbf{C}_l}(X_l) \right)$$

and the effect due to the externality $\alpha_e$

$$\alpha_e = \frac{1}{N}\frac{1}{N_{<2}} \sum_{i:B_i<2}^{N} \sum_{l=1}^{N} \left( m_{\mathbf{B}_l^{(i)},\mathbf{C}_l^{(i)}}(X_l) - m_{\mathbf{B}_l^{(i)},\mathbf{C}_l}(X_l) \right).$$

In Section 4 we will examine to which extent the total impact is due to the externality.[12]

$$\frac{\alpha_e}{\alpha_d + \alpha_e}.$$

[12] In the empirical application, the computation of these effects is somewhat complicated by the fact that only a fraction of the students in a class have been surveyed and tested. In small classes relatively more students have been surveyed than in large classes. Class weights are used to make the analysis representative for the student population. For ease of exposition, these weights are not included in the above exposition as they appear in several places.

### 2.2.2 Reallocation of books within the class

Drawing from the previous discussion, let us now consider the effects of alternative allocations of textbooks *within* the class. If books are equally distributed, each student has the same number of books. If books were distributed in an unequal way, some students would have less than average books but would be surrounded by classmates with an above average number of books. Suppose that resources were available to purchase one book per child. If books are equally distributed, $B_i = 1$ and $C_i = 1$ for each student. If books are unequally distributed, student $i$ may be allocated zero books with a probability $\rho_0$, two books with probability $\rho_2$ and one book with probability $1-\rho_0-\rho_2$. To compare the impact of an equal versus unequal distribution within the class, let the total number of books in the class be equal to the class size $n_{cl(i)}$. Hence, the average number of books among classmates is

$$C_i = \frac{n_{cl(i)} - B_i}{n_{cl(i)} - 1}.$$

With this relationship and an estimate of the conditional mean function $m_{b,c}(x)$, the outcome for a randomly drawn individual can be simulated for alternative values of $\rho_0$ and $\rho_2$. For a choice of $\rho_0 = \rho_2 = 0$, the expected outcome for an equal distribution is obtained. The outcome with $\rho_0 = \rho_2 = 0.5$ corresponds to an allocation where half of the students have no books and half of the students have two books.

### 2.2.3 Allocation of books between schools

In addition to the allocation of books within the class, let us now consider the allocation of books across schools. The degree of equality (or inequality) called for by the optimal allocation may differ greatly between these two levels of analysis. The reason is that textbook externalities are relevant only within the class, but do not affect classes in other schools.[13]

[13] In principle, textbooks might also have externalities on other schools. This can happen if the number of textbooks affects teaching methods and if teachers interchange their pedagogical methods (e.g. when participating at teacher seminars). Moreover, when any kind of books and literature are widely spread

Suppose that the average number of books per student is the same in all schools. Denote the number of books per students by $\mu$. Hence, in expectation each student has the same number of own books and classmates' books: $E[B] = E[C] = \mu$. In principle, the average outcome depends not only on $\mu$ but also on how these books are distributed within the class (as discussed above). To focus solely on the effects of different values of $\mu$, suppose that, within the class, the books are equally distributed. Hence, abstracting from the indivisibility of books, $B = C = \mu$. Accordingly, the population mean outcome is identical to the expected outcome for a randomly drawn individual, which is

$$E\left[Y^{\mu,\mu}\right]. \tag{5}$$

However, since the number of own books $B$ is an integer, (5) is only nonparametrically identified by (2) for $\mu \in \{0, 1, 2\}$. For non-integer values of $\mu$, the number of own books $B$ is drawn randomly such that $E[B] = \mu$ and the distribution is as equal as possible. The mean population outcome is defined as

$$E[Y_\mu] = \begin{array}{ll} E\left[Y^{0,\mu}\right] \cdot (1-\mu) + \mu \cdot E\left[Y^{1,\mu}\right] & \text{if} \quad 0 \leq \mu \leq 1 \\ E\left[Y^{1,\mu}\right] \cdot (2-\mu) + (\mu-1) E\left[Y^{2,\mu}\right] & \text{if} \quad 1 \leq \mu \leq 2. \end{array} \tag{6}$$

This represents the mean population outcome as a function of the number of books per student if books per student is identical in all schools. If books are unequally distributed across schools, e.g. such that half of the schools have no books and half of the schools have one book per student, the mean population outcome is obtained as the weighted sum of the outcome with $\mu = 0$ and with $\mu = 1$.

# 3 PASEC data

The data used for the empirical analysis have been collected for the 'Program on the Analysis of Education Systems' (PASEC) in a random sample of schools during the

in general, so that reading (and writing) becomes an important part of day-to-day life, the incentive rises for those who are illiterate to become literate as well. Related to textbooks alone, however, such effects are likely to be negligible.

academic years 1995/96 in Burkina Faso, Cameroon, Cote d'Ivoire and Senegal, and 1997/1998 in Madagascar. As mentioned above, the primary education system, based on the French colonial administration, is very similar in these countries. The schools were chosen from the list of francophone schools available at the national Ministries of Education (carte scolaire). Coranic schools were not included as they follow a different curriculum and teaching generally takes place in Arabic. Other private schools were included as long as they were covered by the national carte scolaire.[14] Note that in Cameroon only the francophone and not the anglophone education system was covered by the PASEC data collection.

Within the 100 or 120 schools selected in each country, one 2nd grade class and one 5th grade class were randomly selected. Within each class 20 (or 25, depending on countries) students were randomly drawn. We confine our analysis to students of grade 5 as these older students have been asked more questions about their family environment and can be expected to have answered more accurately than the younger students. Note that the 5th grade is the last grade of primary education in Madagascar and the second last in the other four countries. Only few students continue to secondary school.[15]

Data on Math and French achievement are based on standardized tests with test items oriented at the typical curriculum of francophone African primary education. Both tests were administered in French language. The Math test contains a wide variety of items ranging from calculus over problem solving (application to situations of daily life) to simple geometry. The French test covers general understanding and orthography as well as grammar skills. Tests were administered in the classroom, item by item, following detailed instructions on the way to present each question and the time to be allocated to its response. As mentioned earlier, the students were tested at the beginning of the

[14] In many cases, national education ministries are unaware of private schools, in particular those set up locally by parents' initiatives. Strictly speaking, the sample is therefore representative only for those schools registered with the national authorities.

[15] In 1995, at the time of the survey, gross secondary enrolment rates lay between 9% in Burkina Faso and 25% in Cameroon. They have now increased to 33% in the latter, but remained almost unchanged in the other four countries considered here (World Bank 2004).

academic year and, using a similar test, again at the end of the academic year. Test results for both pre- and post-test are coded in terms of the percentage of test items answered correctly in each of the two subjects French and Math. A different pre-test was used in Senegal, but the post-tests were identical in all 5 countries.

For all tests considered here, in both French and Math, Cronbach's alpha, the numerical coefficient of reliability, is between 78% and 84%. This reveals a good inter-item consistency and a high probability that carrying out the same test again would lead to very similar results.

General information on students' homes, schools, classrooms, teachers and principals were collected at the time of the post-test at the end of the academic year. Survey staff was requested to fill in all questionnaires on the basis of individual interviews with each of the sampled students, their teachers and their principals, in order to provide explanations where necessary and to avoid unnecessary non-response. It is obvious that information on students' backgrounds obtained through the interview of primary students themselves cannot be as comprehensive as information collected from household surveys. Nevertheless, PASEC student data contains detailed information on the students themselves (age, sex, nutrition, grade repetition, participation in child labor, support with homework), their families (parents' literacy, languages spoken at home, availability of consumer durables, means of transportation, house equipment and agricultural tools), and the families' endowment with goods that might be directly relevant for education (print and other media, books, dictionaries, black boards etc.).

Teachers' and directors' questionnaires are even more comprehensive. Apart from providing detailed information on personal characteristics (e.g. age, sex, marital status) and teaching quality (number of mistakes detected in a student's dictation, job experience, educational attainment, professional training, language skills, and indicators of personal job satisfaction and general attitudes), they provide rich information on school and classroom equipment, on the location and structure of schools, on the interaction of the different stakeholders within the school environment, and on various pedagogical tools and attitudes.

The directly most relevant variable for our analysis on the impact of textbooks stems from the students' questionnaire. Students were asked whether they possessed a French and/or Math textbook. A student may thus possess 0, 1, or 2 textbooks.

## 3.1 Sample Selection and missing data

The full data set with information from students, teachers and principals contains 12,236 students. In Madagascar, five out of 25 students per class were randomly sampled separately to be tested only in mathematics using a test translated into Malagasy. Their French proficiency was not tested. Data for the 578 students who effectively took this separate test are excluded from the analysis for lack of comparability. For 1,168 of the remaining 11,658 students, one or more of the questionnaires are missing. This includes 196 missing student questionnaires, 73 missing principal questionnaires and 900 missing teacher questionnaires. As unavailable questionnaires imply missing information for so many variables that imputations become extremely unreliable, these students are dropped and the final sample contains 10,489 students in 521 classes. Missing observations for individual variables concerning these students and classes are imputed, and missing data indicators are generated (for details, see Annex B).

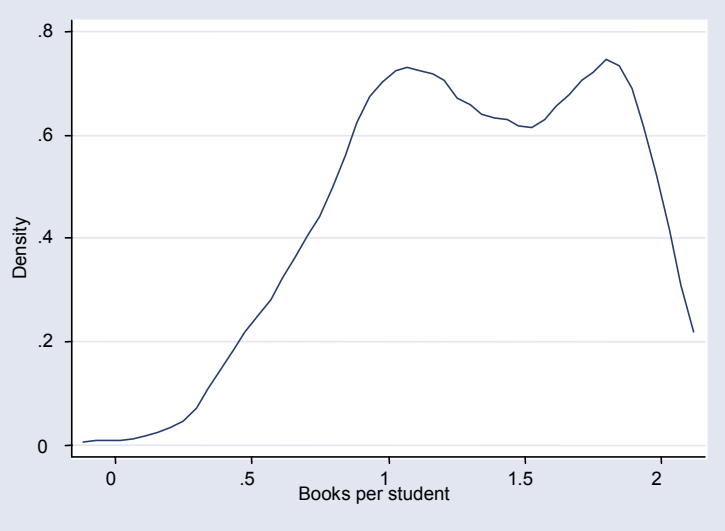
Table 3.1 shows a few summary statistics by country for the 521 classes. Average class size as reported by teachers is provided for comparison in the last column. The number of observations is relatively evenly spread over the five countries, with a smaller number of classes sampled in the Senegal. Average class size varies between countries and is much larger in Burkina Faso than in Cote d'Ivoire and Madagascar. The number of students sampled in each class shows some variation. In a few classes, only five or six students have been interviewed (after having dropped those with missing questionnaires). However, the average number of observations per class is very close to the target of 20 (or 25 in Cameroon).

Table 3.1: General structure of the PASEC data, 5th grade, academic years 1995/96 and 1997/98

| | Classes | Observations | Observations in Class | | | Average class size |
|---|---|---|---|---|---|---|
| | | | min | mean | max | |
| Burkina Faso | 104 | 2072 | 13 | 19.9 | 20 | 62.9 |
| Cote d'Ivoire | 117 | 2243 | 6 | 19.2 | 20 | 35.6 |
| Cameroon | 94 | 2184 | 8 | 23.2 | 25 | 47.7 |
| Madagascar | 116 | 2258 | 5 | 19.5 | 20 | 36.9 |
| Senegal | 90 | 1732 | 6 | 19.2 | 20 | 52.1 |
| Total | 521 | 10489 | 5 | 20.1 | 25 | 46.4 |

Figure 3.1 shows the distribution of the class average number of books per students for the 521 classes. In about one third of the classes less than one textbook per student is available. About two thirds of the classes have less than 1.5 textbooks per student.

Figure 3.1: Distribution of textbooks per student in the 521 classes



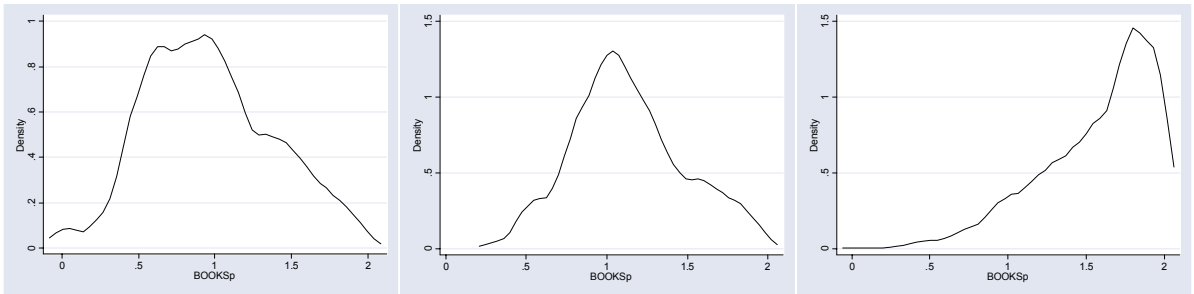

Note: Kernel density plot of the average number of books in class for the 521 classes.

Table 3.2 shows descriptive statistics for selected characteristics of the 10,489 students and their schools. These characteristics include, in particular, the distribution of test scores, the availability of textbooks, and indicators of socioeconomic and cultural background obviously related to both. They also include additional variables typically

assumed to be relevant in an education production function framework, such as indicators of teachers' knowledge and school equipment. Table B.1 provides the same statistics for all variables of the PASEC data set considered as potentially relevant here. Both tables also show the average characteristics for the original sample of 11,658 students. Comparing the results presents convincing evidence that the original sample and the reduced sample are very similar in their characteristics. This suggests that sample selection biases induced by the elimination of students with missing student, teacher or principal questionnaires - if any - should not be so serious as to strongly influence the results of our analysis.

Figures 3.2 and 3.3 convey a more detailed impression of the distribution of textbooks and test scores, for the 10,489 students. Figure 3.2 shows the distribution of books among classmates for students without books (left), with one book (middle) and with two books (right). As could be expected, the number of books is positively correlated with the number of books among classmates: Students without books are usually surrounded by students with few books. Conversely, students possessing both textbooks are typically surrounded by classmates with many books. Nevertheless, there is no perfect segregation and students without books can be found in classes with many books and vice versa.

Figure 3.2: Distribution of textbooks per classmate for students with 0,1or 2 books




Note: Distribution of classmates' books coverage for students without a book (left figure), with a single book (middle figure) and with two books (right figure).

Table 3.2: Selected student, teacher and school characteristics

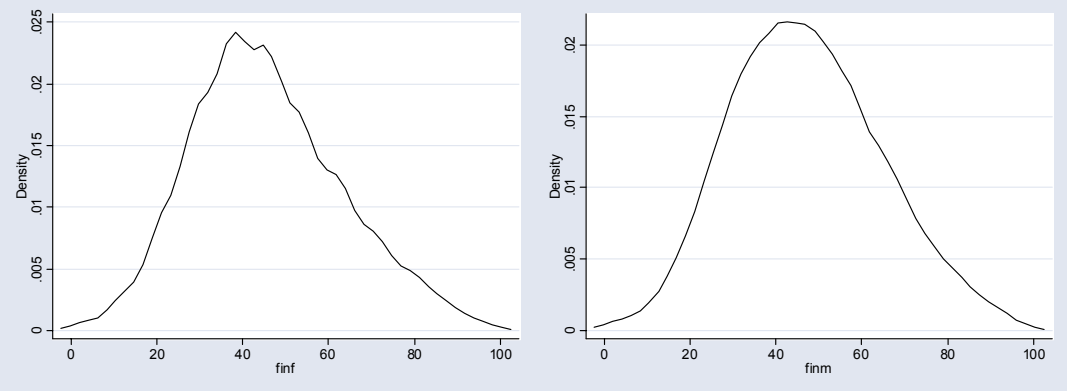
| | Original sample | After deleting missing questionnaires |
|---|---|---|
| Number of Observations | 11658 | 10489 |
| **Test scores (percentage of correct answers)** | | |
| 1st quartile test score French / Math | 34.3 / 34.1 | 34.3 / 34.1 |
| Median test score French / Math | 42.9 / 46.3 | 42.9 / 46.3 |
| 3rd quartile test score French / Math | 57.1 / 58.5 | 57.1 / 58.5 |
| Stddeviation French / Math | 17.6 / 17.6 | 17.6 / 17.7 |
| No of missing values for the test score French / Math | 12 / 12 | 11 / 11 |
| Initial test score French / Math | 43.3 / 48.7 | 43.1 / 48.8 |
| **Textbook availability** | | |
| Percentage of students with a textbook in French / Math | 78 / 53 | 78 / 54 |
| Average number of textbooks per student (for the two subjects combined) | 1.31 | 1.32 |
| **Selected student characteristics** | | |
| Percentage of boys | 52 | 52 |
| Average age | 11.5 | 11.6 |
| Percentage of students repeating 5th grade [a)] | 22 | 22 |
| Average number of earlier grade repetitions | 0.7 | 0.7 |
| Percentage of students whose mother is literate | 58 | 57 |
| Percentage of students whose father is literate | 75 | 76 |
| Percentage of students who speak French at home | 30 | 30 |
| Average socioeconomic status (index of family possessions) | 0.36 | 0.37 |
| Percentage of students who can use books at home | 72 | 72 |
| Percentage of students who study at home | 92 | 92 |
| Percentage of students who get help with studies at home | 63 | 64 |
| Percentage of students taking at least three regular meals a day | 64 | 66 |
| Percentage of students helping their families with commercial activities, agriculture or animal husbandry | 75 | 75 |
| **Selected teacher characteristics** | | |
| Percentage of teachers holding the baccalaureate (i.e. who completed upper secondary education) | 19 | 19 |
| Average percentage of mistakes correctly detected in a dictation [a)] | 82 | 82 |
| Percentage of union members | 25 | 24 |
| **Selected school and classroom characteristics** | | |
| Average number of students in school | 492 | 490 |
| Average number of teachers in school | 9.6 | 9.6 |
| Average class size | 47.5 | 47.0 |
| School equipment, average number of items available (out of 14) | 5.4 | 5.5 |
| Percentage of classrooms with electricity | 25 | 26 |
| Percentage of schools with a library | 9 | 10 |
| Percentage of schools located in rural areas | 43 | 44 |
| Percentage of schools in big villages | 27 | 26 |
| Percentage of schools in small villages | 13 | 13 |

[a)] Information unavailable for Madagascar.

Figure 3.3 shows the distribution of the outcome variable: the test scores in the French and Math achievement tests. They are centered around a mean of 46 and 47 percent of correct answers for French and Math respectively, and show a similar spread

across the range of possible outcomes (from 0 to 100 per cent). Both distributions are relatively symmetric, with a standard deviation of 18 and an interquartile range of about 24 percentage points.

Figure 3.3: Distribution of test scores




Note: Distribution of final test scores in French (left) and Math (right). (Percentage of correct answers.)

## 3.2 Determinants of textbook availability

Central to our identification strategy is the conditional mean independence assumption (2), which requires that all variables that simultaneously cause $B$ and the potential outcomes $Y^{b,c}$ are observed, as well as all variables that simultaneously cause $C$ and $Y^{b,c}$. Hence, we need to control for all relevant characteristics that determine one's own textbook possession or the choice of the peer group and affect learning achievement. To select these characteristics $X$ we follow two different approaches. In the first approach we choose the regressors by economic reasoning alone. The second approach uses statistical selection via repeated regression. As these different approaches lead to different regressor sets, the robustness of the estimation results to the choice of the $X$ set can be examined.

The control variables $X$ chosen by economic reasoning are shown in Table 3.3. Controlling for French and Math ability at the beginning of the academic year is important since the availability of books is inquired only for the year of the interview but not for the previous time periods. By controlling for proficiency at the beginning of the school

year also other unobserved characteristics of the student such as innate ability etc. can be captured.

Other important characteristics that can be expected to jointly determine textbook possession $B$ and educational achievement are the home environment of the student, in particular the parents' wealth or socioeconomic status, their literacy and the use of French at home. Moreover, the availability of other books at home may be relevant directly or as a general indicator of the parents' attitude towards the education of their children. As opposed to that, child work, e.g. the children's participation in agricultural or commercial activities of the household, may indicate the parents' disregard of education.

Selection effects might also be relevant with respect to the composition of classmates. Parents devoted to the education of their children may choose a school or class that is well equipped with textbooks, i.e. where books among future classmates can be expected to be available. To a certain extent, this strategy could even substitute for buying one's own books. Prevalence of books among classmates $C_i$ may also reflect the richness and literacy of the region, the activity of NGOs or the budget allocation to schools or local school financing. If classmates' parents have more books because of their higher wealth or higher literacy rate, a positive correlation between $C_i$ and the outcome $Y_i$ could be the result of an effect of peers' wealth on own educational progress. To isolate the effects of the textbooks among peers, controlling for the socioeconomic status and literacy of the classmates' parents is necessary.

In addition to the socioeconomic status of parents, the equipment of the school may also affect the number of books that are used in the class.

Table 3.3 also gives some indication about the statistical importance of these regressors as determinants of textbook availability. This table shows an ordered probit regression of $B$ and a linear regression of $C$ on a parsimonious choice of explanatory variables. The standard errors account for the stratification and clustering of the sampling design. Several of the regressors are highly significant, in particular the socioeconomic status and the availability of other books at home. The $R^2$ in the linear regression is 0.49, indi-

cating a rather strong predictive ability of these regressors. The simulation results presented in Section 4 are based on this set of 19 control regressors $X$ (without the country dummies).

Table 3.3: Determinants of textbook availability

| | Dependent variable: Number of books $B_i$ | | Dependent variable: Average number of books among classmates $C_i$ | |
|---|---|---|---|---|
| | Est. | Std. | Est. | Std. |
| Dummy Cote d'Ivoire | **1.05** | 0.08 | **0.56** | 0.04 |
| Dummy Cameroon | **0.62** | 0.12 | **0.37** | 0.06 |
| Dummy Madagascar | **0.65** | 0.16 | **0.33** | 0.09 |
| Dummy Senegal | -0.09 | 0.11 | -0.05 | 0.07 |
| **Student & family characteristics** | | | | |
| Initial test score French | 0.00 | 0.00 | 0.00 | 0.00 |
| Initial test score Math | 0.00 | 0.00 | 0.00 | 0.00 |
| Age | **-0.06** | 0.01 | -0.01 | 0.00 |
| Socioeconomic status | **0.60** | 0.06 | **0.03** | 0.01 |
| Literacy of parents | -0.02 | 0.02 | **-0.01** | 0.00 |
| Student speaks French at home | 0.01 | 0.03 | *0.01* | 0.00 |
| Student can use books at home | **0.41** | 0.03 | 0.00 | 0.00 |
| Work activities outside school (index) | -0.02 | 0.01 | 0.00 | 0.00 |
| **Mean characteristics of classmates** | | | | |
| Initial test score French | 0.00 | 0.00 | 0.00 | 0.00 |
| Initial test score Math | 0.00 | 0.00 | 0.00 | 0.00 |
| Socioeconomic status | **1.28** | 0.23 | **0.98** | 0.12 |
| Literacy of parents | **-0.51** | 0.08 | **-0.26** | 0.05 |
| Student speaks French at home | *0.17* | 0.10 | *0.10* | 0.05 |
| Student can use books at home | -0.08 | 0.11 | **0.19** | 0.07 |
| Work activities outside school (index) | -0.07 | 0.06 | -0.05 | 0.03 |
| **Class and school characteristics** | | | | |
| Teacher has a manual for French | **0.22** | 0.06 | **0.12** | 0.04 |
| Teacher's assessment: share of French speaking families | 0.09 | 0.12 | 0.02 | 0.06 |
| School director's education | **0.05** | 0.02 | **0.02** | 0.01 |
| School located in rural area | **0.15** | 0.07 | **0.09** | 0.04 |
| Constant | | | **0.64** | 0.11 |

Note: *Italics* indicates significance at the 10% level. **Bold** indicates significance at the 5% level. **Bold underlined** indicates significance at the 1% level. Left regression: survey ordered probit regression, interval cut-off points: -0.44 (0.22), 0.73 (0.22), F(23,494)=34.08. Right regression: survey linear regression, F(23,494)=36.88, $R^2$=0.4915, 10489 observations.

The second approach to choosing the regressor set $X$ is based on statistical selection via repeated regressions. Since the estimation results might be sensitive to the choice of the set of regressors $X$ and since one could argue that the parsimonious set of regressors in Table 3.3 omits important variables that are also related to the outcome variable $Y$, the estimations are repeated with two enlarged sets of regressors $X$ with 36 and 49

variables respectively. These sets of regressors have been obtained by regressing $B$ and $C$ on an even larger set of regressors (>200 variables, cf. Table B.1) and sequentially eliminating variables that were insignificant in both regressions (for further details, see Annex C).

Despite the high number of control variables, one might be concerned with potential bias due to endogenous school choice and thus endogenous choice of the classmates. Bright but poor students might be accepted by schools that otherwise cater to rich students. Some schools might provide free textbooks to attract particular students. While such effects should be controlled for by the two pre-test ability measures, it cannot be fully excluded that these measures only imperfectly capture cognitive ability or its development over time. If this is the case and if the unobserved cognitive ability or its development is related to the decision to acquire textbooks (directly or via the peers), endogenous school choice or, more particularly, endogenous school change after the 4th grade could be a potential channel for bias.

While this situation appears rather unlikely,[16] as a safeguard, we conduct a separate analysis for rural areas, where the opportunities for school choice are very limited, since often only a single school is available. The sample of students living in rural areas consists of 4642 observations in 237 classes. As the effects of textbooks could be inherently different for rural and urban populations we would not expect the estimates for the full sample and for the rural sample to fully coincide. Large differences or changes in signs,

[16] School change involves high social costs for the child and transaction cost for the parents. Towards the end of primary education when school change required by the education system is imminent anyway, accepting these cost appears rational only under rather unusual circumstances (like migration).

While initial school choice based on relevant characteristics of the child such as ability is much more plausible, this should generally be well captured in the pre-test variable. Only if initial school choice has an effect beyond its impact on the ability at the beginning of the academic year (like a lasting motivation effect from a well organized first year) a bias may arise. However, since we control for pre-test ability and thus compare only children with the same pre-test score, a bias could only arise if ability at entry in the 1st grade was negatively correlated with the subsequent growth in ability. In other words, children with below average abilities would be sent to particularly good schools. This does not seem very realistic in the African context.

however, could be indicative of selection on unobservables bias in the full sample.

# 4 Estimation results

This section presents the estimation results for the potential outcomes $E\left[Y^{b,c}\right]$ and for the different allocation simulations described in Section 2. The results are given for various different specifications and different sets of covariates to examine the robustness of the findings. In the main specification, $m_{b,c}(x)$ is estimated by local linear regression with $x$ containing the 19 variables given in Table 3.3 (without the country dummies). The nonparametric conditional expectation function $m_{b,c}(x)$ is estimated by local linear regression separately for each country, permitting the relationship between outcomes and characteristics $X$ to differ by country.[17] The regressors are grouped into five sets: $\{B\}$, $\{C\}$, {pre-test French, pre-test Math, classmates' mean pre-test French, classmates' mean pre-test Math}, {all non-binary regressors}, {all binary regressors}. Smoothing over each set of regressors is controlled by a different bandwidth. The first two bandwidths control smoothing over the textbook variables, the third bandwidth refers to achievement at the beginning of the academic year and the last two bandwidths refer to all other individual, family, school and peers characteristics. All variables in the third and the fourth set are scaled to mean zero and variance one. This implies that the effective bandwidth is different for each variable and, within each set, proportional to its standard deviation.

The five different bandwidth values are chosen by leave-one-out cross-validation with respect to average achievement (0.5 French score + 0.5 Math score), minimizing the squared out-of-sample prediction error. The chosen bandwidths are {0.7, 0.3, 1.0, 1.4, 0.8}, with a cross-validation value of 97.4. These bandwidths are relatively large, which is not unusual given the large number of regressors (21 including $B$ and $C$). In the smaller rural sample the chosen bandwidths are larger: {4.9, 0.3, 1.5, 2.2, 0.95} with a cross-validation value of 88.4.

[17] As a practical matter, fixing the bandwidth value on the variable country to zero increases the speed of the nonparametric estimation substantially.

The estimation results are presented in Tables 4.1 to 4.4. In addition to this main specification, three alternative specifications are considered to examine the robustness of the estimation results. Those results are given in Tables D.1 to D.4. The first two alternative specifications differ from the specification discussed so far only in that they control for a larger set of characteristics $X$. The first enlarged set of regressors (set 1) contains 36 variables and the second enlarged set of regressors (set 2) consists of 49 variables (see Table C.1). In the full sample, the minimized cross-validation value is 96.3 for set 1 and 95.8 for set 2. Hence the increase in predictive ability by including more regressors is minimal. In the rural sample, predictive ability even worsens with a cross-validation value of 92.5 for set 1 and 94.3 for set 2. The third alternative specification is based on (global) linear least squares regression instead of nonparametric regression, using the regressor set of regressors of Table 3.3. $m_{b,c}(x)$ is estimated, separately for each country, by regressing the final test score on $B$, $C$, $BC$, $C^2$, all other regressors from Table 3.3 and all these regressors interacted with $C$.

With these estimates of $m_{b,c}(x)$, counterfactual simulations are performed for different values of $b$ and $c$. All results are weighted by class size to represent the population of school children.[18] Standard errors are obtained by bootstrapping. Since the PASEC data were collected by sampling classes within schools within countries, the data are not iid and observations within the same class and/or country are likely to be dependent. To replicate the original sampling process, clustering and stratification are taken into account by re-sampling classes within countries. This leads to drastically larger standard errors throughout, than when re-sampling students.

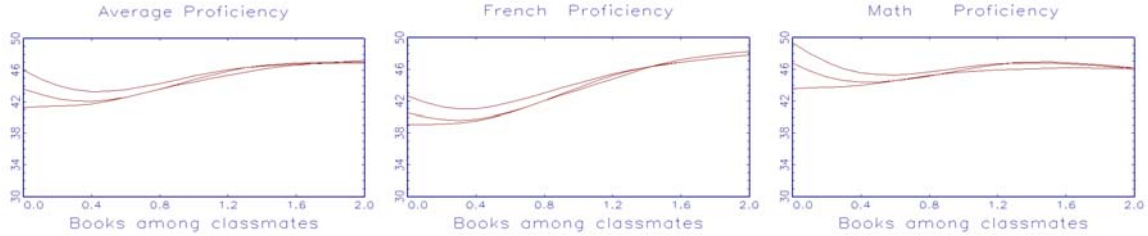
Figure 4.1 shows the estimated expected outcomes $E[Y^{b,c}]$ as a function of classmates' book coverage $c$.[19] In each graph, three lines are shown: for having no book ($b = 0$), for having one book ($b = 1$) and for having two books ($b = 2$). The expected outcomes

[18] E.g. a class of size 80 (with 20 students interviewed) receives twice the weight as a class of size 40 (with also 20 students interviewed). These weights are scaled such that the sum of weights for each country is one fifth.

[19] Confidence bounds are not shown in this figure as it would become illegible. Information on statistical precision is given in Table 4.1 and Figure 4.3.

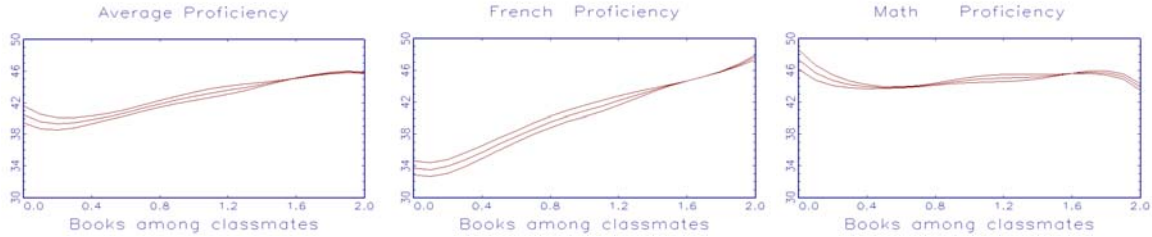
$E[Y^{b,c}]$ are shown for average achievement (= 0.5 French score + 0.5 Math score, left graph), French achievement (middle) and Math achievement (right graph), respectively. Three findings emerge from these graphs: First, the impact of the number of own books $b$ seems to be positive but small. Second, the number of books among classmates appears to be highly relevant, at least for French proficiency. Third, the relevance of this peer effect seems to be greatest for intermediate values of $c$. If the availability of textbooks among students is extremely low, no clear effect can be discerned. The marginal effect then steadily increases up to a point where on average, classmates have at least one of the two textbooks considered here. From there on, the marginal effect decreases again. Once almost all classmates have a textbook, the effect becomes very small, though the slope of the function remains slightly positive throughout. For Math, the overall effect appears to be of much smaller magnitude, but here as well, the positive peer effect is relatively most pronounced for intermediate values of $c$.

Figure 4.1: Expected achievement $E[Y^{b,c}]$ as a function of own books and classmates book coverage




Note: Average outcome (left figure), French outcome (middle figure) and Math outcome (right figure), as a function of classmates book coverage $c$ for b=2 (top line), b=1 (middle line) and b=0 (lowest line) respectively.

Figure 4.2: Expected achievement $E[Y^{b,c}]$ in rural areas




Note: Average outcome (left figure), French outcome (middle figure) and Math outcome (right figure), as a function of classmates book coverage c for b=2 (top line), b=1 (middle line) and b=0 (lowest line) respectively.

Figure 4.2 shows the corresponding graphs for the rural population. Here, French proficiency depends even stronger on the number of classmates' books, while Math achievement remains largely unaffected.

Confidence bounds have been suppressed in Figures 4.1 and 4.2. To assess the statistical precision of the previous findings, Table 4.1 shows the resulting estimates of $E[Y^{b,c}]$ relative to a situation with one book per child. It presents the estimated effects $E[Y^{b,c} - Y^{1,1}]$, with $t$-values simulated by bootstrap. The middle row, with $b = c = 1$, shows the benchmark estimate of $E[Y^{1,1}]$, on the left for the full population and on the right for the rural population. The estimates in the second and in the second last row show the effects of reducing or increasing the number of own books while keeping the number of books per classmate constant at $c = 1$. Focusing on French proficiency, it can be seen that increasing the number of textbooks from 1 to 2 increases French achievement on average by 0.56. An increase from 0 to 1 leads to an improvement in French by 0.28. These direct effects are relatively small and insignificant and are of similar magnitude for Math achievement.

The effects of classmates' books are much larger and significant. For having one personal book ($b = 1$), an increase in the number of classmates' books from 1 to 2 increases French proficiency by 4.13. Increasing the number of classmates' books $c$ from 0 to 2 for a child without textbooks ($b = 0$) improves French proficiency by 9.19. This corresponds to *half* a standard deviation of the French test scores. It is also more than the difference between the 25% quantile and the median of the test score distribution. (This difference is 8.6 as given in Table 3.2.) Hence, the effects of classmates' textbooks are substantial. In the rural population, the effects are somewhat larger but also more volatile and mostly insignificant.

These findings are qualitatively robust to the alternative specifications examined in Table D.1. For French proficiency, the signs are identical for all effects, but the estimates are more volatile and mostly insignificant. For Math proficiency all effects are insignificant.

To correctly interpret Figure 4.1 and Table 4.1, note that these estimates represent the effects of changing $b$ and/or $c$ for a single, randomly drawn student. This has two consequences: First, with average class size being about 47, increasing $c$ by one unit would require purchasing about 46 additional books, whereas for increasing $b$ only one

additional book would need to be provided. Second, if, for example, $b$ were increased for a randomly drawn student, then the number of books among her classmates' classmates would increase, too. I.e. if $b_i$ changed for student $i$, then $c_j$ would also change for $i$'s classmates. This is not reflected in the estimates in Figure 4.1 and Table 4.1. The overall effects of changes in the allocation of books are considered in the next section.

Table 4.1: Relationship between textbooks and achievement:
Estimates of E[Yb,c-Y1,1]

| | | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Own book | Peer book | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| *b* | *c* | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| 0 | 0 | -3.50 | 0.83 | -4.64 | 0.93 | -2.35 | 0.51 | -3.34 | 0.66 | -8.03 | 1.32 | 1.35 | 0.21 |
| 0 | 1 | -0.27 | 0.54 | -0.28 | 0.43 | -0.27 | 0.46 | *-0.50* | 1.78 | *-0.68* | 1.83 | -0.32 | 0.96 |
| 0 | 2 | 2.39 | 1.44 | **4.55** | 2.44 | 0.24 | 0.13 | 3.03 | 0.77 | 6.49 | 1.40 | -0.43 | 0.09 |
| 1 | 0 | -1.20 | 0.32 | -3.22 | 0.78 | 0.83 | 0.20 | -2.31 | 0.45 | -7.17 | 1.17 | 2.56 | 0.40 |
| 1 | 1 | 44.79 | | 43.68 | | 45.89 | | 42.81 | | 40.86 | | 44.75 | |
| 1 | 2 | 2.22 | 1.38 | **4.13** | 2.37 | 0.31 | 0.17 | 2.96 | 0.72 | 6.76 | 1.41 | -0.84 | 0.17 |
| 2 | 0 | 1.20 | 0.32 | -1.03 | 0.26 | 3.44 | 0.81 | -1.24 | 0.24 | -6.28 | 1.02 | 3.79 | 0.59 |
| 2 | 1 | 0.45 | 1.05 | 0.56 | 1.08 | 0.34 | 0.74 | *0.53* | 1.87 | *0.71* | 1.89 | 0.35 | 1.04 |
| 2 | 2 | 2.10 | 1.17 | **4.11** | 2.11 | 0.10 | 0.05 | 2.88 | 0.66 | 7.05 | 1.40 | -1.28 | 0.24 |

Note: Estimates of $E[Y^{b,c}\text{-}Y^{1,1}]$ for main specification. $E[Y^{1,1}]$ is the base category. Results for alternative specifications are given in Table D.1.
*Italics* indicate significance at the 10% level. **Bold** indicates significance at the 5% level. **Bold underlined** indicates significance at the 1% level.
Results weighted proportional to class-size to represent the student population. Full sample 10489 observations, rural sample 4642 observations.
Full sample 170 bootstrap replications, rural sample 100 bootstrap replications. Bootstrapping is based on re-sampling classes within countries.

## 4.1 Textbook externalities

Table 4.2 shows the decomposition of the impact of one additional textbook into the direct and the indirect effect. When randomly allocating an additional book to a student who does not already have two books, her classmates also benefit from this additional book. Using the previously obtained estimates $\hat{m}_{b,c}(x)$, the impact of one book on the population mean outcome can be simulated as discussed in section 2.2.1. The direct effect is obtained by ignoring any increase in $C$, i.e. pretending that the additional book increased the number of personal books without increasing the number of books in the class. The indirect effect is the difference between the total effect and the direct effect. This indirect effect shows how much the classmates gain from the increase in the total number of books. The estimates in Table 4.2 are multiplied by the number of observations to make the results for the full sample and for the rural sample comparable.

The estimated direct effects are of similar size as in Table 4.1. They are not identical to the effects of Table 4.1 because they represent the direct effect at different values of $b$ and $c$. Furthermore, the population of students who can receive an additional book is restricted to those who do not already have two books. If the direct effect was linear in $b$ and independent of $c$, the estimates in Tables 4.1 and 4.2 would be identical.

In contrast to Table 4.1, the estimates of the direct effect are all significant in Table 4.2 (for the full sample). The reason for this could be the correlation between $B$, $C$ and $X$. For several values of $X$, the values of $B$ and $C$ examined in Table 4.1 could be in regions with little density. In the analysis of the effects of one additional textbook, however, only small changes in $C$ and one book changes in $B$ from the observed values $B_i$, $C_i$ and $X_i$ occur. This reduces the variance of the estimates.

While the direct effects can thus be shown to be significant as well, they still appear relatively small. As shown in Table 4.2, the estimates of the total effect as much as ten times larger than the direct impacts. This means that 90% of the effects of an additional textbook is due to the indirect effect on the classmates. Note that this is an average result which is largely due to the strong effect of classmates' books in the region of intermediate overall textbook availability. In classes in which only very few books are available, the effect of a privately owned book relative to the peer effect appears to be somewhat stronger, as seen in Figure 4.1 and Table 4.1.

Nevertheless, the strong overall dominance of the peer effect may come as a surprise. It should be noted, however, that the 90% represent the effect on all classmates *together*. With an average class size of about 47 students, if the indirect benefits were shared equally by all students in the class, the indirect effect *per classmate* on, for example, French proficiency would be about 0.04. This is one sixth of the direct effect. In other words, a student benefits six times as much from a book given to him personally, than from a book given to one of his classmates. Hence, the direct effect is still substantially larger than the average effect on each classmate. Nevertheless, since there are so many classmates, together they reap 90% of the total effect. This result is remarkably robust to different specifications, at least with respect to French proficiency (see Table D.2).

For French, although the absolute values of the estimates vary somewhat and are not always significant, particularly in the rural sample, the finding that about 90% of the total effect is due to the indirect effect is stable throughout. The estimates for Math proficiency are much more volatile and mostly insignificant.

Overall, this shows that textbook externalities are highly relevant for the assessment of marginal benefits. If only about 10% of the marginal benefits accrue to the owner of the textbook, this implies that regression models neglecting the externality are likely to result in strongly downward biased estimates for the overall effect. Omitting the peer-group variable, the estimator of the impact of textbooks will only capture the direct effect and those parts of the indirect effect which arise through its correlation with the direct effect.[20] In their study using PASEC data for Madagascar, for instance, Lassibille and Tan (2003) only find an effect of textbooks corresponding to 11% of a standard deviation of combined 5th grade scores in Math and French. Their estimate refers to an increase from zero to either one or two textbooks and should therefore lie in between our estimates for an increase by one and by two books, i.e. around 15-40% depending on the initial availability of books. As noted by Glewwe, Kremer, and Moulin (2000), earlier studies sometimes find similarly high estimates around 30%, but they may be biased upward due to the omission of relevant socioeconomic, school environment and ability related variables which can be expected to be positively related to the availability of books. Here, it appears as if the omission of these variables on the one hand simply compensated for the omission of the peer effects on the other hand.

As opposed to studies analyzing the effect of individual textbook possession, studies analyzing the overall availability of textbooks in the classroom should implicitly include the impact of the peer effect. Indeed, again based on the PASEC dataset, Michaelowa (2001) finds an effect of about half a standard deviation of test scores for an increase

[20] For example, consider a linear relationship between achievement $Y$ and books as $Y_i = 0.1B_i + 0.9C_i$. If the number of books is increased from 0 to 2 for all students, achievement $Y_i$ increases by 2. The regression of $Y_i$ on $B_i$, however, results in $E[Y|B=2] - E[Y|B=0] = 0.2 + 0.9(E[C|B=2] - E[C|B=0]) < 2$, unless there is no variation in the number of books within a class (i.e. all students in a class have the same number of books).

of textbook availability in the classroom from 0 to 2 books per student. This is in line with our estimates. For Kenya, Glewwe, Kremer, Moulin, and Zitzewitz (2004) only find lower estimates (as a maximum, one more textbook per student leading to an increase in test scores of 13% of a standard deviation), but in this particular context, flip charts have been introduced as an alternative, so that the relevance of textbooks as a means of instruction may be reduced.

Using a prospective evaluation approach, Glewwe, Kremer, and Moulin (2000) find even less evidence for the relevance of textbooks, but the magnitude of the effects is difficult to compare to the results of our analysis. The problem is that the actual increase in the number of books available to the Kenyan students does not become fully clear due to contradictions between different surveys. This would be crucial to know as our own results are based entirely on the actual availability of textbooks.

In any case, it should be kept in mind that the effects of textbooks depend on the initial prevalence of textbooks, as the nonlinearities of Figure 4.1 have indicated, and might therefore be larger in Francophone Africa where textbook availability is rather low.

It remains to explain how an externality as high as 90% can actually come about. To some extent, this large externality may be explained by students sharing a book in class, either voluntarily or being constraint to do so by the teacher. Suppose for the moment that *book sharing* is the only transmission channel of the externality. If a book was shared by two children in class and if there were no benefits from possessing the book, the direct and indirect benefits would be of the same size. If four children were sharing a book, the indirect benefits would represent about 75% of the total impact. However, with four children sharing a book, the earlier assumption of no private benefits from the possession of the book becomes rather unrealistic. Therefore, in reality, the owner of the book is likely to derive higher benefits from the book than the other three students, such that the share of the indirect benefits would be less than 75%.

Although the sharing of books is indeed a frequent phenomenon in African schools (see also Glewwe, Kremer, and Moulin (2000) for Kenya), it cannot explain a ratio

of indirect to total effect as high as 90%. Other factors also seem to matter. One factor could be shared knowledge, whereby the whole class benefits from the increased knowledge of a student with additional books. This actually reflects the typical peer-effect generally referred to in the literature. A related effect could be an increase in the student's motivation which might as well spill over to his classmates. Despite such potential variations in the exact interpretation of this transmission channel we will refer to it as "knowledge sharing" for reasons of simplification.

Another channel, possibly even more important in our context, works via the change in instructional methods employed by the teacher. The benefits of books are likely to be small or zero if the teacher does not resort or refer to these books. It appears plausible to assume that the more textbooks are present among the students, the more likely the teacher is going to use these books. For example, a particular teacher might start using books only if their availability is above a certain threshold level, e.g. if 50% of the students have at least one book. Moreover, he might adjust the time he spends on textbook based teaching to the availability of books among his students.

Figure 4.1 provides some evidence for these additional transmission channels. In particular, improvements in French proficiency do not level off as early as one would expect if book sharing were the only relevant mechanism at work. In fact, once every second student has the relevant books, additional gains via book sharing should be rather small. As we can still make out a significant increase in student performance thereafter,[21] this provides some evidence for transmission channels such as teaching methods or knowledge sharing. Moreover, as discussed earlier, the curves for French proficiency seem to be flat if the number of books per classmate is smaller than 0.5. In this region, the peers' textbooks do not seem to matter, perhaps because the teachers rarely resort to books in their teaching. As Figure 4.3 indicates, however, this finding is not statistically significant.

The large externality may lead to socially suboptimal decisions of parents in buying

[21] See also Table 4.1 for the significant increase in French proficiency from an average of one to an average of two textbooks among classmates.

textbooks for their children. If there is some social coercion (or coercion by the teacher) to share books, parents might hope that someone else in class has a book to share so that their own children become free-riders. Other less visible externalities will probably even go unnoticed. In any case, the full value of textbooks cannot be expected to find its reflection in the parents' private investment decision. Hence, the number of textbooks bought is likely to be too low.

Table 4.2: Direct and indirect effects of an additional textbook

| | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| Direct effect | **0.24** | 2.78 | **0.24** | 2.24 | **0.24** | 2.31 | *0.34* | 1.93 | *0.41* | 1.84 | 0.27 | 1.32 |
| Indirect effect | **1.78** | 2.46 | **1.96** | 2.56 | **1.60** | 2.02 | 2.92 | 1.27 | *4.27* | 1.76 | 1.58 | 0.57 |
| Total effect | **2.02** | 2.72 | **2.20** | 2.79 | **1.84** | 2.25 | 3.26 | 1.36 | *4.68* | 1.85 | 1.84 | 0.64 |
| Indirect as % of total | 88 | | 89 | | 87 | | 90 | | 91 | | 86 | |

Note: Results multiplied by the number of observations in order to obtain comparability between the two samples. *Italics* indicate significance at the 10% level. **Bold** indicates significance at the 5% level. **Bold underlined** indicates significance at the 1% level. Results weighted proportional to class-size to represent the student population. Full sample 10489 observations, rural sample 4642 observations. Full sample 170 bootstrap replications, rural sample 100 bootstrap replications. Bootstrapping is based on re-sampling classes within countries.

## 4.2 Allocation of books within classes

Having found that textbook externalities seem to be relevant, these externalities may affect the optimal allocation of books within classes. If books are equally distributed within the class, all children face the same number of books among classmates. In an extremely unequal allocation, half of the children receive no books whereas the other half of the children receive two books. Although the children without books are in a first instance directly harmed by this allocation policy, they benefit from their classmates having more books. With nonlinear peer effects, these benefits may partly outweigh the losses incurred by not having books. If sharing of books is common, the allocation may have no effects at all as long as the total number of books remains constant.

Table 4.3 shows the average achievement with an equal and an unequal allocation of books. In the first row, each student has exactly one book. In the second row, the most unequal distribution of books is considered: In each class, half of all students are

without books and the other half of students has two books each.[22] The difference to the outcome with equal allocation is shown in the second row of Table 4.3. The unequal allocation seems to lead to a slightly better average outcome. Although these estimates are very small and highly insignificant, they seem to indicate that an unequal allocation of books within the class may not do much harm, at least with respect to the average achievement in the population.[23] Thus the way how textbooks are distributed within a class does not seem to play a relevant role. The results are similar for the alternative specifications, given in Table D.3, which are either very small or insignificant. This is in line with the observation that the sharing of textbooks is indeed a frequent phenomenon in African schools.

Table 4.3: Allocation within class: Equal versus unequal distribution

| | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| Each student has a book | 44.79 | | 43.68 | | 45.89 | | 42.81 | | 40.86 | | 44.75 | |
| Half without books and half with two books | 0.08 | 0.37 | 0.14 | 0.56 | 0.02 | 0.07 | 0.00 | 0.02 | 0.02 | 0.82 | -0.02 | 1.02 |

Note: First line gives the average outcome if each student had one book. The second line gives the average outcome if *within each class* half of the students had no books and the other half had two books each. None of these results is significant at the 10% level.

## 4.3 Allocation of books across schools

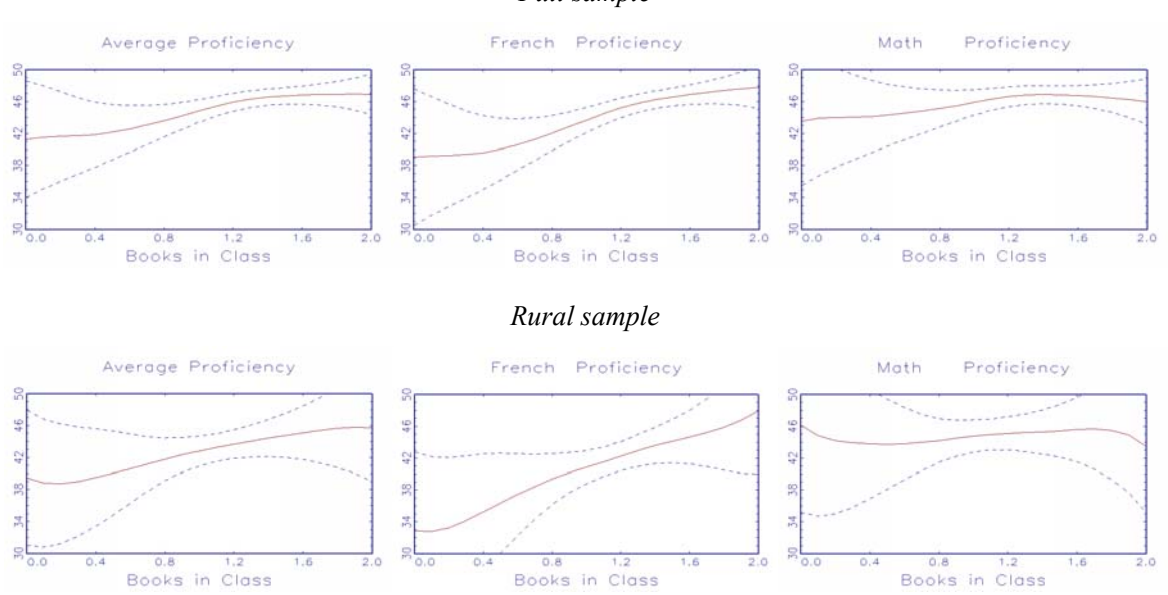
Even though the allocation of books within the class does not seem to matter, the allocation of books between schools could be important. Students might be willing (or constraint) to share books if they are in the same class, but they are not able to do so across schools. From the $\hat{m}_{b,c}(x)$ estimates, the mean outcome $E[Y_\mu]$ as a function of the number of books in class $\mu$ can be simulated, as discussed in Section 2.2.3. These mean outcomes are shown in Figure 4.3 together with 90% confidence intervals. The curves

[22] Other allocations have also been examined and led to similar results.

[23] It may, however, affect the dispersion of the test score outcomes in that those students with two books do better than those without books.

in Figure 4.3 are somewhat steeper than in Figures 4.1 and 4.2 since they combine both the direct and the peer effect. As the average number of books per student $\mu$ increases, both the number of personal books and the number of books among classmates increases and these two effects cumulate to a higher overall effect.

Figure 4.3: Expected achievement for different combinations of own books and classmates' book coverage




Notes: The dashed lines represent the 90% point wise confidence intervals based on170 bootstrap replications for the full sample and 100 bootstrap replications for the rural sample. Bootstrapping is based on re-sampling classes within countries.

Figure 4.3 suggests that achievement increases non-linearly with the number of books in class. In the full population, for a number of books below 0.5, French proficiency is flat. It increases almost monotonously afterwards until, with a high number of books available, it slightly flattens down again. Math proficiency first improves with the number of books and decreases slightly when books are available abundantly. The functions' concavity towards the right hand side of the graphs could be interpreted as some positive evidence for the benefits of a relatively equal distribution. However, the convexity of the curves towards the left of the curves appears to imply that this is not the case if the overall availability of textbooks is very low. Generally, confidence bands are too wide to be

confident about any precise functional form. For the rural population, confidence bands are even wider, i.e. the curves depicted for the rural sample are even more unreliable.

Table 4.4 compares the outcomes of alternative allocations of books between schools. The first three rows show the outcomes for the average number of books per student being 0.5. In the first of these rows, the average achievement is given when the books are equally distributed across schools ($\mu$=0.5). The second row represents an allocation where half of the schools have $\mu$=0.3 books per child and the other half of schools have $\mu$=0.7 books. In the third row, the distribution of books is more unequal and half of the schools have only $\mu$=0.1 books per child, while the other half has $\mu$=0.9. The following three rows give the corresponding results when the average number of books in all schools is 1.0. In the last three rows, the average number of books is 1.5.

For the full sample, the signs of the coefficients are consistent with the interpretation that with a very low overall availability of books, an unequal distribution might increase average scores, while with a higher overall availability, an equal distribution could improve average performance. However, the numbers in Table 4.4 are generally small, and all are insignificant. This result remains unchanged for the alternative specifications in Table D.4. Notwithstanding the insignificant effect of textbook distribution on average countrywide achievement, according to the results of previous sections, textbook distribution will of course affect the *distribution* of outcomes.

Table 4.4: Allocation between schools: Equal versus unequal distribution

| | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| 0.5 books per student | 42.16 | | 40.03 | | 44.30 | | 40.04 | | 36.34 | | 43.74 | |
| 0.3 versus 0.7 books | 0.21 | 0.79 | 0.30 | 1.02 | 0.12 | 0.41 | 0.07 | 0.08 | -0.05 | 0.05 | 0.18 | 0.20 |
| 0.1 versus 0.9 books | 0.69 | 0.76 | 0.99 | 0.96 | 0.39 | 0.38 | 0.52 | 0.25 | 0.13 | 0.05 | 0.91 | 0.41 |
| 1.0 books per student | 44.79 | | 43.68 | | 45.89 | | 42.81 | | 40.86 | | 44.75 | |
| 0.8 versus 1.2 books | -0.04 | 0.21 | -0.05 | 0.22 | -0.03 | 0.16 | -0.08 | 0.25 | -0.05 | 0.13 | -0.12 | 0.31 |
| 0.6 versus 1.4 books | -0.23 | 0.39 | -0.26 | 0.37 | -0.20 | 0.33 | -0.29 | 0.27 | -0.37 | 0.29 | -0.22 | 0.18 |
| 1.5 books per student | 46.70 | | 46.57 | | 46.83 | | 44.76 | | 44.11 | | 45.41 | |
| 1.3 versus 1.7 books | -0.12 | 0.79 | -0.11 | 0.67 | -0.13 | 0.78 | -0.02 | 0.05 | -0.04 | 0.08 | 0.00 | 0.00 |
| 1.1 versus 1.9 books | -0.54 | 0.96 | -0.52 | 0.87 | -0.56 | 0.91 | -0.23 | 0.21 | 0.03 | 0.02 | -0.48 | 0.30 |

Notes: In first three rows, outcomes of alternative allocations for average number of books per student being 0.5. In first of these rows, average achievement is given when books are equally distributed across schools. The second row represents an allocation where half of the schools have 0.3 books per child and the other half of schools have 0.7 books. In third row, the distribution of books is more unequal and half of the schools have only 0.1 books per child, while the other half has 0.9. The second three rows give the corresponding results when the average number of books in all schools is 1.0. In the last three rows, the average number of books is 1.5.

# 5 Conclusions

Analyzing the impact of textbooks on 5th grade student achievement in francophone sub-Saharan Africa, our focus has been on the externality or peer effect of these books on other students in the class. Extending nonparametric estimation methods from the treatment evaluation literature to the case of two simultaneous treatments involving one discrete and one continuous variable, we were able to distinguish this externality from the textbooks' direct effect on students' learning. Moreover, the flexibility involved with nonparametric estimation allowed us to explore potential nonlinearities and the related issue of different channels through which textbook possession may affect other classmates' learning, e.g. book sharing, knowledge sharing and changes in teachers' instructional methods.

Textbook externalities may have important consequences for public educational policies. First, if externalities are neglected in the empirical analysis (and all other sources of potentially compensating omitted variable bias are eliminated), the overall benefits of textbooks will generally be underestimated. Second, externalities induce parents to make socially suboptimal investment decisions because they buy textbooks for their children without taking into account the benefits for other students. Third, nonlinearities in the peer effects can affect the optimal allocation of books within the class and between classes.

Although a purely nonparametric analysis naturally leads to less precise estimates, several findings could be established. Primarily, it turns out that textbooks do have a positive and very large externality on other students in the class. With respect to French proficiency, the externality is as much as 9 times larger than the direct effect of textbooks and this result is remarkably robust across different specifications. For mathematics, results are less robust, but equally point to the prevalence of strong externalities. Any individual student still has a higher benefit from his own book because the overall peer effect has to be shared by an average of 47 other students in the class.

Nevertheless, such a large externality cannot be explained by book sharing alone, and other transmission channels such as knowledge sharing of students possessing a

book or change in teaching methods have to be at work. This result is confirmed by the observation that the impact of increasing the classmates' books on French proficiency does not level off early as one would expect this to happen with simple book sharing. At the same time, it appears that it becomes relevant only when average number of books per classmate is around 0.5. This may reflect the teachers' reluctancy to effectively make use of textbooks as long as their availability is very low.

In any case, with such a large externality, private underprovision of textbooks is a concern. This calls for a change of public policy towards either much higher subsidies or public provision and distribution. According to our data, the latter has been surprisingly uncommon so far in the countries considered here.

Regarding the optimal allocation of books within class and between classes, the statistical precision of the estimates was too weak to draw any firm conclusions. The functional form of the relationship weakly suggests that a relatively equal distribution across classes might increase overall countrywide achievement as long as the overall availability of textbooks is not extremely low. If it is very low, the opposite may be true. Among other things, this could reflect that it is inefficient to increase textbooks in a situation where the number will still remain so small that the teacher will not use them.

The insignificant results for the effects of reallocation of textbooks within the class are in line with the evidence for book sharing and for textbook externalities in general. It should be noted that a small or insignificant effect of textbook redistribution on average achievement does not rule out large impacts on the distribution, i.e. the degree of inequality, of these outcomes.

# A Econometric appendix

This appendix provides some further details on the nonparametric estimator.

There are several options how to estimate the conditional expectation function $m_{b,c}(x)$. A common choice would be a Nadaraya-Watson kernel regression which, in our

case, would lead to the estimator:

$$\hat{m}_{b,c}(x) = \frac{\sum_j Y_j \cdot \mathbf{K}_H \left(B_j - b, C_j - c, X_j - x\right)}{\sum_j \mathbf{K}_H \left(B_j - b, C_j - c, X_j - x\right)},$$

where $\mathbf{K}_H$ is a multivariate kernel function with bandwidth matrix $H$, which is further described below.

However, instead of a local constant model implied by the Nadaraya-Watson kernel regression, a local parametric model is often more appropriate (Fan and Gijbels 1996). In particular, using a local parametric model that is closer to the true conditional mean function reduces bias (Gozalo and Linton 2000). In addition, in a treatment effect interpretation, local constant regression tends to lead to a downward bias in the treatment effects $E[Y^{b'',c''}] - E[Y^{b',c'}]$ due to the local constant smoothing if the expectation functions are monotonous. This leads to an underestimation of the impacts of $B$ and $C$. Local linear regression can help to avoid such downward biased estimates and is also known to behave better in boundary regions (Fan 1992, Fan and Gijbels 1996). Therefore, we estimate $m_{b,c}(x)$ by local linear regression

$$\begin{aligned}
&\hat{m}_{b,c}(x) = \hat{\alpha}, \text{ where} \\
&\quad \hat{\alpha}, \hat{\beta}_b, \hat{\beta}_c, \hat{\beta}_x = \underset{\alpha,\beta_b,\beta_c,\beta_x}{\arg\min} \sum_j \left(Y_j - \alpha - \beta_b \left(B_j - b\right) - \beta_c \left(C_j - c\right) - \beta_x (X_j - x)\right)^2 \\
&\qquad\qquad \cdot \mathbf{K}_H \left(B_j - b, C_j - c, X_j - x\right).
\end{aligned}$$

The estimate of $\hat{m}_{b,c}(x)$ is capped at the boundaries of the support of the test scores, which are at 0 and at 100 percent of correct answers.[24]

A common choice for the multivariate kernel function $\mathbf{K}_H$ is a product kernel

$$\mathbf{K}_H \left(B_j - b, C_j - c, X_j - x\right) = K\left(\frac{B_j - b}{h_b}\right) \cdot K\left(\frac{C_j - c}{h_c}\right) \prod_{k=1}^{\kappa} K\left(\frac{X_{j,k} - x_k}{h_k}\right),$$

[24] For small bandwidth values the estimate may be undefined at some $x$ due to local near-collinearity. In this case, the bandwidths are locally, proportionally increased, repeatedly until a valid estimate is obtained.

where $K$ is a univariate kernel function, $x_k$ is the $k$-th variable of the $\kappa \times 1$ vector $x$ and $X_{j,k}$ is the $k$-th variable of $X_j$. The bandwidths $h_b$, $h_c$ and $h_1 ... h_\kappa$ control the smoothing over $B$, $C$ and $X$. As some of the components of $(B, C, X)$ are continuous, some are ordered discrete and some are unordered discrete variables or dummy variables, a generalized kernel of the type proposed in Racine and Li (2004) is used. We distinguish in the following only between variables with and without natural ordering.[25] If $X_{j,k}$ is a continuous or ordered discrete random variable, the kernel weights are computed by the Gaussian kernel $K\left(\frac{X_{j,k}-x_k}{h_k}\right) = \Phi\left(\frac{X_{j,k}-x_k}{h_k}\right)$. If $X_{j,k}$ is an unordered or binary random variable, the kernel weight is $K\left(\frac{X_{j,k}-x_k}{h_k}\right) = h_k^{1\left(X_{j,k} \neq x_k\right)}$ with $h_k \in [0,1]$ and $1(\cdot)$ being an indicator function. In the latter case, $h_k$ controls the smoothing over unordered and dummy variables. Consider the extreme choices for $h_k$. For $h_k = 0$, the kernel weight is zero if $X_{j,k} \neq x_k$ and one if $X_{j,k} = x_k$. For $h_k = 1$, the kernel weight is the same regardless of whether $X_{j,k}$ equals $x_k$ or not. In nonparametric econometrics it is often proposed to estimate the regression curve within each cell formed by the dummy regressors. This is equivalent to setting $h_k = 0$ for all dummy variables. However, in many economic applications it appears to make sense to consider two observations which agree in, say, 9 out of 10 binary characteristics to be more similar than two observations which are equal on fewer characteristics. Indeed, smoothing over the dummy variables can improve substantially the precision in small samples, see Racine and Li (2004). Therefore, we allow $h_k > 0$.

The bandwidth values are chosen by leave-one-out cross-validation, which can be interpreted as finding the bandwidth values that minimize out-of-sample squared prediction error. In principle, different bandwidth parameters could be used for each variable, which however makes bandwidth choice very cumbersome. The common alternative used here is to choose the bandwidths for continuous and ordered discrete regressors proportional to their standard deviation, i.e. $h_k \propto std(X_k)$, such that only

[25] Racine and Li (2004) propose different kernels for continuous and for ordered discrete variables. In particular, they use geometrically declining weights for the ordered discrete variables. There are no reasons, though, for not using Gaussian weights also for the ordered discrete variables.

the common multiplier has to be chosen.

# B Data appendix

Table B.1 provides descriptive statistics on all variables of the data set considered as potentially relevant in the context of our analysis. The first column refers to the original sample of 11658 observations. The subsequent columns refer to the final sample with 10489 observations, first jointly and then separately for the five different countries. The table presents the mean of each variable followed by the number of missing values (in brackets). In case of binary variables, the means are expressed in percentage terms. Missing items are imputed using other observed variables with which some close relationship can be expected. In some cases, teachers and directors were asked almost identical questions so that the answers provided to one of the questionnaires provide a natural substitute for missing values in the other questionnaire. In other cases, theoretical relationships such as between class size and student-teacher ratios can be explored. For the remaining variables, imputation is based on linear regressions with subsequent rounding and trimming to ensure that the imputed values are in the support of the underlying variable. In some cases, several of the above imputation strategies are combined.

Whenever the original information is missing, missing data indicators are generated. They generally take the form of dummy variables. For composite variables, however, i.e. for variables including information on several related questions, missing value indicators reflect the sum of missing values in the original data. For instance, for the variable on meals which includes information on breakfast, lunch and dinner, the missing value indicator takes values in {0,1,2,3}. In these cases, the numbers in brackets provided in Table B.1 represent the mean of this missing value indicator.

The missing variable indicators are themselves used in several of the specifications as additional regressors when they were significant as determinants of textbook availability (see Table C.1). This provides a useful solution to the problem of missing values in

the control variates. Dropping all observations with missing items would have led to a large loss of observations and a very selected sample. On the other hand, imputing values without accounting for its missingness could omit important information contained in the very fact that data was missing. Most of the missing data regressors, nevertheless, turned out not to be significant determinants of the number of textbooks, thereby instilling confidence that missing data may not undermine the validity of the empirical analysis.

Table B.1: Descriptive statistics (Means or shares)

| Variable and Range | Original Sample | All question-naires | Burkina Faso | Cote d'Ivoire | Cameroon | Madagascar | Senegal |
|---|---|---|---|---|---|---|---|
| Observations | 11658 | 10489 | 2072 | 2243 | 2184 | 2258 | 1732 |
| Student has a textbook for French (dummy) | 78 | 78 | 81 | 87 | 76 | 76 | 68 |
| Student has a textbook for Math (dummy) | 53 | 54 | 20 | 83 | 71 | 48 | 42 |
| Student has a textbook for French, for Math or both (0-2) | 1.3 | 1.3 | 1.0 | 1.7 | 1.5 | 1.2 | 1.1 |
| Student's final test score in French (0-100 % of correct answers) | 45.6 (12) | 45.6 (11) | 43.7 (5) | 50 (10) | 55.8 (19) | 42.6 (9) | 34.4 (11) |
| Student's final test score in Math (0-100 % of correct answers) | 46.9 (12) | 47.1 (11) | 46.4 (5) | 40.4 (10) | 50.5 (19) | 58.8 (9) | 37 (11) |
| Student's final test score, average for French and Math (0-100 % correct) | 46.3 (12) | 46.3 (11) | 45.1 (5) | 45.2 (10) | 53.2 (19) | 50.8 (9) | 35.7 (11) |
| Student's initial test score in French (0-100 % of correct answers) | 43.3 (2) | 43.1 (1) | 40.9 (0) | 48.7 (0) | 53.2 (0) | 42.6 (0) | 26.3 (3) [a] |
| Student's initial test score in Math (0-100 % of correct answers) | 48.7 (2) | 48.8 (1) | 41 (0) | 50.4 (0) | 56.2 (1) | 64.2 (0) | 26.5 (4) [a] |
| Student's classmates' initial test score in French (0-100 % correct answers) | 43.3 (1) | 43.1 (0) | 40.9 (0) | 48.7 (0) | 53.2 (0) | 42.6 (0) | 26.3 (0) [a] |
| Student's classmates' initial test score in Math (0-100 % of correct answers) | 48.6 (1) | 48.6 (0) | 41 (0) | 50.4 (0) | 56.2 (0) | 63.6 (0) | 26.5 (0) [a] |
| Availability of Frenchbooks among student's classmates(0-1 books per student) | 0.78 | 0.78 | 0.81 | 0.87 | 0.76 | 0.76 | 0.68 |
| Availability of Math books among student's classmates (0-1 books per student) | 0.53 | 0.54 | 0.20 | 0.83 | 0.71 | 0.47 | 0.42 |
| Availability of French and/or Math textbooks among student's classmates (0-2) | 1.3 | 1.3 | 1.0 | 1.7 | 1.5 | 1.2 | 1.1 |
| Class management in double shifts (dummy) | 9 (14) | 9 (7) | 2 (7) | 4 (5) | 17 (5) | 8 (13) | 16 (3) |
| Class management with multi-grade teaching (dummy) | 6 (14) | 6 (7) | 3 (7) | 4 (5) | 11 (5) | 7 (13) | 3 (3) |
| Class management with multi-grade teaching, junior group (dummy) | 0 (12) | 0 (4) | 0 (2) | 1 (3) | 0 (11) | 0 (3) | 1 (1) |
| Class management with multi-grade teaching, senior group (dummy) | 1 (12) | 1 (4) | 0 (2) | 0 (3) | 0 (11) | 4 (3) | 1 (1) |
| Class size (6-139 students) | 47.51 (26) | 46.97 (20) | 62.84 (13) | 36.34 (19) | 49.07 (32) | 36.82 (22) | 52.32 (9) |
| Classroom has electricity (dummy) | 25 | 26 | 20 | 35 | 19 | 26 | 32 |
| Classroom is equipped with a blackboard (dummy) | 94 (8) | 94 (0) | 93 (0) | 94 (0) | 95 (0) | 94 (0) | 94 (0) |
| Classroom is equipped with a blackboard and chalk (dummy) | 93 | 93 | 92 | 92 | 94 | 93 | 93 |
| Classroom is equipped with a dictionary (dummy) | 22 (8) | 22 (0) | 27 (0) | 26 (0) | 22 (0) | 21 (0) | 15 (0) |
| Classroom is equipped with chalk (dummy) | 98 | 97 | 99 | 97 | 97 | 97 | 97 |
| Classroom space per student (0-31.8m²) [e] | 1.70 (20) | 1.74 (12) | 1.07 (19) | 2.31 (8) | 1.53 (15) | 2.01 (9) | - [b] |
| Director completed the baccalaureate (BAC) (dummy) | 12 (4) | 13 (3) | 4 (0) | 9 (0) | 14 (0) | 16 (0) | 25 (21) |
| Director followed on-the-job training in didactics of French (dummy) | 39 | 41 | 20 | 30 | 54 | 54 | 46 |
| Director followed on-the-job training in didactics of Math (dummy) | 34 | 35 | 15 | 31 | 58 | 28 | 45 |
| Director often speaks French at home (dummy) | 70 (4) | 72 (2) | 88 (1) | 95 (0) | 81 (3) | 37 (2) | 57 (2) |
| Director received some pedagogical training (dummy) | 67 (1) | 69 | 60 | 81 (0) | 77 (0) | 64 (0) | 62 (0) |

Table B.1 cont.

| Variable and Range | Original Sample | All question-naires | Burkina Faso | Cote d'Ivoire | Cameroon | Madagascar | Senegal |
|---|---|---|---|---|---|---|---|
| Director speaks local language (dummy) | 75 (5) | 76 (2) | 78 (1) | 51 (4) | 69 (3) | 97 (1) | 86 (3) |
| Director's education index, from below primary completion to 3 years of higher education and above (0-6) | 2.89 (2) | 2.97 (2) | 2.68 (1) | 2.78 (2) | 3.07 (0) | 3.02 (0) | 3.35 (6) |
| Frequent exchange among teachers (dummy) | 72 (8) | 72 (0) | 88 (0) | 71 (0) | 79 (0) | 54 (0) | 67 (0) |
| Next city at least one hour away from school location (dummy) | 23 | 23 | 13 | 20 | 20 | 36 | 27 |
| Next city two or more hours away from school location (dummy) | 7 | 7 | 2 | 3 | 9 | 14 | 6 |
| Parents easily mobilized for school issues (dummy) | 36 (11) | 35 (3) | 33 (2) | 24 (2) | 28 (3) | 62 (7) | 25 (2) |
| School area has a fence | 32 | 34 | 13 | 28 | 20 | 49 | 68 |
| School equipment indicator, low to high (0-14) | 5.38 | 5.53 | 5.82 | 6.51 | 4.62 | 5.14 | 5.54 |
| School has a canteen | 31 | 31 | 75 | 47 | 9 | 6 | 17 |
| School has a court yard | 90 | 91 | 87 | 98 | 86 | 95 | 90 |
| School has a garden (dummy) | 27 | 28 | 14 | 34 | 24 | 44 | 21 |
| School has a health care center | 3 | 3 | 4 | 2 | 5 | 2 | 2 |
| School has a library (dummy) | 9 | 10 | 7 | 10 | 6 | 13 | 13 |
| School has a separate room for the teachers (dummy) | 5 | 5 | 0 | 4 | 5 | 11 | 1 |
| School has a storage room (dummy) | 49 | 50 | 87 | 56 | 33 | 24 | 53 |
| School has access to fresh water (dummy) | 59 | 60 | 73 | 62 | 53 | 45 | 72 |
| School has an office room for the director (dummy) | 49 | 51 | 25 | 74 | 61 | 46 | 42 |
| School has specific sports equipment (dummy) | 28 | 28 | 35 | 39 | 17 | 31 | 14 |
| School has toilets | 58 | 60 | 60 | 42 | 73 | 57 | 69 |
| School inspected during the last 12 months (dummy) | 84 (8) | 84 (0) | 88 (0) | 79 (0) | 89 (0) | 80 (0) | 84 (0) |
| School is located in a big village (dummy) | 27 | 26 | 24 | 29 | 22 | 34 | 20 |
| School is located in a rural area (dummy) | 43 | 44 | 43 | 53 | 35 | 54 | 32 |
| School is located in a small village | 13 | 13 | 13 | 22 | 6 | 16 | 11 |
| School is located in a suburban area (dummy) | 9 | 10 | 9 | 10 | 13 | 10 | 9 |
| School is located in a town | 42 | 42 | 53 | 40 | 58 | 8 | 56 |
| School is located in an urban area | 46 | 47 | 56 | 47 | 60 | 11 | 67 |
| School participates in a pilot project, exchange program etc. (dummy) | 21 (11) | 22 (9) | 20 (6) | 6 (5) | 6 (8) | 25 (6) | 59 (24) |
| School provides housing for a guard (dummy) | 15 | 16 | 12 | 10 | 11 | 22 | 30 |
| School provides housing for teachers (dummy) | 24 | 24 | 32 | 49 | 16 | 14 | 6 |
| School provides housing for the director (dummy) | 35 | 36 | 40 | 59 | 23 | 30 | 24 |
| School receives financial support from students' parents | 43 (5) | 44 (3) | 47 (2) | 35 (3) | 42 (3) | 54 (4) | 43 (1) |
| School rewards students with prizes (dummy) | 56 (8) | 55 (6) | 45 (3) | 34 (0) | 62 (9) | 69 (11) | 69 (3) |
| School's overall number of classes (2-101) | 8.80 (8) | 8.81 (6) | 6.31 (5) | 6.53 (4) | 9.57 (11) | 10.83 (5) | 11.16 (4) |
| School's overall number of students (14-2733) | 492.58 (9) | 489.56 (6) | 475.74 (4) | 275.93 (3) | 581.32 (12) | 452.30 (1) | 715.60 (14) |
| School's overall number of teachers (1-43) | 9.64 (10) | 9.56 (7) | 7.45 (1) | 6.68 (0) | 11.20 (6) | 11.27 (0) | 11.50 (35) |
| School's quality ranking within the country according to teacher, low to high (1-4) | 3.10 (17) | 3.10 (10) | 3.00 (12) | 2.93 (8) | 3.47 (10) | 2.94 (8) | 3.19 (14) |
| Share of female students in the class (0-100%) | 46.60 (11) | 46.50 (3) | 45.04 (2) | 41.43 (1) | 49.29 (3) | 52.11 (4) | 43.95 (7) |
| Share of female students in the school (0-1) | 0.47 (12) | 0.47 (9) | 0.45 (2) | 0.44 (2) | 0.49 (9) | 0.50 (3) | 0.44 (38) |
| Share of student's classmates who can use books at home (0-1) | 0.72 | 0.72 | 0.52 | 0.73 | 0.84 | 0.79 | 0.68 |
| Share of students' families speaking French according to the teacher (0-1) | 0.36 (10) | 0.36 (3) | 0.26 (4) | 0.48 (0) | 0.64 (3) | 0.21 (4) | 0.15 (3) |
| Student can use books at home (dummy) | 72 (2) | 72 (2) | 52 (0) | 73 (1) | 84 (4) | 80 (2) | 68 (3) |
| Student can use newspapers at home (dummy) | 34 (3) | 35 (3) | 24 (1) | 36 (2) | 36 (7) | 38 (3) | 39 (4) |
| Student gets help with studies at home (dummy) | 63 (3) | 64 (3) | 60 (1) | 62 (3) | 70 (4) | 51 (2) | 79 (2) |
| Student has breakfast never, sometimes or regularly (0-1) | 0.91 (7) | 0.91 (8) | 0.90 (4) | 0.90 (7) | 0.87 (15) | 0.92 (6) | 0.95 (5) |
| Student has breakfast, lunch and/or dinner (0-3) | 2.7 (0.18) | 2.7 (0.18) | 2.7 (0.07) | 2.7 (0.18) | 2.4 (0.36) | 2.6 (0.15) | 2.8 (0.11) |

Table B.1 cont.

| Variable and Range | Original Sample | All question-naires | Burkina Faso | Cote d'Ivoire | Cameroon | Madagascar | Senegal |
|---|---|---|---|---|---|---|---|
| Student has lunch never, sometimes or regularly (0-1) | 0.85 (5) | 0.86 (5) | 0.89 (2) | 0.90 (5) | 0.74 (10) | 0.84 (4) | 0.95 (3) |
| Student has dinner never, sometimes or regularly (0-1) | 0.89 (5) | 0.89 (6) | 0.94 (2) | 0.91 (6) | 0.83 (12) | 0.85 (5) | 0.94 (3) |
| Student helps with agricultural activities and/or animal husbandry (0-2) | 1.0 (0.05) | 1.0 (0.05) | 1.0 (0.04) | 0.9 (0.03) | 0.9 (0.07) | 1.1 (0.04) | 0.8 (0.06) |
| Student helps with agricultural work and animal husbandry (dummy) | 42 (3) | 41 (3) | 39 (2) | 29 (2) | 32 (4) | 63 (2) | 39 (3) |
| Student helps with cleaning at home (dummy) | 64 (1) | 63 (2) | 49 (1) | 57 (1) | 90 (2) | 73 (1) | 41 (2) |
| Student helps with commercial activities (dummy) | 31 (2) | 31 (2) | 19 (2) | 31 (2) | 43 (3) | 34 (2) | 24 (3) |
| Student helps with commercial activities, agricultural activities and/or animal husbandry (0-3) | 1.3 (0.07) | 1.3 (0.07) | 1.2 (0.06) | 1.2 (0.05) | 1.4 (0.1) | 1.4 (0.07) | 1.1 (0.09) |
| Student helps with cooking at home (dummy) | 47 (1) | 47 (1) | 30 (1) | 38 (1) | 58 (2) | 72 (1) | 30 (3) |
| Student helps with field work (dummy) | 56 (2) | 55 (2) | 61 (2) | 61 (1) | 62 (3) | 44 (2) | 42 (2) |
| Student helps with laundry (dummy) | 72 (2) | 70 (2) | 76 (2) | 83 (1) | 85 (2) | 61 (2) | 41 (2) |
| Student helps with shopping | 85 (2) | 84 (2) | 84 (2) | 88 (2) | 81 (3) | 79 (1) | 92 (3) |
| Student helps with work at home, number of activities (0-9) | 5.2 | 5.2 | 4.7 | 5.1 | 6.1 | 5.6 | 4.2 |
| Student helps with work at home, excluding shopping (0-8) | 4.4 | 4.3 | 3.8 | 4.2 | 5.3 | 4.8 | 3.3 |
| Student is a boy (dummy) | 52 (0) | 52 (0) | 53 (0) | 59 (0) | 48 (1) | 44 (0) | 56 (0) |
| Student is more than 11 years old (dummy) | 49 | 50 | 47 | 45 | 38 | 66 | 52 |
| Student is repeating the 5th grade (dummy) [e)] | 22 (10) | 22 (10) | 14 (5) | 24 (11) | 27 (17) | - [c)] | 20 (5) |
| Student looks after smaller siblings (dummy) | 63 (2) | 63 (2) | 54 (2) | 60 (1) | 70 (3) | 60 (2) | 70 (3) |
| Student received his French textbook from his parents (dummy) | 59 | 58 | 71 | 75 | 65 | 27 | 53 |
| Student received his French textbook from his school (dummy) | 11 | 11 | 5 | 4 | 1 | 38 | 7 |
| Student received his French textbook from other sources than his parents or the school (dummy) | 3 | 3 | 5 | 3 | 2 | 2 | 3 |
| Student received his Math textbook from his parents (dummy) | 40 | 40 | 16 | 72 | 60 | 20 | 29 |
| Student received his Math textbook from his school (dummy) | 6 | 7 | 1 | 4 | 1 | 21 | 7 |
| Student received his Math textbook from other sources than his parents or the school (dummy) | 2 | 3 | 3 | 3 | 2 | 3 | 2 |
| Student speaks French at home (dummy) | 30 (18) | 30 (16) | 34 (10) | 38 (27) | 51 (26) | 11 (11) | 16 (5) |
| Student studies at home (dummy) | 92 (2) | 92 (2) | 89 (1) | 94 (2) | 91 (4) | 91 (2) | 96 (2) |
| Student's age (7-20 years) | 11.5 (1) | 11.6 (1) | 11.5 (0) | 11.3 (0) | 11 (1) | 12.3 (3) | 11.6 (0) |
| Student's classmates average for socio-economic indicator 1 (0-3) | 0.63 | 0.65 | 0.37 | 0.58 | 1.01 | 0.42 | 0.91 |
| Student's classmates average for socio-economic indicator 2 (0-8) | 2.87 | 2.91 | 1.97 | 3 | 3.77 | 2.06 | 3.97 |
| Student's classmates average for socio-economic indicator 3 (0-1) | 0.36 | 0.37 | 0.27 | 0.36 | 0.46 | 0.26 | 0.51 |
| Student's classmates help with agricultural activities or animal husbandry (0-2) | 0.98 | 0.95 | 1 | 0.9 | 0.94 | 1.08 | 0.81 |
| Student's classmates help with commercial activities, agricultural activities and/or animal husbandry (0-3) | 1.29 | 1.26 | 1.2 | 1.21 | 1.37 | 1.42 | 1.06 |
| Student's classmates help with work at home, average number of activities (0-9) | 5.2 | 5.2 | 4.7 | 5.1 | 6.1 | 5.6 | 4.2 |
| Student's classmates help with work at home, excluding shopping (0-8) | 4.4 | 4.3 | 3.8 | 4.2 | 5.3 | 4.8 | 3.3 |
| Student's classmates speak French at home (0-1) | 0.3 | 0.3 | 0.34 | 0.38 | 0.51 | 0.1 | 0.16 |
| Student's classmates' families possess a radio and/or TV (0-2) | 1.24 | 1.25 | 1.01 | 1.26 | 1.39 | 1.15 | 1.47 |
| Student's classmates' fathers are literate (0-1) | 0.75 | 0.76 | 0.58 | 0.69 | 0.88 | 0.87 | 0.75 |
| Student's classmates' mothers and or fathers are literate (0-2) | 1.33 | 1.33 | 0.88 | 1.11 | 1.72 | 1.68 | 1.2 |
| Student's classmates' mothers are literate (0-1) | 0.58 | 0.57 | 0.29 | 0.42 | 0.84 | 0.82 | 0.45 |
| Student's family has a flush toilet | 25 (3) | 26 (3) | 12 (1) | 23 (2) | 32 (5) | 23 (3) | 43 (2) |
| Student's family has access to tab water (dummy) | 34 (2) | 35 (2) | 19 (1) | 38 (2) | 39 (4) | 23 (2) | 58 (2) |
| Student's family has electricity (dummy) | 41 (2) | 41 (2) | 28 (0) | 56 (3) | 67 (3) | 2 (2) | 58 (2) |

Table B.1 cont.

| Variable and Range | Original Sample | All question-naires | Burkina Faso | Cote d'Ivoire | Cameroon | Madagascar | Senegal |
|---|---|---|---|---|---|---|---|
| Student's family possesses a bed (dummy) | 87 (2) | 87 (2) | 78 (0) | 86 (2) | 94 (3) | 84 (2) | 94 (2) |
| Student's family possesses a bicycle (dummy) | 39 (2) | 39 (2) | 81 (0) | 35 (2) | 20 (3) | 33 (2) | 25 (2) |
| Student's family possesses a car (dummy) | 19 (2) | 19 (2) | 12 (1) | 16 (2) | 30 (3) | 15 (2) | 25 (2) |
| Student's family possesses a dish washer (dummy) | 64 (2) | 63 (2) | 53 (1) | 58 (1) | 86 (3) | 70 (2) | 42 (3) |
| Student's family possesses a gas cooker (dummy) | 32 (2) | 33 (2) | 23 (1) | 21 (2) | 52 (3) | 13 (2) | 62 (2) |
| Student's family possesses a motorcycle (dummy) | 25 (2) | 25 (2) | 60 (0) | 24 (3) | 13 (4) | 9 (3) | 18 (2) |
| Student's family possesses a plough (dummy) | 21 (3) | 22 (3) | 43 (1) | 4 (4) | 6 (5) | 29 (2) | 28 (2) |
| Student's family possesses a radio (dummy) | 82 (2) | 82 (2) | 78 (1) | 77 (2) | 83 (4) | 84 (1) | 89 (3) |
| Student's family possesses a radio and/or TV (0-2) | 1.24 (0.04) | 1.25 (0.04) | 1.01 (0.01) | 1.26 (0.04) | 1.39 (0.08) | 1.16 (0.03) | 1.47 (0.05) |
| Student's family possesses a radio, TV and/or a video player (0-3) | 1.41 (0.07) | 1.43 (0.07) | 1.1 (0.02) | 1.37 (0.07) | 1.69 (0.13) | 1.3 (0.06) | 1.71 (0.08) |
| Student's family possesses a refrigerator (dummy) | 27 (2) | 28 (2) | 16 (1) | 31 (2) | 42 (3) | 13 (3) | 41 (2) |
| Student's family possesses a video player (dummy) | 17 (3) | 18 (3) | 9 (1) | 12 (3) | 30 (5) | 15 (2) | 24 (3) |
| Student's family possesses an armchair (dummy) | 54 (2) | 55 (2) | 56 (1) | 48 (1) | 69 (3) | 41 (2) | 61 (1) |
| Student's family possesses TV (dummy) | 42 (2) | 43 (2) | 24 (1) | 49 (2) | 55 (4) | 31 (2) | 58 (2) |
| Student's father is literate (dummy) | 75 (3) | 76 (3) | 58 (1) | 69 (3) | 88 (6) | 88 (2) | 75 (2) |
| Student's mother and/or father are literate (0-2) | 1.33 (0.06) | 1.33 (0.06) | 0.88 (0.03) | 1.11 (0.07) | 1.72 (0.12) | 1.69 (0.04) | 1.2 (0.04) |
| Student's mother is literate (dummy) | 58 (3) | 57 (3) | 29 (1) | 42 (4) | 84 (6) | 82 (2) | 45 (2) |
| Student's number of languages spoken at home (0-7) | 1.02 (1.43) | 1.02 (1.36) | 1.17 (1.36) | 0.95 (2.33) | 0.9 (1.97) | 0.97 (1.07) | 1.15 (0.32) |
| Student's number of previous grade repetitions (0-4) | 0.70 (0.32) | 0.70 (0.32) | 0.43 (0.21) | 0.79 (0.35) | 0.85 (0.56) | 1.02 (0.28) | 0.30 (0.15) |
| Student's socio-economic background, indicator 1: family possession of high profile consumer goods, video player, car and/or refrigerator (0-3) | 0.64 (0.07) | 0.65 (0.07) | 0.37 (0.02) | 0.58 (0.07) | 1.01 (0.12) | 0.43 (0.07) | 0.91 (0.07) |
| Student's socio-economic background, indicator 2: family possession of various consumer goods (0-8) | 2.87 (0.19) | 2.92 (0.18) | 1.97 (0.06) | 3.00 (0.17) | 3.77 (0.32) | 2.07 (0.18) | 3.97 (0.17) |
| Student's socio-economic background, indicator 3: family possession of various consumer and investment goods, adjusted to urban/rural differences (0-1) | 0.36 (0.02) | 0.37 (0.02) | 0.27 (0.01) | 0.36 (0.02) | 0.46 (0.04) | 0.27 (0.02) | 0.51 (0.02) |
| Students' socio-economic background according to the teacher, low to high(1-4) | 2.19 (10) | 2.20 (3) | 2.03 (2) | 2.18 (2) | 2.25 (2) | 2.38 (4) | 2.11 (3) |
| Teacher absenteeism perceived as a major problem by principal (dummy) | 88 (6) | 89 (4) | 88 (7) | 96 (2) | 95 (5) | 95 (1) | 67 (6) |
| Teacher completed the baccalaureate (BAC) (dummy) | 19 (12) | 19 (4) | 8 (0) | 33 (0) | 10 (0) | 8 (0) | 42 (27) |
| Teacher gives private tuitions (dummy) | 12 (8) | 12 (0) | 14 (0) | 10 (0) | 17 (0) | 10 (0) | 10 (0) |
| Teacher has a teacher manual for French (dummy) | 82 (10) | 82 (3) | 80 (2) | 85 (2) | 72 (2) | 91 (4) | 81 (5) |
| Teacher has a teacher manual for Math (dummy) | 64 (12) | 64 (5) | 73 (3) | 79 (3) | 59 (2) | 48 (9) | 60 (7) |
| Teacher has no pedagogical diploma (dummy) | 10 (8) | 10 (0) | 14 (0) | 5 (0) | 22 (0) | 6 (0) | 0 (0) |
| Teacher has not received any pedagogical training (dummy) | 13 (8) | 13 (0) | 34 (0) | 5 (0) | 16 (0) | 5 (0) | 3 (0) |
| Teacher has received other pedagogical training | 5 | 5 | 9 | 4 | 7 | 5 | 1 |
| Teacher is male (dummy) | 72 (8) | 71 (0) | 71 (0) | 96 (0) | 74 (0) | 37 (0) | 80 (0) |
| Teacher is satisfied with his job (dummy) | 53 (8) | 53 (0) | 57 (0) | 45 (0) | 54 (0) | 65 (0) | 44 (0) |
| Teacher is union member (dummy) | 25 (8) | 24 (0) | 23 (0) | 44 (0) | 13 (0) | 3 (0) | 40 (0) |
| Teacher never – almost always speaks French at home (1-4) | 288 (10) | 288 (2) | 311 (2) | 341 (1) | 314 (2) | 220 (1) | 248 (6) |
| Teacher often speaks French at home (dummy) | 72 | 71 | 89 | 96 | 86 | 28 | 53 |
| Teacher participated in on-the-job training sessions (dummy) | 77 (8) | 76 (0) | 91 (0) | 44 (0) | 84 (0) | 81 (0) | 86 (0) |
| Teacher pursues other (non-school) activities (dummy) | 61 (8) | 61 (0) | 48 (0) | 62 (0) | 82 (0) | 73 (0) | 32 (0) |
| Teacher received pedagogical training of less than one month (dummy) | 17 | 17 | 46 | 7 | 17 | 15 | 0 |

Table B.1 cont.

| Variable and Range | Original Sample | All question-naires | Burkina Faso | Cote d'Ivoire | Cameroon | Madagascar | Senegal |
|---|---|---|---|---|---|---|---|
| Teacher received pedagogical training of 1-3 months (dummy) | 16 | 16 | 7 | 10 | 3 | 52 | 6 |
| Teacher received pedagogical training of 6 months (dummy) | 3 | 3 | 0 | 3 | 1 | 0 | 11 |
| Teacher received pedagogical training of 12 months (dummy) | 35 | 36 | 14 | 40 | 47 | 22 | 60 |
| Teacher received pedagogical training of more than 12 months (dummy) | 23 | 23 | 25 | 37 | 25 | 6 | 23 |
| Teacher speaks local language (dummy) | 64 (13) | 64 (5) | 69 (1) | 39 (3) | 57 (2) | 97 (1) | 54 (20) |
| Teacher works on a non-civil servant contract (dummy) | 9 (8) | 10 (0) | 0 (0) | 2 (0) | 29 (0) | 14 (0) | 0 (0) |
| Teacher would like to change the school (dummy) | 44 (13) | 43 (6) | 43 (7) | 54 (3) | 39 (7) | 22 (4) | 61 (7) |
| Teacher's age (21-60 years) | 37.8 (15) | 37.8 (7) | 33.4 (5) | 36.8 (4) | 37.8 (7) | 42.6 (11) | 38.1 (9) |
| Teacher's education index, from below primary completion to 3 years of higher education and above (0-6) | 3.15 (9) | 3.15 (1) | 2.85 (0) | 3.35 (2) | 3.05 (1) | 2.89 (0) | 3.71 (2) |
| Teacher's job experience (0-40 years) | 13.48 (22) | 13.50 (16) | 10.91 (4) | 13.57 (44) | 13.04 (20) | 16.03 (5) | 13.76 (1) |
| Teacher's participation in on-the-job training sessions during the last five years (0-7 sessions per year) | 0.66 | 0.66 | 0.59 | 0.33 | 0.71 | 0.76 | 0.97 |
| Teacher's share of correctly detected mistakes in a student's dictation (0-1) [e] | 0.82 (16) | 0.82 (7) | 0.81 (5) | 0.85 (3) | 0.83 (5) | - [d] | 0.79 (18) |
| Teachers' absence from class (0-25 days per month) | 2.24 (22) | 2.20 (15) | 2.04 (19) | 1.29 (7) | 1.82 (21) | 2.03 (3) | 4.25 (26) |

Note: The first column gives the variable name, with the numbers in brackets indicating the logical range of the variable (or the observed range if no logical range exists). Variables for which no range is provided are *binary* variables. For non-binary variables the *mean* is given. For binary variables the *mean multiplied by 100* is shown. The numbers in brackets give the *percent* of missing observations. If the variable is a summary measure of several items, such as meals which is coded as breakfast+lunch+dinner, the missing value indicator takes values in {0,1,2,3} and the number in brackets given is the *mean* of the missing value indicator.

[a] The mathematics and French pre-tests in Senegal are different from those of the other four countries.

[b] Classroom space per student is not available for Senegal.

[c] The information on whether the student is repeating the 5th grade is not available for Madagascar.

[d] The teacher's share of correctly detected mistakes in a student's dictation is not available for Madagascar.

[e] Information on this item is available in only 4 of the 5 countries and the percentage of missing values due to non-response refers only to these four contries.

# C Determinants of textbook availability

As mentioned in Section 3.2, the results presented in the paper have been validated by using two enlarged sets of control variables $X$ (set 1 and set 2). In analogy to Table 3.3, Table C.1 presents the regression estimates of the number of books $B_i$ and the number of books among classmates $C_i$ on these alternative sets of regressors. For each set of regressors, the left column represents the ordered probit regression for the discrete variable $B_i$. The right column shows the linear regression for the continuous variable $C_i$. The standard errors calculated for both regressions account for clustering and stratification.

The enlarged sets of regressors were obtained by starting with an even larger set of regressors (>200 variables, cf. Table B1 and additional missing indicators) and sequen-

tially eliminating insignificant variables. Set 1 contains variables that are generally significant at the 5% level in either of the two regressions. Set 2 also keeps variables that are significant only at the 10% level. Pre-test scores and test score missing indicators are kept in the set of regressors in spite of their low significance levels. Even though they may have only little impact on the book variables, they are very important determinants of the final test outcomes.

With a value of 0.55 the $R^2$ is with very high for both linear regressions, indicating that a substantial amount of the determinants of textbook availability is captured by these regressors. On the other hand, compared to the much smaller set of control variables in Table 3.3, the $R^2$ increased only slightly from 0.49 to 0.55.

In the regressions in Table C.1, the initial test scores enter separately for Senegal because a different pre-test was administered there. Since the nonparametric estimation of $m_{b,c}(x)$ in Section 4 proceeds separately for each country, interacted test scores as well as country dummies do not enter as control variables there. Set 1 therefore consists of 36 variables and set 2 of 49 variables, compared to the 19 regressors in the main specification (see Table 3.3).

Table C.1: Determinants of textbook availability-enlarged sets of regressors

| | Enlarged regressor set 1 | | | | Enlarged regressor set 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Dependent variable: | | | | Dependent variable: | | | |
| | Number of books | | Average number of books among classmates | | Number of books | | Average number o books among classmates | |
| | Est. | Std. | Est. | Std. | Est. | Std. | Est. | Std. |
| Dummy Cote d'Ivoire | **1.15** | 0.09 | **0.60** | 0.05 | **1.17** | 0.10 | **0.63** | 0.05 |
| Dummy Cameroon | **0.51** | 0.13 | **0.29** | 0.07 | **0.49** | 0.15 | **0.30** | 0.08 |
| Dummy Madagascar | **0.62** | 0.19 | **0.25** | 0.10 | **0.66** | 0.20 | **0.28** | 0.11 |
| Dummy Senegal | **-0.47** | 0.22 | **-0.30** | 0.13 | -0.34 | 0.22 | **-0.25** | 0.13 |
| Student's initial test score in French | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Student's initial test score in Math | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Student's classmates' initial test score in French | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Student's classmates' initial test score in Math | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 |
| Student's initial test score in French, missing value indicator | -0.03 | 0.34 | 0.09 | 0.08 | -0.02 | 0.33 | 0.09 | 0.08 |
| Student's initial test score in Math, missing value indicator | -0.15 | 0.25 | -0.06 | 0.05 | -0.15 | 0.27 | -0.06 | 0.04 |
| Student's initial test score in French, Senegal [a)] | 0.00 | 0.00 | **0.00** | 0.00 | 0.00 | 0.00 | **0.00** | 0.00 |
| Student's initial test score in Math, Senegal [a)] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Student's classmates' initial test score in French, Senegal (0-100 % correct answers) | *0.02* | 0.01 | **0.01** | 0.01 | *0.02* | 0.01 | **0.01** | 0.01 |
| Student's classmates' initial test score in Math, Senegal [a)] | -0.01 | 0.01 | 0.00 | 0.01 | -0.01 | 0.01 | 0.00 | 0.01 |
| Student's initial test score in French, Senegal, missing value indicator [a)] | **1.40** | 0.47 | **-0.19** | 0.10 | **1.30** | 0.47 | **-0.23** | 0.10 |
| Student's initial test score in Math, Senegal, missing value indicator [a)] | -0.01 | 0.35 | **0.17** | 0.07 | -0.02 | 0.36 | **0.17** | 0.07 |
| Student's age | **-0.06** | 0.01 | -0.01 | 0.00 | **-0.08** | 0.02 | 0.00 | 0.01 |
| Student is more than 11 years old | | | | | **0.09** | 0.04 | -0.01 | 0.01 |
| Student gets help with studies at home | **0.09** | 0.03 | 0.00 | 0.01 | **0.10** | 0.03 | 0.01 | 0.01 |
| Student's socio-economic background, index of family possession of various consumer and investment goods, adjusted to urban/rural differences (indicator 3) | **0.58** | 0.07 | **0.05** | 0.02 | **0.47** | 0.08 | 0.03 | 0.03 |
| Student's number of grade repetitions before grade 5, missing value indicator | **0.06** | 0.02 | **0.03** | 0.01 | **0.05** | 0.02 | **0.03** | 0.01 |
| Student studies at home, missing value indicator | | | | | -0.02 | 0.14 | -0.04 | 0.03 |
| Student gets help with studies at home, missing value indicator | | | | | *0.21* | 0.12 | **0.09** | 0.04 |
| Student's classmates average for socio-economic background (indicator 1: number of high profile consumer durables) | **0.44** | 0.07 | **0.31** | 0.04 | **0.43** | 0.08 | **0.31** | 0.04 |
| Student' classmates help with work at home, excluding shopping | **0.43** | 0.15 | **0.24** | 0.08 | **0.41** | 0.15 | **0.23** | 0.08 |
| Student's classmates help with agricultural activities or animal husbandry | -0.13 | 0.09 | *-0.08* | 0.05 | -0.13 | 0.09 | *-0.09* | 0.05 |
| Student's number of languages spoken at home | | | | | -0.04 | 0.03 | -0.01 | 0.01 |
| Student's number of languages spoken at home, missing value indicator | **-0.04** | 0.01 | **-0.02** | 0.01 | **-0.04** | 0.01 | **-0.02** | 0.01 |
| Student's father is literate | **-0.08** | 0.03 | -0.01 | 0.01 | **-0.08** | 0.03 | -0.01 | 0.01 |
| Student's mother is literate | 0.03 | 0.03 | **-0.02** | 0.01 | 0.03 | 0.03 | **-0.02** | 0.01 |
| Student can use books at home | **0.47** | 0.04 | 0.00 | 0.01 | **0.47** | 0.04 | -0.01 | 0.01 |
| Student can use books at home, missing value indicator | **0.62** | 0.14 | 0.05 | 0.04 | **0.57** | 0.14 | 0.03 | 0.03 |

Table C.1 cont.

| | Enlarged regressor set 1 | | | | Enlarged regressor set 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Dependent variable: | | | | Dependent variable: | | | |
| | Number of books | | Average number of books among classmates | | Number of books | | Average number o books among classmates | |
| | Est. | Std. | Est. | Std. | Est. | Std. | Est. | Std. |
| Student's classmates' mothers are literate | **-0.59** | 0.15 | **-0.27** | 0.08 | **-0.60** | 0.15 | **-0.27** | 0.08 |
| Student's classmates can use books at home | *-0.19* | 0.11 | **0.15** | 0.06 | *-0.19* | 0.11 | **0.15** | 0.06 |
| Teacher has a teacher manual for French | **0.17** | 0.06 | **0.09** | 0.03 | **0.17** | 0.06 | **0.09** | 0.03 |
| Share of students' families speaking French | | | | | 0.15 | 0.11 | 0.04 | 0.06 |
| Director speaks local language | **-0.12** | 0.05 | -0.04 | 0.03 | **-0.11** | 0.05 | -0.04 | 0.03 |
| Director's education index | **0.05** | 0.02 | **0.02** | 0.01 | **0.05** | 0.02 | **0.03** | 0.01 |
| School's overall number of classes | | | | | 0.00 | 0.01 | 0.00 | 0.00 |
| School's overall number of students | | | | | 0.00 | 0.00 | 0.00 | 0.00 |
| School's average class size | | | | | 0.00 | 0.00 | 0.00 | 0.00 |
| School equipment indicator | **-0.02** | 0.01 | *-0.01* | 0.01 | **-0.03** | 0.01 | *-0.01* | 0.01 |
| School has a canteen | **0.20** | 0.08 | **0.08** | 0.04 | **0.20** | 0.08 | **0.08** | 0.04 |
| Student has lunch (never – regularly) | **-0.14** | 0.06 | -0.03 | 0.03 | *-0.11* | 0.06 | -0.03 | 0.03 |
| Student has dinner (never – regularly), missing value indicator | | | | | **0.15** | 0.07 | 0.02 | 0.02 |
| Student looks after smaller siblings | 0.03 | 0.03 | **0.03** | 0.01 | 0.03 | 0.03 | **0.03** | 0.01 |
| Student's family possesses an armchair | 0.04 | 0.03 | *0.02* | 0.01 | 0.04 | 0.03 | *0.02* | 0.01 |
| Student's family possesses a refrigerator | | | | | **0.09** | 0.04 | 0.01 | 0.01 |
| Student's family possesses a bicycle | **0.13** | 0.03 | *0.02* | 0.01 | **0.13** | 0.03 | *0.02* | 0.01 |
| Student's family possesses a motorcycle | | | | | 0.05 | 0.04 | *0.02* | 0.01 |
| Student's family possesses a gas cooker | **0.12** | 0.03 | **0.02** | 0.01 | **0.11** | 0.03 | *0.02* | 0.01 |
| Student's family possesses a plough | **-0.10** | 0.04 | *-0.04* | 0.02 | **-0.09** | 0.04 | *-0.03* | 0.02 |
| Student's family possesses a refrigerator, missing value indicator | | | | | 0.14 | 0.10 | **0.06** | 0.03 |
| Student's family possesses TV, missing value indicator | **0.25** | 0.10 | **0.07** | 0.03 | 0.16 | 0.10 | 0.04 | 0.03 |
| School is located in a rural area | **0.13** | 0.06 | *0.06* | 0.03 | *0.13* | 0.07 | *0.07* | 0.04 |
| Student's classmates help with work at home | **-0.38** | 0.14 | **-0.22** | 0.07 | **-0.36** | 0.14 | **-0.22** | 0.07 |
| Student helps with work at home | **-0.02** | 0.01 | 0.00 | 0.00 | **-0.02** | 0.01 | 0.00 | 0.00 |
| Student is repeating the 5th grade | **0.13** | 0.04 | 0.01 | 0.01 | **0.13** | 0.04 | 0.01 | 0.01 |
| Teacher completed the baccalaureate | | | | | -0.10 | 0.06 | *-0.05* | 0.03 |
| Constant | | | **0.93** | 0.13 | | | **0.87** | 0.14 |

Note: *Italics* indicates significance at the 10% level. **Bold** indicates significance at the 5% level. **Bold underlined** indicates significance at the 1% level. For enlarged regressor set 1: Regression for dependent variable "Number of school books": survey ordered probit regression, interval cut-off points: -0.81 (0.26), 0.41 (0.26), F(46,471)=21.87. Regression for dependent variable "Books among classmates": survey linear regression, F(46,471)=22.40, $R^2$=0.5416. For enlarged regressor set 2: Regression for dependent variable "Number of school books": survey ordered probit regression, interval cut-off points: -0.98 (0.30), 0.23 (0.30), F(59,458)=17.44. Regression for dependent variable "Books among classmates": survey linear regression, F(59,458) =17.86, $R^2$=0.5461. 10489 observations.

[a] In Senegal a different pre-test was used at the beginning of the academic year.

# D Additional estimation results

The tables this annex present the simulation results for the alternative specifications. Tables D.1 to D.4 are identical in structure to Tables 4.1 to 4.4. They first provide the nonparametric estimation results when using the first enlarged set of regressors (set 1) with 36 variables (cf. Table C.1) instead of the main set of 19 regressors $X$ (cf. Table

3.3). They then provide the results when using the second enlarged set of regressors (set 2) with 49 variables (see again Table C.1). Finally, the results for the parametric specification with the 19 regressors $X$ (of Table 3.3) and square and interaction terms are presented.

Table D.1: Estimates of E[Yb,c-Y1,1], for different specifications

| | | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Own book | Peer book | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| *b* | *c* | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| Alternative specification: enlarged regressor set 1 | | | | | | | | | | | | | |
| 0 | 0 | -2.97 | | -4.75 | | -1.19 | | -2.77 | 0.65 | -5.39 | 1.13 | -0.16 | 0.04 |
| 0 | 1 | -0.38 | | -0.35 | | -0.42 | | -0.25 | 0.92 | -0.43 | 1.30 | -0.06 | 0.18 |
| 0 | 2 | 2.05 | | 3.82 | | 0.28 | | 2.28 | 0.72 | 4.50 | 1.30 | 0.06 | 0.02 |
| 1 | 0 | -2.75 | | -4.27 | | -1.23 | | -2.42 | 0.60 | -4.86 | 1.08 | 0.02 | 0.00 |
| 1 | 1 | 45.28 | | 44.42 | | 46.14 | | 43.66 | | 41.94 | | 45.38 | |
| 1 | 2 | 2.05 | | 3.35 | | 0.75 | | 2.24 | 0.69 | 4.47 | 1.25 | 0.00 | 0.00 |
| 2 | 0 | -1.82 | | -3.22 | | -0.43 | | -2.03 | 0.52 | -4.33 | 1.01 | 0.28 | 0.07 |
| 2 | 1 | 0.54 | | 0.66 | | 0.42 | | 0.30 | 1.11 | 0.47 | 1.44 | 0.12 | 0.37 |
| 2 | 2 | 2.11 | | 3.31 | | 0.92 | | 2.23 | 0.67 | 4.49 | 1.21 | -0.03 | 0.01 |
| Alternative specification: enlarged regressor set 2 | | | | | | | | | | | | | |
| 0 | 0 | -4.21 | | -5.99 | | -2.43 | | -2.85 | 0.84 | -5.94 | 1.52 | 0.24 | 0.06 |
| 0 | 1 | -0.51 | | -0.47 | | -0.55 | | -0.19 | 0.62 | -0.43 | 1.26 | 0.06 | 0.15 |
| 0 | 2 | 2.23 | | 3.80 | | 0.66 | | 2.57 | 0.76 | 4.51 | 1.07 | 0.63 | 0.16 |
| 1 | 0 | -3.37 | | -5.01 | | -1.73 | | -2.65 | 0.82 | -5.48 | 1.46 | 0.18 | 0.05 |
| 1 | 1 | 45.09 | | 44.08 | | 46.10 | | 43.44 | | 41.64 | | 45.24 | |
| 1 | 2 | 2.36 | | 3.67 | | 1.04 | | 2.74 | 0.77 | 4.90 | 1.13 | 0.58 | 0.14 |
| 2 | 0 | -2.53 | | -4.01 | | -1.05 | | -2.40 | 0.77 | -4.98 | 1.37 | 0.18 | 0.05 |
| 2 | 1 | 0.51 | | 0.54 | | 0.47 | | 0.23 | 0.77 | 0.47 | 1.37 | -0.01 | 0.03 |
| 2 | 2 | 2.55 | | 3.74 | | 1.36 | | 2.95 | 0.80 | 5.34 | 1.19 | 0.57 | 0.13 |
| Alternative specification: parametric estimation | | | | | | | | | | | | | |
| 0 | 0 | -13.1 | 1.30 | *-16.1* | 1.67 | -10.2 | 0.84 | -13.8 | 0.60 | -19.0 | 0.70 | -8.53 | 0.31 |
| 0 | 1 | -0.26 | 0.76 | -0.33 | 0.88 | -0.19 | 0.47 | -0.47 | 0.86 | -0.68 | 1.04 | -0.26 | 0.39 |
| 0 | 2 | 0.21 | 0.07 | 3.31 | 1.01 | -2.89 | 0.81 | 2.61 | 0.20 | 4.21 | 0.30 | 1.01 | 0.06 |
| 1 | 0 | -12.3 | 1.29 | -14.7 | 1.61 | -9.93 | 0.86 | -12.8 | 0.58 | -17.7 | 0.68 | -7.92 | 0.31 |
| 1 | 1 | 44.51 | | 43.14 | | 45.87 | | 42.23 | | 40.08 | | 44.38 | |
| 1 | 2 | -0.08 | 0.03 | 2.59 | 0.78 | -2.76 | 0.77 | 2.56 | 0.18 | 4.20 | 0.28 | 0.92 | 0.05 |
| 2 | 0 | -11.5 | 1.26 | -13.3 | 1.53 | -9.68 | 0.87 | -11.8 | 0.57 | -16.3 | 0.66 | -7.30 | 0.30 |
| 2 | 1 | 0.26 | 0.76 | 0.33 | 0.88 | 0.19 | 0.47 | 0.47 | 0.86 | 0.68 | 1.04 | 0.26 | 0.39 |
| 2 | 2 | -0.38 | 0.12 | 1.86 | 0.54 | -2.63 | 0.70 | 2.51 | 0.17 | 4.19 | 0.27 | 0.83 | 0.04 |

Note: No t-values for the enlarged regressor sets 1 and 2 for the full sample, due to excessive computational burden. 100 bootstrap replications for enlarged regressor sets 1 and 2 in rural sample. 2000 bootstrap replications for the parametric estimation. See note below Table 4.1.

Table D.2: Direct and indirect effects of an additioal textbook, for different specifications

| | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| Alternative Specification: enlarged regressor set 1 | | | | | | | | | | | | |
| Direct effect | **0.24** | 2.69 | **0.28** | 2.77 | *0.20* | 1.78 | 0.27 | 1.54 | **0.37** | 1.98 | 0.18 | 0.74 |
| Indirect effect | 0.74 | 1.35 | **1.36** | 2.39 | 0.12 | 0.19 | 1.55 | 0.83 | 3.31 | 1.62 | -0.21 | 0.11 |
| Total effect | *0.98* | 1.71 | **1.64** | 2.84 | 0.32 | 0.46 | 1.82 | 0.95 | *3.68* | 1.74 | -0.04 | 0.02 |
| Indirect as % of total | 76 | | 83 | | 38 | | 85 | | 90 | | | |
| Alternative Specification: enlarged regressor set 2 | | | | | | | | | | | | |
| Direct effect | **0.22** | 2.86 | **0.24** | 2.55 | **0.20** | 2.22 | 0.23 | 1.03 | *0.39* | 1.65 | 0.07 | 0.25 |
| Indirect effect | 0.90 | 1.51 | **1.48** | 2.39 | 0.32 | 0.48 | 1.88 | 0.69 | 3.42 | 1.13 | 0.34 | 0.11 |
| Total effect | *1.12* | 1.79 | **1.72** | 2.65 | 0.52 | 0.75 | 2.11 | 0.74 | 3.81 | 1.21 | 0.41 | 0.12 |
| Indirect as % of total | 80 | | 86 | | 62 | | 89 | | 90 | | 83 | |
| Alternative Specification: parametric estimation | | | | | | | | | | | | |
| Direct effect | **0.16** | 1.98 | *0.16* | 1.77 | 0.16 | 1.55 | 0.29 | 0.97 | 0.43 | 1.18 | 0.16 | 0.42 |
| Indirect effect | **1.74** | 2.06 | **2.28** | 2.58 | 1.20 | 1.25 | 3.85 | 0.65 | 5.19 | 0.74 | 2.52 | 0.34 |
| Total effect | **1.90** | 2.17 | **2.44** | 2.68 | 1.36 | 1.36 | 4.14 | 0.68 | 5.61 | 0.77 | 2.67 | 0.35 |
| Indirect as % of total | 92 | | 93 | | 88 | | 93 | | 92 | | 94 | |

Note: See note below Table 4.2.

Table D.3: Allocation within class, for different specifications

| | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| Alternative Specification: enlarged regressor set 1 | | | | | | | | | | | | |
| Each student has a book | 45.28 | | 44.42 | | 46.14 | | 43.66 | | 41.94 | | 45.38 | |
| Half without books and half with two books | 0.09 | 0.68 | 0.17 | 1.10 | 0.01 | 0.04 | **0.03** | 2.16 | *0.03* | 1.83 | **0.03** | 1.98 |
| Alternative Specification: enlarged regressor set 2 | | | | | | | | | | | | |
| Each student has a book | 45.09 | | 44.08 | | 46.10 | | 43.44 | | 41.64 | | 45.24 | |
| Half without books and half with two books | 0.00 | 0.09 | 0.05 | 0.66 | -0.04 | 0.63 | **0.02** | 2.61 | **0.02** | 2.12 | **0.02** | 2.61 |
| Alternative Specification: parametric estimation | | | | | | | | | | | | |
| Each student has a book | 44.51 | | 43.14 | | 45.87 | | 42.23 | | 40.08 | | 44.38 | |
| Half without books and half with two books | 0.01 | 0.60 | 0.02 | 1.22 | -0.00 | 0.14 | 0.01 | 0.33 | 0.01 | 0.35 | 0.01 | 0.22 |

Note: See note below Table 4.3.

Table D.4: Allocation between schools: Equal versus unequal distribution

| | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| Alternative Specification: enlarged regressor set 1 | | | | | | | | | | | | |
| 0.5 books per student | 43.78 | | 42.12 | | 45.45 | | 41.53 | | 38.22 | | 44.84 | |
| 0.3 versus 0.7 books | 0.00 | | -0.01 | | 0.01 | | 0.13 | 0.89 | 0.18 | 1.07 | 0.08 | 0.52 |
| 0.1 versus 0.9 books | 0.01 | | -0.04 | | 0.06 | | 0.50 | 0.89 | 0.69 | 1.10 | 0.31 | 0.51 |
| 1.0 books per student | 45.28 | | 44.42 | | 46.14 | | 43.66 | | 41.94 | | 45.38 | |
| 0.8 versus 1.2 books | -0.01 | | -0.01 | | -0.01 | | -0.03 | 0.24 | -0.05 | 0.33 | -0.02 | 0.13 |
| 0.6 versus 1.4 books | -0.07 | | -0.09 | | -0.04 | | -0.13 | 0.25 | -0.18 | 0.33 | -0.08 | 0.14 |
| 1.5 books per student | 46.56 | | 46.41 | | 46.70 | | 45.41 | | 45.13 | | 45.70 | |
| 1.3 versus 1.7 books | -0.04 | | -0.05 | | -0.02 | | -0.11 | 0.71 | -0.17 | 0.94 | -0.06 | 0.35 |
| 1.1 versus 1.9 books | -0.14 | | -0.22 | | -0.07 | | -0.43 | 0.69 | -0.63 | 0.91 | -0.22 | 0.35 |
| Alternative Specification: enlarged regressor set 2 | | | | | | | | | | | | |
| 0.5 books per student | 43.19 | | 41.36 | | 45.02 | | 41.99 | | 38.72 | | 45.26 | |
| 0.3 versus 0.7 books | -0.03 | | -0.05 | | -0.02 | | 0.00 | 0.07 | -0.01 | 0.14 | 0.02 | 0.26 |
| 0.1 versus 0.9 books | -0.13 | | -0.18 | | -0.08 | | 0.01 | 0.07 | -0.03 | 0.14 | 0.06 | 0.27 |
| 1.0 books per student | 45.09 | | 44.08 | | 46.10 | | 43.44 | | 41.64 | | 45.24 | |
| 0.8 versus 1.2 books | -0.03 | | -0.04 | | -0.03 | | 0.01 | 0.11 | -0.01 | 0.12 | 0.02 | 0.41 |
| 0.6 versus 1.4 books | -0.14 | | -0.18 | | -0.10 | | 0.02 | 0.08 | -0.04 | 0.16 | 0.08 | 0.41 |
| 1.5 books per student | 46.56 | | 46.23 | | 46.88 | | 44.93 | | 44.41 | | 45.44 | |
| 1.3 versus 1.7 books | -0.03 | | -0.05 | | -0.02 | | 0.00 | 0.05 | -0.02 | 0.36 | 0.01 | 0.21 |
| 1.1 versus 1.9 books | -0.12 | | -0.18 | | -0.07 | | -0.01 | 0.05 | -0.07 | 0.39 | 0.05 | 0.23 |
| Alternative Specification: parametric estimation | | | | | | | | | | | | |
| 0.5 books per student | 39.63 | | 36.89 | | 42.38 | | 36.75 | | 32.42 | | 41.08 | |
| 0.3 versus 0.7 books | -0.27 | 1.34 | -0.28 | 1.42 | -0.26 | 1.07 | -0.23 | 0.36 | -0.30 | 0.42 | -0.15 | 0.20 |
| 0.1 versus 0.9 books | -1.08 | 1.34 | -1.14 | 1.42 | -1.02 | 1.07 | -0.90 | 0.36 | -1.19 | 0.42 | -0.62 | 0.20 |
| 1.0 books per student | 44.51 | | 43.14 | | 45.87 | | 42.23 | | 40.08 | | 44.38 | |
| 0.8 versus 1.2 books | -0.27 | 1.34 | -0.28 | 1.42 | -0.26 | 1.07 | -0.23 | 0.36 | -0.30 | 0.42 | -0.15 | 0.20 |
| 0.6 versus 1.4 books | -1.08 | 1.34 | -1.14 | 1.42 | -1.02 | 1.07 | -0.90 | 0.36 | -1.19 | 0.42 | -0.62 | 0.20 |
| 1.5 books per student | 46.00 | | 45.85 | | 46.16 | | 44.89 | | 44.03 | | 45.76 | |
| 1.3 versus 1.7 books | -0.27 | 1.34 | -0.28 | 1.42 | -0.26 | 1.07 | -0.23 | 0.36 | -0.30 | 0.42 | -0.15 | 0.20 |
| 1.1 versus 1.9 books | -1.08 | 1.34 | -1.14 | 1.42 | -1.02 | 1.07 | -0.90 | 0.36 | -1.19 | 0.42 | -0.62 | 0.20 |

Note: No t-values for the enlarged regressor sets 1 and 2 for the full sample, due to excessive computational burden. 100 bootstrap replications for enlarged regressor sets 1 and 2 in rural sample. 2000 bootstrap replications for the parametric estimation. See note below Table 4.4.

# E Separate Effects of French books and Math books

Instead of using the *number* of textbooks as the treatment variable of interest, we also analyzed the impacts of French and Math textbook separately. The results are qualitatively similar, though less precise. They are presented in Tables E.1 and E.2.

When analyzing the effects of a French or a Math book alone, $B_i$ takes values in $\{0, 1\}$ and $C_i \in [0, 1]$. Apart from obvious modifications to the formulae given in Section 2, the simulations proceed exactly as before. To reduce computational burden, only

the parametric estimation corresponding to the third variant in Tables D.1 to D.4 is performed.[26]

The effects of French- and Math books are roughly similar, particularly for the marginal effects in the full population shown in Table E.2. These results are not directly comparable to the numbers in Tables 4.2 and D.2 since they refer to a different population, which is all students who do not have a French book (or a Math book) whereas previously, the relevant population included all students with less than 2 books. The estimation results are somewhat less similar for the rural sample, but most estimates are highly insignificant. Generally, the effects are larger on French proficiency than on Math proficiency, which is in line with all the previous results.

In Table E.1, the peer effects are always positive. Increasing $C$ from 0 to 1 increase achievement irrespective of the value of $B$ ( compare the first to the second row and the third to the fourth row). The effect of increasing $B$ from 0 to 1 is less consistent, though. For a French book, the effect is negative if $C$ is zero and it is positive if $C$ is one. For a Math book, this relationship is reversed. French books thus appear to have a positive direct impact only if many classmates have a book, whereas Math books seem only to be directly beneficial if few classmates have a book. Otherwise the direct effects of books can be negative. This, however, is in conflict with the overall positive peer effects and the positive marginal benefits found in Table E.2. Since Table E.1 shows the estimates of $E[Y^{b,c}]$ at the extremes of the support of $C$, the negative direct effects could be an artifact of the parametric regression plane used. In any case, most of these results are insignificant.

[26] $m_{b,c}(x)$ is estimated, separately for each country, by regressing the final test score on $B$, $C$, $BC$, $C^2$, all other regressors from Table 3.3 and all these regressors interacted with $C$.

Table E 1: Estimates of E[Yb,c-Y1,1], separate for French and Mathbook

| Own book | Peer book | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| *b* | *c* | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| | | | | | | Effects of French textbook | | | | | | | |
| 0 | 0 | -6.61 | 0.48 | -14.9 | 1.12 | 1.70 | 0.11 | -34.2 | 0.93 | -45.3 | 1.09 | -23.2 | 0.53 |
| 0 | 1 | -1.00 | 1.55 | -0.40 | 0.56 | **-1.60** | 2.05 | -0.14 | 0.08 | -0.89 | 0.45 | 0.60 | 0.26 |
| 1 | 0 | -8.63 | 0.68 | -15.8 | 1.28 | -1.47 | 0.10 | -32.6 | 0.96 | -43.5 | 1.13 | -21.7 | 0.54 |
| 1 | 1 | 46.11 | | 45.73 | | 46.49 | | 44.15 | | 43.91 | | 44.39 | |
| | | | | | | Effects of Math textbook | | | | | | | |
| 0 | 0 | -6.88 | 0.99 | -10.1 | 1.41 | -3.63 | 0.45 | -13.9 | 0.66 | -15.6 | 0.69 | -12.3 | 0.47 |
| 0 | 1 | **2.02** | 2.42 | **2.83** | 2.13 | 1.20 | 1.17 | 0.24 | 0.12 | 0.40 | 0.17 | 0.08 | 0.03 |
| 1 | 0 | -3.96 | 0.61 | -6.11 | 0.91 | -1.81 | 0.24 | -11.2 | 0.54 | -12.6 | 0.57 | -9.72 | 0.38 |
| 1 | 1 | 44.34 | | 45.39 | | 43.29 | | 51.39 | | 53.90 | | 48.88 | |

Note: See note below Table 4.1. Inference based on at least 2000 bootstrap replications.

Table E 2: Direct and indirect effects of an additional textbook, separate for French book and Mathbook

| | Full sample | | | | | | Rural sample | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average proficiency | | French proficiency | | Math proficiency | | Average proficiency | | French proficiency | | Math proficiency | |
| | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ | Est. | $t^*_{clust}$ |
| | | | | | Effects of French textbook | | | | | | | |
| Direct effect | 0.10 | 0.66 | 0.12 | 0.71 | 0.08 | 0.41 | 0.80 | 0.89 | 1.08 | 0.99 | 0.51 | 0.51 |
| Indirect effect | 3.14 | 1.52 | *4.08* | 1.93 | 2.20 | 0.93 | 16.8 | 0.70 | 18.4 | 0.64 | 15.2 | 0.48 |
| Total effect | 3.24 | 1.51 | *4.20* | 1.92 | 2.28 | 0.93 | 17.6 | 0.72 | 19.5 | 0.66 | 15.7 | 0.49 |
| Indirect as % of total | 96 | | 97 | | 96 | | 95 | | 94 | | 97 | |
| | | | | | Effects of Math textbook | | | | | | | |
| Direct effect | **0.40** | 3.06 | **0.44** | 2.78 | **0.36** | 2.25 | *0.94* | 1.85 | *0.94* | 1.75 | 0.94 | 1.41 |
| Indirect effect | **3.60** | 2.49 | **4.36** | 2.78 | *2.84* | 1.74 | 2.39 | 0.23 | 2.75 | 0.24 | 2.04 | 0.16 |
| Total effect | **4.00** | 2.66 | **4.80** | 2.94 | *3.20* | 1.88 | 3.33 | 0.30 | 3.68 | 0.31 | 2.98 | 0.22 |
| Indirect as % of total | 90 | | 91 | | 89 | | 72 | | 75 | | 68 | |

Note: See note below Table 4.2.

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