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Math skills and market and non-market outcomes: Evidence from an Amazonian society of forager-farmers

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Abstract

Research in industrial nations suggests that formal math skills are associated with improvements in market and non-market outcomes. But do these associations also hold in a highly autarkic setting with a limited formal labor market? We examined this question using observational annual panel data (2008 and 2009) from 1,121 adults in a native Amazonian society of forager-farmers in Bolivia (Tsimane'). Formal math skills were associated with an increase in wealth in durable market goods and in total wealth between data collection rounds, and with improved indicators of own reported perceived stress and child health. These associations did not vary significantly by people's Spanish skills or proximity to town. We conclude that the positive association between math skills and market and non-market outcomes extends beyond industrial nations to even highly autarkic settings.

Keywords

Economic development; educational economics; human capital

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1 Introduction

Economists have long highlighted the importance of individual skills in labor market outcomes, and there is abundant evidence of the increasing importance of cognitive skills in the labor market of industrial countries (Ishikawa & Ryan, 2002; Murnane, Willett, & Levy, 1995). However, much less is known about the importance of cognitive skills in developing nations (Glewwe, 2002). While there is some evidence that culturally appropriate math pedagogy improves math skills acquisition, increases in math skills in non-western settings have rarely been examined for their relation with personal and community outcomes (Nasir, Hand, & Taylor, 2008). Human capital theory suggests that cognitive skills increase labor productivity, and therefore income and wealth. If cognitive skills are associated with important outcomes in industrial and developing nations, investments to develop cognitive skills might be a policy priority.

In comparison to what we know about the importance of school attainment or cognitive skills like reading or writing, less is known about the importance of formal math skills, particularly in rural societies of developing nations. Estimates in industrial nations suggest that individuals with better math skills receive higher earnings (McIntosh & Vignoles, 2001; Murnane, et al., 1995). Here, we examine whether the relation of formal math skills with market and non-market outcomes found in industrial nations also hold in a rural setting with a limited formal labor market.

We address two questions: Are formal math skills associated with market (income and wealth) and non-market (nutrition and health) outcomes in a highly autarkic rural society? Are these associations larger as people gain a stronger foothold in the market economy? We address these questions using annual panel data collected in 2008 and 2009 from 1,121 adults in a native Amazonian society of forager-farmers in Bolivia, the Tsimane'. We measured formal math skill by scores on tests that required people to use computational skills. We find that math skills are positively associated with the value of durable market goods and total wealth. Math skills are also associated with better indicators of own and child reported health among the Tsimane'. Our results suggest there is no differential association for math skills in relation to fluency in Spanish (Bolivia's national language) or to village proximity to towns or roads.

Our findings have several strengths. First, because there is very limited or no formal job market for Tsimane' workers, we could rule out the association of math skills and economic outcomes from solely having a diploma as opposed to having skills. Second, common confounders such as ethnic or cultural heterogeneity, school type, or residential segregation, are absent among the small-scale, relatively homogenous, and egalitarian Tsimane' society. Third, we used a relatively large sample of adults compared with the sample sizes used in previous related studies in developing nations. Fourth, we used instrumental variables to reduce measurement error.

2 Background and expectations

2.1 Math skills in developing countries

Taken together, previous research in developing countries points to a positive association between math skills and market and non-market outcomes, but the evidence draws for the most part on small cross-sectional samples of formally employed urban workers, and focuses mainly on market outcomes. For example, Glewwe (1996) studied 389 workers in Ghana (1988–1989) and found that an increase of one point in math skills improved wages in the public sector by 2.3–2.8%, but not in the private-sector. Also in Ghana, Jolliffe (1998) found that an increase of one standard deviation in mean and maximum household math score resulted in 8.6% and 4.9% higher household off-farm income, but had no effect on farm income (n=1,388). Vijverberg (1999) found no effects of math skills on self-employment in Ghana. Using data from urban and rural workers in South Africa (n=133; collected 1993), Moll (1998) found that each extra point in math test scores resulted in 21–30% higher wages; the wage elasticity of math skills was 0.4. Aslam, Bari, and Kingdon (2012) analyzed the returns to math skills in urban and rural Pakistan (n=4,907; collected 2006–2007). They found (weak) evidence that, among men, math skills increased the probability of having a lucrative occupation, and reduced the likelihood of female unemployment (only after reaching a threshold of 4.8 and 5.6 out of 12 points in a math test). Using data from Pakistan (1998–1999 and 2000–2001), Kingdon and Söderbom (2008) found that math skills were associated with an increase in a male worker's probability of being self-employed (~2.8% increase for young men and ~6.7% for older men), a decrease in the chances of being out of the labor force (~2.8% decrease for young men and ~4.5% for older men), and higher agricultural earnings. Last, Boissiere, Knight, and Sabot (1985) examined data from primary and high-school graduates in Kenya (n=205) and Tanzania (n=179), and found significant returns to literacy and math (~1.3%–1.7%, and 0.8%–1.2% increase in pre-tax earnings in Kenya and Tanzania).

Godoy et al. (2005) estimated earning functions in a comparative study of four foraging-horticultural societies in the Bolivian lowlands (Tsimane', Yuracaré, Mojeño, and Chiquitano). Formal math skills bore no association with wages, imputed farm income, or total personal income (imputed + monetary), but did bear a significant positive association with monetary income among the sub-sample of participants (n=244) who reported monetary earnings. A one-point improvement in math score (range: 0–4) was associated with a 13.5% increase in monetary earnings (p=0.03). The study found no significant interaction effects between math skills and town propinquity, with the exception of higher imputed farm income.

Last, research in developing countries suggests a positive association between math skills and health outcomes (Grigorenko, Jarvin, Kaani, Kapungulya, Kwiatkowski, & Sternberg, 2007). Other studies have shown an association between mother's math skills and child health, possibly because math skills facilitates mothers ability to acquire health knowledge on their own (Glewwe, 1999; Glewwe & Desai, 1999).

2.2 Math skills among the Tsimane'

The Tsimane' live in the tropical rain forest of the department of Beni, Bolivia. Recent estimates suggest that they number about 12,000 people living in approximately 100 villages of at least eight households (typically around 20 households), with about 6 people per household. Subsistence centers on farming and foraging. Contact with the outside is limited to the sporadic sale of local goods and to occasional work as rural laborers in cattle ranches or logging camps. Tsimane' society is relatively egalitarian, and displays much sharing and reciprocity. Mean daily monetary income per capita (wages + sales) reaches only about US $0.96 (2008–2009).

Most Tsimane' villages have schools covering the first five grades and, since 2005, a few larger villages have built middle schools. School attendance is in practice voluntary, and classes have traditionally been taught in Tsimane'; Spanish is taught as a second language. Tsimane' (and other native Amazonians in Bolivia) might be gaining math and other cognitive skills owing to the recent implementation of government programs, including adult schooling (*Yo sí puedo; Centros de Educación Técnico-Humanística Agropecuaria*), which may allow them to take advantage of increasing market opportunities, and conditional cash transfer schemes (*Juancito Pinto*, school children; *Juana Azurduy*, prenatal care; *Bono*

Dignidad, old-age retirement), which may expose them to more frequent cash transactions and formal banking.

As is true in other native Amazonian societies, there is limited cultural significance for numbers among the Tsimane'. For all large numbers, Tsimane' borrow words from Spanish. For instance, the number one hundred (*yiri' cien*) combines the Tsimane' *yiri'* or *yiris* (one) and the Spanish *cien* (100). Native Tsimane' bilingual teachers interviewed for this article stated that most Tsimane' still do not use numbers often and instead prefer to speak in generalities such as few *(dam)* or many *(dai)*. This includes the domain of age for which exact numbers are rarely known for adults and older generations. An elderly person's age is therefore commonly reported simply as *dai momo* or many.

2.3 Hypotheses and rationale

Conditioning for relevant covariates, we expected formal math skills to be positively associated with market and non-market outcomes, possibly because math skills are related to a more efficient use of traditional inputs, or more bargaining power in economic transactions. Math skills and own and child health are also likely related through several paths, including increases in income and farm output and the ability to estimate proportions when preparing or medicines. Like other rural populations, Tsimane' draw on different sources of medicinal knowledge, and we expected people with more market exposure to be more open to modern health treatments. In sum, we hypothesize:

> H_1: Formal math skills are positively associated with monetary income, wealth, and total consumption.
>
> H_2: Formal math skills are associated with better adult and child nutritional status and perceived morbidity.

We expect the relation of both market and non-market outcomes and math skills to increase as people gain a stronger foothold in the market.

3 Materials and methods

3.1 Survey data

We used a unique data set from a randomized control trial (RCT) that assessed the effects of in-kind rice transfers on individual health. The RCT included 40 villages (471 households, 1,121 people), and was informed by a panel study (2002–2010) among the Tsimane' (Leonard & Godoy, 2008). In Treatment 1 (T_1), all households from 13 villages received the same amount of edible rice (a proxy for income). In Treatment 2 (T_2), the total allocation of edible rice per village was divided equally among the poorest 20% of households of the village (n=13), and each household in the remaining top 80% of the village income distribution received 5.9 kg of improved rice seed. The 14 villages of the control group received 5.9 kg of improved rice seed. The treatments did not affect scores in formal math tests (Saidi, Behrman, Undurraga, & Godoy, 2012), so we use the data as an observational panel, with a baseline (February–March 2008) and a follow-up survey (February–March 2009). We collected demographic, anthropometric, and self-reported health information from all people in a household, but limited data collection on most other variables to adults. We selected 16 years of age as the cut off for adults because Tsimane' typically set up independent households by that age.

3.2 Definition and description of variables

3.2.1 Market outcomes, nutrition, and health—Table 1 contains definitions and summary statistics of the variables used in the analysis.

For market outcomes, we defined six variables. We estimated the current total monetary value of selected physical assets owned by the participant at the time of the survey. We included four measures of physical assets: (i) goods made from *local* materials, (ii) goods acquired in the *market*, (iii) the current monetary stock value of domesticated *animals*, and (iv) an aggregate measure of wealth (*local+market+animal*). We also included two measures of income: *(v)* total monetary *income* earned from the sale of forest and farm goods and from paid wage labor, and *(vi)* total *consumption* of several goods (purchased and non-purchased) and services in the seven days before the survey. We used inflation-adjusted real values, and the exchange rate observed during fieldwork in the town of San Borja (the main town in the area) during 2008.

For non-market outcomes, we used four variables: (i) current body-mass index (*BMI*=body weight/standing height^2 [kg/m^2]), (ii)) a measure of *perceived stress* based on self-reported negative emotions, (iii) *child morbidity*, based on reported illnesses and symptoms, and (iv) a measure of child nutrition based on weight-for-height-Z-score (*WHZ*). BMI is a standard anthropometric indicator for short-run nutritional status (Shetty & James, 1994), although it is only a surrogate of body fatness and has some limitations (see for example Burkhauser & Cawley, 2008). We followed the protocol by Lohman, Roche, and Martorell (1988) to collect anthropometric data. *Perceived stress* captures the self-reported total number of episodes of eight negative emotions (e.g., worry "*dyijy*", anger "*facoijdye*", not having enough time "*jam junbu'yi*") experienced by the participant in the seven days prior to the interview (range:0–8). The questions were adapted from the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983). *Childmorbidity* captures the number of illnesses and symptoms of illnesses a child had in the seven days before the interview, as reported by the child's principal caretaker. Because of matrilocal post-marriage residence, households sometimes include not only a couple and their children, but also their parents. We examined the relation between the *math* skills of the household head that attained the greatest *math* score and the morbidity and nutritional status of children in that household. Last, *WHZ* captures the difference between the measured value of the Tsimane' child's WHZ and the median value of the reference population of the same sex and age (WHO, 2006), with low values of WHZ reflecting acute energy deficiency. To reduce recall bias when measuring *income, consumption, perceived stress*, and *child morbidity* we limited the recall periods to the seven days before the interview.

3.2.2 Explanatory variables: Human capital and control variables—Interviewers presented participants with four computational tasks, which required participants to add, subtract, multiply, and divide, sequenced in that order. We developed three questions of about equal difficulty for each of the four math skills (twelve in total), and randomly selected one question per math skill for each participant (four in total, one point per each), without replacement. Where households had four or more adults (~13%), we carried out the math tests separately. The interviewer presented the participant with a card and read it aloud. If the participant answered correctly, the interviewer would show the participant a second card. If the participant did not answer correctly, the test stopped. We used this design to minimize the burden on the participants, but the procedure may have underestimated math scores for some respondents, as a person making a random mistake in a question would have the test stopped.

We also collected data on two aspects of modern human capital: ability to speak *Spanish* and *schooling*. Control variables included *distance* from the village of residence to the town of San Borja or to the nearest road during dry season, number of people in the household (*size)*, number of children <5 years in a household (*children*), participant's *age*, sex (*male*=1, female=0), survey *year*, and two indicator variables for the two treatments of the trial (T_1, T_2).

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3.3 Analysis

Our model specification is shown in the following equation (1):

$$Y_{\mathrm{ihvt}}=\alpha+\beta M_{\mathrm{ihvt}}+\gamma X_{\mathrm{ihvt}}+\varepsilon_{\mathrm{ihvt}} \quad (1)$$

where the subscripts stand for individual (i), household (h), village (v), and year (t). The outcome variable, Y_{ihvt}, includes market and non-market outcomes. M_{ihvt} is the variable of interest, *math* score, X_{ihvt} is the vector of control variables, and ε_{ihvt} is a standard disturbance term. As additional analysis, we added an interaction term to equation (1) between math skills and four explanatory variables –*sex*, *schooling*, *Spanish* skills, and *distance* to nearest town. We used OLS regressions with robust standard errors for *local* and *market* wealth, total *consumption*, *BMI*, *perceived stress* and *WHZ*. We used Tobit regressions for *animal* wealth, *income*, and *child morbidity* because observations were censored at zero (Table 1). All regressions included standard errors clustered at the village level. Because the math tests are likely to have measured math skills with random measurement error and math skills among adults are not likely to change significantly over one year, we instrumented the math score in 2009 with the math score in 2008.

4 Results

4.1 Descriptive analyses

The Tsimane' have limited competence in formal math skills. For instance, during the baseline survey (2008) 63% (n=682) of all Tsimane' ≥16 years of age (n=1,076) could not perform any of the four arithmetic operations (Figure 1; women: 77%, men: 49%; p<0.001). The share of people who had some math competence was lower than the share of participants who could solve the four tasks (14%). The share of men who got a perfect math score (24%) was higher than the share of men who could only add, add and subtract, or add, subtract, and multiply (~8–11%).

We compared *math* skills by ability to speak *Spanish* and *schooling* (Figure 2). We found a positive correlation between *schooling* and formal *math* skills (r =0.65, p<0.001), significant for monolingual Tsimane' (r =0.49, p<0.001), and for Tsimane' who could speak *Spanish* (r =0.59, p<0.001). We also found a significant correlation between *schooling* and *Spanish* (r =0.48, p<0.001). Tsimane' who could speak *Spanish* had, on average, 1.7 more grades of schooling than monolingual Tsimane (p<0.001).

The share of adults who could not perform any of the four arithmetic operations over the two years was about twice as high among monolingual speakers of Tsimane' (95%) than among participants who knew some Spanish (53%; p<0.001). Participants who knew some *Spanish* scored, on average, 1.2 more points in the math score (range: 0–4) than monolingual speakers of Tsimane' (p<0.001).

Math skills tend to be relatively persistent (Figure 3). About two-thirds of the adult sample did not change their math scores (2008–2009). We found a significant difference in the change in *math* scores between participants with no *schooling* and those with some *schooling* (p<0.001). Ninety-one percent of participants with no *schooling* and 45% of participants with at least one year of *schooling* did not change their *math* scores. About the same share of people saw their *math* scores improve (17%) as decrease (18%). We basically assume that these differences are due to random measurement errors in the math tests capturing true math skills. But we acknowledge that there are other possibilities. Only 14 out the 63 people who did worse in the math test in 2009 were attending school, possibly suggesting that lack of exposure to formal schooling might have contributed to the erosion of math skills. Or there may have been systematic measurement error from panel conditioning (i.e., learning that answering correctly a math question meant being asked more questions).

Last, we divided villages into near (n=28) and far (n=12) based on the walking *distance* during the dry season (hours) to the nearest town or road. We coded villages with >5 hours walk as far, since a five-hour walk implies that the person has to stay overnight or at least travel during the evening. Farther away villages had a higher share of people with no formal math skills (69%) than villages nearer to market towns (61%) and a smaller share of people who could satisfactorily compute all four operations (11%) than people in villages closer to market towns (16%; p<0.05).

In sum, baseline data suggests that the distribution of *math* skills is bi-modal, with the largest share having no skills, followed by participants who answered all questions correctly. The comparatively higher share of participants who received a perfect math score raises the question of whether positive associations with math skills arise only when people attain proficiency in all four basic math operations. The descriptive evidence also suggests correlations between (i) math skills and (ii) sex and spoken *Spanish*, with men and Tsimane'-Spanish bilingual speakers having higher math scores than women or than monolingual speakers of Tsimane'.

4.2 Multivariate regressions

4.2.1 Market and non-market outcomes—The results in Table 2 show that, on average, a one-point improvement in *math* skills was associated with an average increase of $24.00 (p<0.001) in the value of wealth held in *market* wealth, and $33.41 increase in *total* wealth (p=0.004). Spanish skills did not mediate the relation between *math* skills and market outcomes. If the ability to speak Spanish was positively associated with formal *math* skills and market outcomes (Godoy, Reyes-Garcia, Seyfried, Huanca, Leonard, McDade, et al., 2007), conditioning for *Spanish* fluency would have attenuated the coefficients for *math*, which was not the case (regressions without conditioning for *Spanish* not shown).

An increase in *math* skills was associated with an increase in *BMI*, and with an improvement in *perceived stress* (Table 2). A one-point improvement in *math* score was associated with a 1% increase in *BMI* (p=0.007), assuming that each point-improvement in *math* skills increased *BMI* by a constant percent, and was associated with a decrease of 0.36 reported episodes of negative emotions in the seven days prior to the survey (p=0.009). Again we found no mediating role for *Spanish.*

4.2.2 Threshold effects—To assess threshold effects we created four dummy variables (one each for ability to *add*, *subtract*, *multiply*, and *divide*; Table 3), with no formal math skills as the excluded category. The results suggest that advanced math skills drive the association between *math* skills and market outcomes. Knowing all four basic arithmetic operations (score of 4) was associated with a $96.98 increase in wealth from *market* assets (p=0.001), and a $144.26 increase in *total wealth* (p=0.004), compared with a person without math skills. Having a score of 3 (sum, subtraction, and multiplication) was also associated with a $73.18 increase in *animal* wealth (p=0.09). Having advanced *math* skills was associated with a 4% increase in *BMI* (p=0.001), and 1.18 (p=0.03) less reported negative emotions, compared to participants with no math skills. Last, the math skills of the household head were associated with a decrease in reported illness and symptoms of children of 0.37 episodes (p=0.04) if the household head knew addition and subtraction, and a decrease of 0.31 episodes (p=0.09) if the household head had advanced *math* skills, compared to participants with no math skills.

4.2.3 Interaction with Spanish and distance—We tested whether the associations between *math* skills and outcomes depended on the magnitude of *Spanish* skills and *distance* to nearest town or road, by adding an interaction term to the regressions in Table 2 (regressions not shown). We only found a significant interaction between math skills and Spanish for child morbidity (β=−0.46, se=0.60; p<0.001), which suggests that the association between household head's math score and child morbidity was even more negative for household heads who were fluent in Spanish (regressions not shown).

4.2.4 Instrumental variables—We used the panel data to reduce biases from measurement error in math skills, by instrumenting math scores in 2009 ($math_2$) with math scores in 2008 ($math_1$). A regression of $math_2$ against our instrument $math_1$ and other covariates suggests $math_1$ is relevant (β=0.25, se=0.07, p=0.002; R^2=0.54). The IV regressions (Table 4) suggested that on average a one-point improvement in math skills was associated with $103.86 higher *market* wealth (p=0.001), a $118.45 higher *total* wealth (p=0.003, and 2.41 less reported episodes of negative emotions (p=0.03). These results confirm the association between *market* wealth, *total* wealth, and perceived stress (negative emotions) with math skills in our sample. If we did not instrument to control for measurement error, and consider only 2009 data, we found that a one-point improvement in math scores was associated with an increase of $28.26 (p=0.002) in *market* wealth, $32.34 (p=0.06) in *animal* wealth, and $41.29 (p=0.009) in total wealth. Also, on average an additional point in math score in 2009 was associated with a 1% (p=0.06) increase in BMI, and 0.28 (p=0.08) less episodes of negative emotions in the previous 7 days. These results suggest that using the panel data with IV to control for measurement error has important effects, as the IV estimation shows significantly larger associations.

4.3 Test of attrition bias

Two hundred ninety people ≥ 16 years of age (21% of the baseline sample) left by the time of the follow-up survey. To test for attrition bias we re-estimated all the regressions of Table 2 with all study participants but using only the baseline year (2008), and added an indicator variable for attriters (*attriter*=1 present at baseline but absent at follow up; *attriter*=0 surveyed twice) and interaction terms between *attriter* and all explanatory variables (not shown). The results suggest that attrition was random, with two exceptions. We found a statistically significant interaction between *attriters* and *math* score for *market* wealth (β= −21.9, se=11.52; p=0.07) and for *total* wealth (β=−45.8, se=19.6; p=0.03), which suggests that the association between *math* score and *market* and *total* wealth was possibly higher than the estimates presented so far.

5 Discussion and conclusions

Our findings make several contributions to the comparative study of relations between *math* skills and market and non-market outcomes. We found only partial confirmation for our first hypothesis that math skills are positively associated with market outcomes, as we only found significant results for *market* and *total* wealth (Table 4). Considering mean daily income per capita (2008–2009), a one-point increase in math scores was associated with an increase in *total* wealth equivalent to about 25 days of income. People who increased their *math* skills by one standard deviation (1.5 points) saw their *total* wealth increase by approximately 17% above the mean wealth in the sample. Having advanced *math* skills was associated with an increase in *total* wealth equivalent to about 150 days of income. These results are possibly conservative, considering the higher estimates when using instrumental variables. We found no confirmation for an earlier study among four different native Amazonian groups in which the authors found that math skills were associated with 13.5% higher monetary earnings (Godoy, Karlan, et al., 2005). The difference in results may be explained because the previous study included four diverse Amazonian groups (Mojeño, Chiquitano, Yuracaré, and Tsimane'), with only about 10% of the sample being Tsimane'.

The results also partially support our second hypothesis that math skills are associated with better nutritional status and perceived health. An increase in *math* skills was associated with a marginal increase in own *BMI*, and a decrease in the number of reported episodes of negative emotions. We only found results for child health when analyzing threshold effects. Our findings suggest three plausible pathways for why math skills might be associated with improved nutritional status and perceived child health. If Tsimane' *math* skills are associated with more wealth, math skills may indirectly contribute to better nutritional status by, for example, allowing households to smooth consumption in the face of income shocks. The association between wealth and nutritional status is consistent with previous findings among the Tsimane' (Godoy, Reyes-Garcia, Vadez, Leonard, & Huanca, 2005). Another path might be related to the relation between math skills and modern medicine. Household heads' *math* skills were significantly associated with a lower probability of reporting child illnesses and symptoms of illnesses. Tsimane' draw on different sources of medicinal knowledge. If Tsimane' who have *math* skills are also more open to the outside world and have more access to outside knowledge, including modern health treatments, we would expect them to be healthier. Third, health might have affected the participants' math skills if, for instance, a participant's negative emotions affected that person's test scores. This is less likely in the case of child health, but might still be the case as the child's health is reported by her or his principal caretaker.

Last, we found no confirmation that *math* skills have larger associations with outcomes for people with a stronger foothold in the market economy. The interactions between *math* and *Spanish* skills, and between *math* and *distance* to the nearest village or road, were never significantly different from zero, except for Spanish and math skills in the child morbidity, which is plausible if knowing Spanish and having math skills is an indicator of being more acculturated. The private ownership of skills might not be as important in taking advantage of market opportunities, as opportunities get diluted in the group because of prevailing sharing and reciprocity norms.

In sum, when we examine the associations between math skills and market and non-market outcomes in a highly autarkic setting with a limited labor market and without confounders that plague estimates in industrial nations, we found that math skills bore a positive association with market, and total wealth, and a negative association with reported negative emotions and child reported morbidity. These findings are in broad accord with the results of studies from industrial nations.

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References

Aslam M, Bari F, Kingdon G. Returns to schooling, ability and cognitive skills in Pakistan. Education Economics. 2012; 20(2):139–173.

Boissiere M, Knight JB, Sabot RH. Earnings, Schooling, Ability, and Cognitive Skills. American Economic Review. 1985; 75(5):1016–1030.

Burkhauser RV, Cawley J. Beyond BMI: The value of more accurate measures of fatness and obesity in social science research. Journal of Health Economics. 2008; 27(2):519–529. [PubMed: 18166236]

Cohen S, Kamarck T, Mermelstein R. A Global Measure of Perceived Stress. Journal of Health and Social Behavior. 1983; 24(4):385–396. [PubMed: 6668417]

Glewwe P. The relevance of standard estimates of rates of return to schooling for education policy: A critical assessment. Journal of Development Economics. 1996; 51(2):267–290.

Glewwe P. Why does mother's schooling raise child health in developing countries? Evidence from Morocco. Journal of Human Resources. 1999; 34(1):124–159.

Glewwe P. Schools and skills in developing countries: Education policies and socioeconomic outcomes. Journal of Economic Literature. 2002; 40(2):436–482.

Glewwe, P.; Desai, J. Child Health and Mothers' Education in Ghana. In: Glewwe, P., editor. The Economics of School Quality Investments in Developing Countries. London: Macmillan Press; 1999. p. 295-326.

Godoy RA, Karlan D, Rabindran S, Huanca T. Do modern forms of human capital matter in primitive economies? Comparative evidence from Bolivia. Economics of Education Review. 2005; 24(1):45–53.

Godoy RA, Reyes-Garcia V, Seyfried C, Huanca T, Leonard WR, McDade T, Tanner S, Vadez V. Language skills and earnings: Evidence from a pre-industrial economy in the Bolivian Amazon. Economics of Education Review. 2007; 26(3):349–360.

Godoy RA, Reyes-Garcia V, Vadez V, Leonard WR, Huanca T. Human Capital, Wealth, and Nutrition in the Bolivian Amazon. Economics and Human Biology. 2005; 3(1):139–162. [PubMed: 15722266]

Grigorenko EL, Jarvin L, Kaani B, Kapungulya PP, Kwiatkowski J, Sternberg RJ. Risk factors and resilience in the developing world: One of many lessons to learn. Development and Psychopathology. 2007; 19(3):747–765. [PubMed: 17705901]

Ishikawa M, Ryan D. Schooling, basic skills and economic outcomes. Economics of Education Review. 2002; 21(3):231–243.

Jolliffe D. Skills, schooling, and household income in Ghana. World Bank Economic Review. 1998; 12(1):81–104.

Kingdon, GG.; Söderbom, M. Education Working Paper Series. Vol. 11. Washington, DC: The World Bank; 2008. Education, Skills, and Labor Market Outcomes: Evidence from Pakistan.

Leonard WR, Godoy RA. Tsimane' Amazonian Panel Study (TAPS): The First 5 Years (2002–2006) of Socioeconomic, Demographic, and Anthropometric Data Available to the Public. Economics & Human Biology. 2008; 6(2):299–301. [PubMed: 18479985]

Lohman, TG.; Roche, AF.; Martorell, R. Anthropometric Standardization Reference Manual. Vol. 10. Champaign, Illinois: Human Kinetics Publishers; 1988.

McIntosh S, Vignoles A. Measuring and assessing the impact of basic skills on labour market outcomes. Oxford Economic Papers-New Series. 2001; 53(3):453–481.

Moll PG. Primary schooling, cognitive skills and wages in South Africa. Economica. 1998; 65(258): 263–284.

Murnane RJ, Willett JB, Levy F. The Growing Importance of Cognitive Skills in Wage Determination. Review of Economics and Statistics. 1995; 77(2):251–266.

Nasir NS, Hand V, Taylor EV. Culture and mathematics in school: Boundaries between "Cultural" and "Domain" knowledge in the mathematics classroom and beyond. Review of Research in Education. 2008; 32:187–240.

Saidi, F.; Behrman, JR.; Undurraga, EA.; Godoy, RA. Inequality, Relative Income, and Development: Field-Experimental Evidence from the Bolivian Amazon. New York: New York University; 2012.

Shetty, PS.; James, WPT. FAO Food and Nutrition Paper. Rome: Food and Agriculture Organization; 1994. Body Mass Index: A Measure of Chronic Energy Deficiency in Adults.

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Vijverberg, WPM. The impact of schooling and cognitive skills on income from non-farm self-employment. In: Glewwe, P., editor. The economics of school quality investments in developing countries: An empirical study of Ghana. London: Macmillan; 1999. p. 206-252.

WHO. Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development. Geneva, Switzerland: Multicentre Growth Reference Study Group, World Health Organization; 2006. WHO Child Growth Standards.

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Highlights

- Are math skills important in a rural setting with limited markets?
- We use panel data from adults in a native Amazonian society of forager-farmers
- Math skills were associated with higher durable market goods and total wealth
- Math skills were associated with reported own mental health and child health
- Our findings are in broad accord with studies from industrial nations

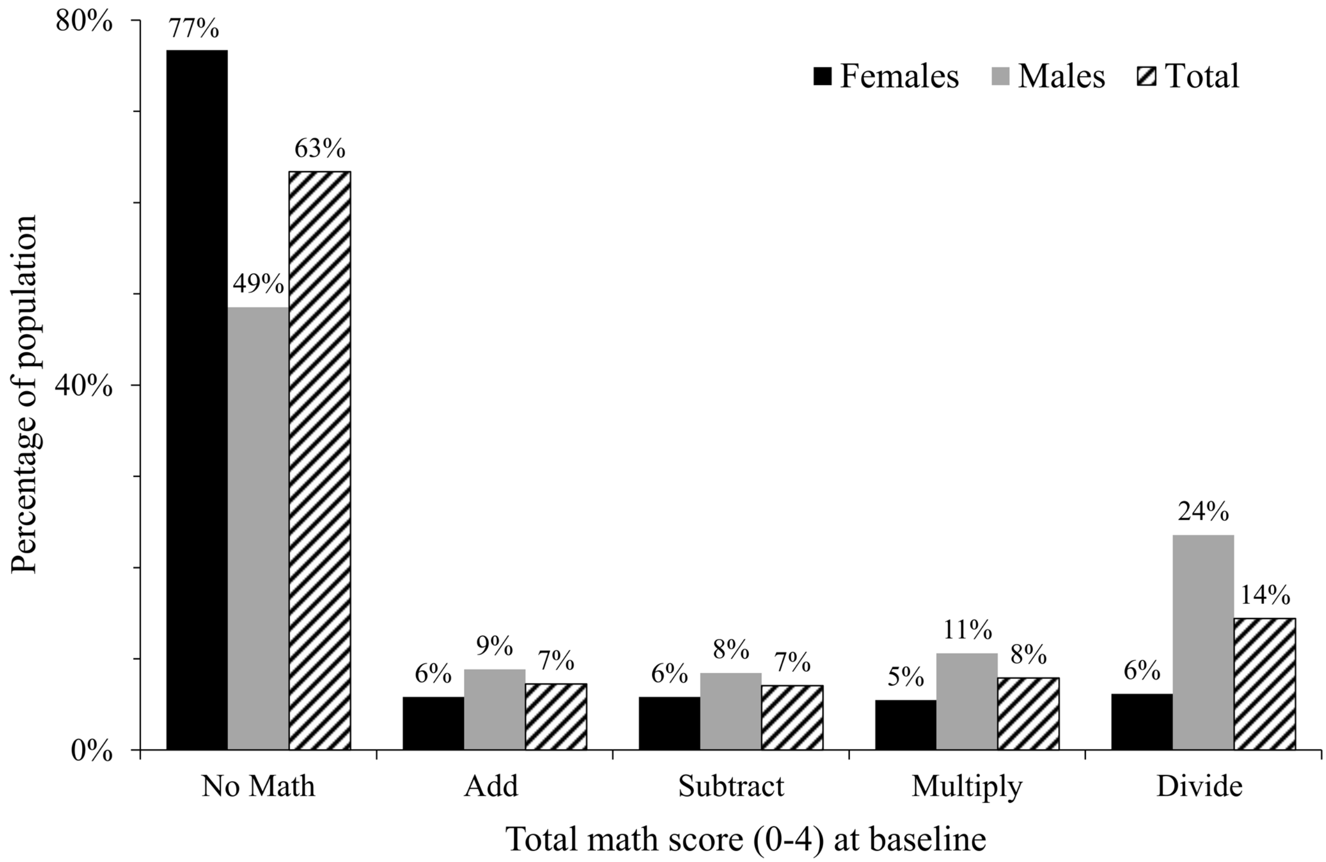

Figure 1.
Formal math skills among Tsimane' adults (≥16 years old) at baseline (2008), by sex

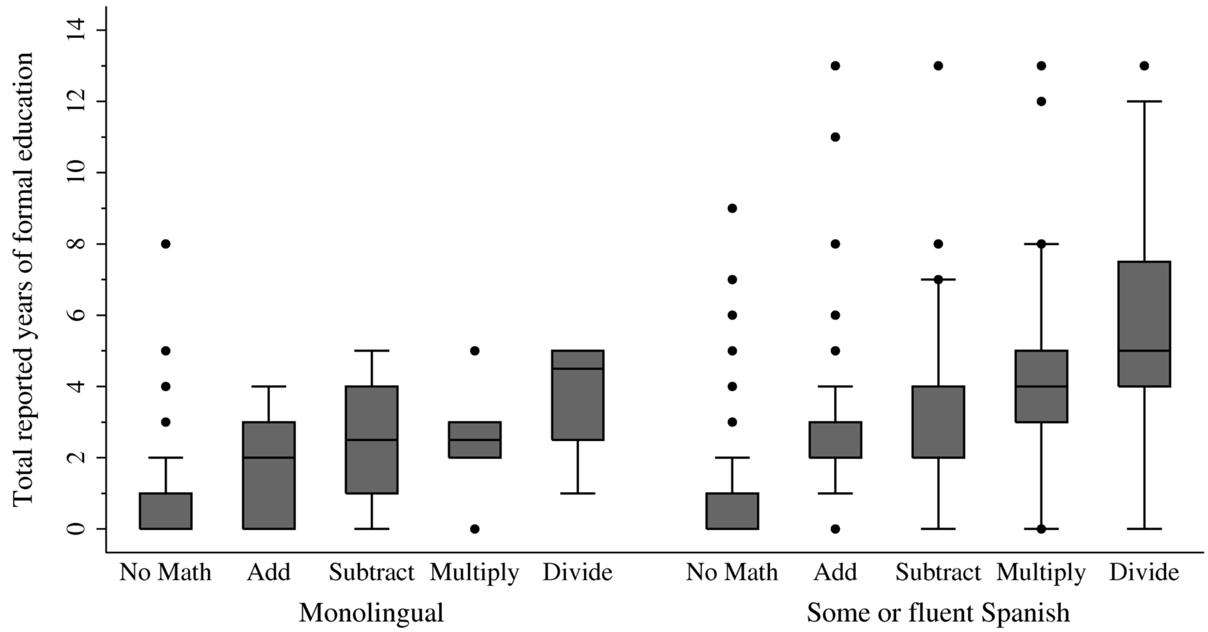

Figure 2.
Formal math skills among Tsimane' adults (≥16 years old) by schooling and fluency in Spanish (2008–2009)

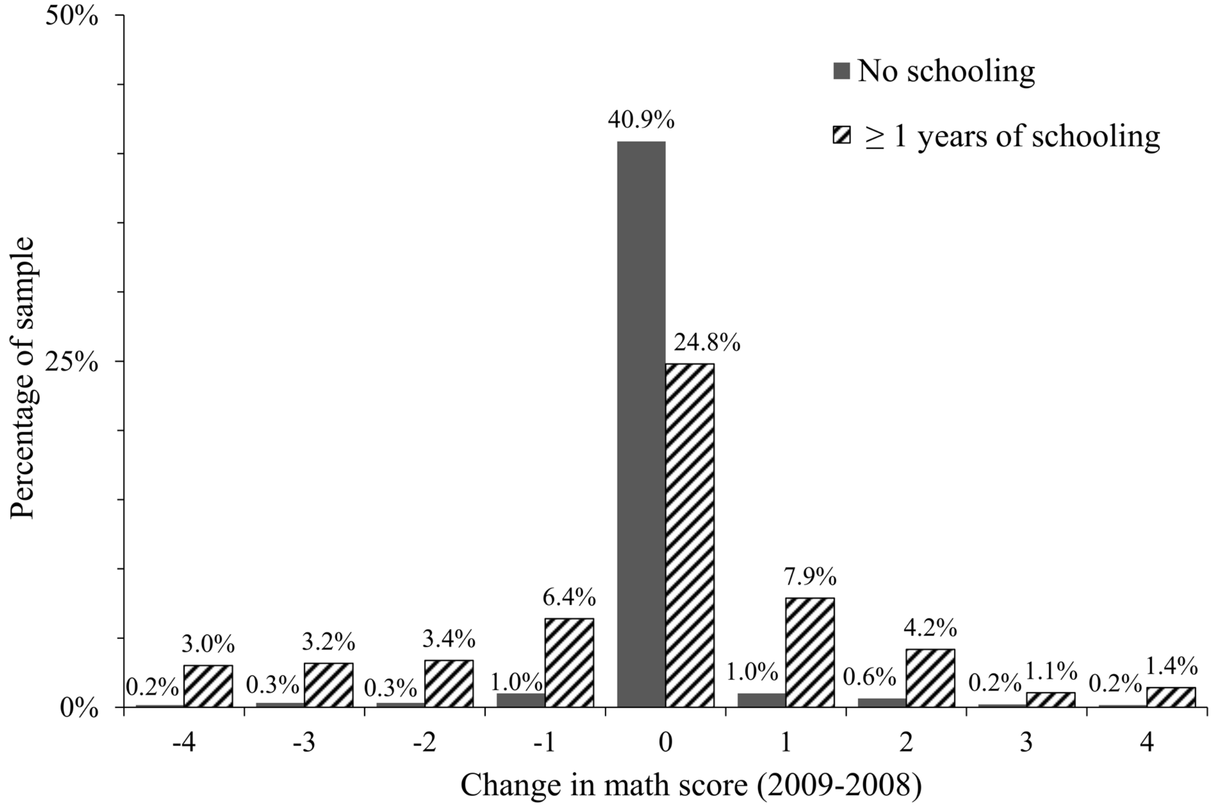

Figure 3.
Change in scores of math test among Tsimane' adults (≥16 years old) between 2008 and 2009, by level of schooling

Table 1

Definition and summary statistics of variables for Tsimane' ≥16 years of age (2008–2009)

Variable	Definition	2008			2009			2008 & 2009	
		Obs.	Mean	St.dev.	Obs.	Mean	St.dev.	%0[a]	Corr.[b]
[I] Dependent variables:									
[A] Market outcomes [US$2008]									
Local	Assets made by Tsimane' from local materials and owned by participant: dugout canoes, mortars, hand-woven bags, grinding stones, and bows/arrows.	1,096	53	82	1,123	48	65	9%	0.53
Market	Commercial assets acquired in market and owned by participant: bicycles, shotguns, rifles, cooking pots, fishing nets, metal fishing hooks, machetes, axes, mosquito nets, radios, watches, grinding mills, metal knives.	1,096	155	194	1,123	211	242	2%	0.59
Animals	Domesticated edible animals owned by subject: Ducks, pigs, chickens, and cattle.	1,096	38	174	1,123	76	521	43%	0.65
Total wealth	Sum of total wealth (local+market+animals)	1,096	246	318	1,123	335	607	1%	0.62
Income	Sum of two different sources of income (i) sale of forest and farm goods and (ii) wages, during the seven days before the survey	1,091	19.2	55.4	1,123	15.1	54.3	59%	0.18
Consumption	Total consumption during the seven days prior to survey. Includes market food (e.g., wheat products, oil), durable assets (e.g., kitchen utensils), health (e.g., medicine), game (various mammals, fish, and wild birds), farm products (e.g., manioc), and other goods (e.g. transport fares)	1,091	16.6	30.6	1,122	13.2	21.0	0%	0.16
[B]. Non-market outcomes									
BMI	Current body-mass index (body weight/standing height^2) [kg/m^2]. Lactating and pregnant women excluded.	1,031	23.7	2.8	1,099	23.5	2.7	0%	0.73
Perceived stress	Total number of episodes of the following negative emotions during the seven days before the survey: nervousness, anger, worry, sadness, inability to sleep, shame, frazzled at not having enough time to do all the subsistence and household chores needed, and envy.	1,078	7.0	6.9	1,119	7.9	6.4	11%	0.37
Child morbidity	Number of illnesses and symptoms of illnesses in the last 7 days (reported by principal caretaker)	1,586	0.6	0.7	1,405	0.4	0.7	57%	0.20
WHZ	Difference between weight-for-height value of Tsimane' child and median value of reference population for the same sex and age, divided by the standard deviation of the reference population	1,200	0.42	1.1	939	0.25	0.9	0%	0.36
[II]. Explanatory variables:									
[D]. Human capital									
Math	Total score in math assessment. Participants had to sequentially add, subtract, multiply, and divide. Correct answers received one point. The test was stopped if participants did not answer correctly [0–4].	1,076	1.0	1.5	992	1.0	1.5	63%	0.62
Spanish	Fluency in Spanish: participants were asked a simple question in Spanish. 0=no Spanish, did not answer question (either in Tsimane' or Spanish), 1= some knowledge or fluent Spanish	1,077	79%	41%	995	73%	44%	24%	0.34
Schooling	Years of formal education	1,065	2.1	2.7	1,115	2.0	2.7	43%	0.82
[E].Controls									

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Variable	Definition	2008			2009			2008 & 2009	
		Obs.	Mean	St.dev.	Obs.	Mean	St.dev.	%0[a]	Corr.[b]
Distance	Walking distance [hrs.] from village to nearest town or road during dry season (1day=12hrs)	40	5.7	6.8	40	5.7	6.8		
Size	Number of people in the household	1,118	6.8	3.1	1,123	6.7	3.0		
Children	Number of children <5 years old in the household	1,118	1.7	1.1	1,123	1.4	1.1		
Age	Self-reported age (years)	1,118	35.5	15.6	1,123	36.0	15.6		
Male	Participant's sex (men=1, women=0)	1,118	48%		1,123	48%			
T1	In-kind rice income transfers to all households (13 villages)	13	30%		13	30%			
T2	In-kind rice income transfers to households in bottom 20% of village income distribution (14 villages)	14	35%		14	35%			

Notes:

[a] % 0 denotes the share of observations=0.

[b] Corr.= intra-participant Pearson correlation coefficient between baseline and follow-up measure (i.e. the correlation over time).

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Table 2

Regression of market and non-market outcomes against formal math skills and other covariates among adult Tsimane' (≥16 years; 2008–2009)

Variables	Local	Market	Animals[a]	Total wealth	Income[a]	Consumption	BMI	Perceived stress	Child morbidity[a]	Child WHZ
Math	1.84 (1.77)	24.00*** (5.50)	22.65 (14.31)	33.41*** (10.94)	1.09 (3.38)	0.80 (0.51)	0.01*** (0.003)	−0.36*** (0.13)	−0.06 (0.04)	0.02 (0.02)
Spanish	10.55 (3.45)	67.70*** (13.85)	−25.76 (22.48)	73.85*** (18.42)	31.18*** (9.54)	5.25*** (1.16)	0.01 (0.01)	0.12 (0.41)	−0.02 (0.15)	(0.10) (0.06)
Schooling	−0.20 (0.86)	−1.60 (3.06)	0.09 (6.59)	2.84 (5.09)	0.07 (1.08)	−0.03 (0.28)	−0.002 (0.002)	−0.03 (0.10)	0.008 (0.02)	−0.02 (0.01)
Distance	2.14*** (0.73)	7.31*** (2.35)	−7.15** (3.61)	6.01* (3.21)	−3.93*** (1.33)	−0.20* (0.16)	−0.002 (0.001)	−0.02 (0.09)	0.01 (0.01)	−0.01 (0.01)
Observations	2,026	2,026	2,026	2,026	2,026	2,025	1,964	2,014	3,005	2,111
R^2	0.14	0.16	0.002	0.09	0.02	0.08	0.02	0.07	0.02	0.02

Notes: Standard errors in parentheses.

*** p<0.01,

** p<0.05,

* p<0.1 All regressions included standard errors clustered at the village level and the following controls (not shown): household size, number of children (<5 years old) in the household, age, sex, survey year, and treatments 1 and 2. OLS regressions include robust standard errors. BMI was transformed to natural logarithms. WHZ denotes child weight-for-height-Z-score.

[a] Tobit regression, censored at zero.

Table 3

Threshold effects of math skills for adult Tsimane' (≥16 years old; 2008–2009)

Variables	Local	Market	Animals	Total wealth	Income	Consumption	BMI	Perceived stress	Child morbidity	Child WHZ
Addition	7.04 (9.42)	37.90* (21.75)	6.11 (40.40)	61.45* (34.24)	−2.02 (12.37)	2.85 (2.26)	0.01 (0.01)	0.73 (0.68)	−0.08 (0.26)	−0.12 (0.10)
Subtraction	14.40 (10.56)	35.64* (20.37)	13.05 (31.86)	32.40 (35.91)	12.07 (10.41)	3.10 (2.73)	0.01 (0.02)	−0.41 (0.53)	−0.37** (0.18)	−0.002 (0.09)
Multiplication	13.07 (8.78)	80.23*** (15.27)	73.18* (43.37)	104.50*** (33.76)	6.24 (8.52)	2.47 (2.02)	0.02* (0.01)	−1.13* (0.56)	−0.004 (0.14)	−0.03 (0.10)
Division	2.70 (5.91)	96.98*** (25.95)	95.51 (61.66)	144.26*** (46.89)	0.19 (16.87)	3.09 (2.74)	0.04*** (0.01)	−1.18** (0.51)	−0.31* (0.18)	0.08 (0.10)
Spanish	8.74** (3.44)	66.75*** (13.61)	−22.65 (22.11)	72.67*** (17.63)	31.12*** (9.54)	4.97** (1.25)	0.01 (0.01)	0.02 (0.42)	−0.005 (0.15)	0.14** (0.06)
Schooling	−0.03 (0.78)	−1.82 (3.17)	−0.13 (6.31)	1.98 (5.15)	0.25 (1.24)	0.04 (0.32)	−0.002 (0.002)	−0.05 (0.10)	0.01 (0.02)	−0.02 (0.01)
Distance	2.14*** (0.72)	7.28*** (2.37)	−7.13** (3.59)	5.96* (3.24)	−3.90*** (1.32)	0.20 (0.16)	−0.002 (0.001)	−0.01 (0.09)	0.01 (0.01)	−0.01 (0.01)
Observations	2,033	2,033	2,033	2,033	2,033	2,031	1,970	2,021	3,005	2,111
R^2	0.10	0.16	0.002	0.09	0.01	0.04	0.02	0.07	0.02	0.02

Notes: Same notes as in Table 2. We added dummies for math scores (e.g. addition=1 if math score was 1, addition=0 otherwise). The excluded category includes participants who scored 0 in the math test.

Table 4

Results of market and non-market outcomes against math skills and other covariates among Timane' ≥16 years of age, 2009, using math scores in 2008 as instrumental variable

Variables	Local	Market	Animals	Total wealth	Income	Consumption	BMI	Perceived stress	Child morbidity	Child WHZ
Math	3.90 (5.31)	103.86*** (31.68)	−5.71 (49.77)	118.45*** (39.63)	−11.73 (15.95)	16.12 (15.88)	0.01 (0.01)	−2.41** (1.08)	−0.23 (0.23)	−0.20 (0.16)
Spanish	3.66 (6.66)	−11.42 (35.87)	−12.73 (51.87)	−26.88 (49.36)	21.40* 12.06	14.38 (12.32)	0.01 (0.01)	1.26 (1.16)	0.08 (0.25)	0.36** (0.14)
Schooling	−1.17 (1.69)	−25.22*** (9.56)	8.04 (15.86)	23.60* (12.95)	4.05 4.77	−2.49 (4.74)	−0.003 (0.004)	0.63 (0.42)	0.09 (0.09)	0.05 (0.06)
Distance	1.69** (0.68)	0.78 (2.67)	−19.39** (8.57)	−5.57* (3.23)	−4.40 (2.64)	−4.40* (2.62)	−0.001 (0.001)	−0.05 (0.11)	0.004 (0.02)	−0.02*** (0.01)
Observations	953	953	953	953	953	952	936	949	1,392	923

Notes: Same notes as in Table 2. All regressions include the score of math in the first period as an instrument and standard errors clustered at the village level. OLS-IV regressions included robust standard errors.