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The determinants and impact of private tutoring classes in Vietnam

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Abstract

Private tutoring is a widespread phenomenon in many developing countries, including Vietnam. Using the Vietnam Living Standards Surveys 1997–1998 and 1992–1993 for analysis, this paper finds evidence that private tutoring in Vietnam is a necessity in the household budget for both primary students and lower secondary students, and the trend to attend private tutoring is stronger at higher education levels. There is no evidence of gender discrimination in expenditure on private tutoring. Ethnic minority students spend less on private tutoring at the primary level but not at the lower secondary level, as do students living in rural areas. However, spending on private tutoring would fall significantly if the qualifications of primary school teachers are increased. Private tutoring is found to have significant impact on a student's academic performance, but the influence is larger for lower secondary students. This paper contributes to the available estimation techniques by extending the simultaneous Tobit model of Amemiya [(1974). Multivariate regression and simultaneous equation models when the dependent variables are truncated normal. *Econometrica*, *42*(6), 999–1012] to a joint Tobit-ordered probit econometric model to address the possible endogeneity of household spending on private tutoring.

JEL classifications: I21; I22; C30

Keywords: Private tutoring; Demand for schooling; Academic performance; Joint Tobit-ordered probit model

1. Introduction

Together with recent economic growth, Vietnam's educational sector has been steadily expanding, with gross enrolment rates more than doubling from 32% to 73% at the secondary level, and increasing fivefold from 2% to 10% at the tertiary level from 1991 to 1994 (World Bank, 2006). However, one recent and growing phenomenon of the Vietnamese education system is a "shadow" education system that exists alongside the official education system. In this system, students attend extra classes ("*di hoc them*") to acquire knowledge that they do not appear to obtain during their hours in school. These extra classes or private tutoring sessions have become widespread in both urban and rural areas in Vietnam. To attend these classes, students must pay tuition fees.

Private tutoring is not an issue unique to developing countries such as Vietnam. Indeed, it is widespread and can be found in countries as diverse economically and geographically as Canada, Cambodia, Egypt, Greece, Japan, Kenya, Singapore,

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Taiwan, Morocco, Romania, the United Kingdom, the United States, and Zimbabwe. In South Korea, Kim and Lee (2004) find that parents spent an amount approximately equal to 2.9% of the nation's GDP on private tutoring for primary and secondary students. A survey of the extent of private tutoring in selected countries can be found in Dang (2006).

There are several possible reasons for the growing existence of private tutoring. First, private tutoring can be considered some form of private supplementary education: it thrives in countries where the public education system fails to satisfy the needs of the students—as is the case not just in most developing countries (Glewwe & Kremer, 2006), but also in South Korea (Kim & Lee, 2004) or Canada (Davies, 2004). In this role, private tutoring is also popular in countries where passing examinations becomes the gateway to further education and advancement in society (Bray, 1999; Dore, 1976). Second, private tutoring can result from corruption in the education system in some developing countries, where teachers require their students to go to their extra classes to supplement their income because they are poorly paid and monitored (Biswal, 1999; Buchmann, 1999). Last but not least, cultural factors can play an important role in the development of private tutoring. Most of the high school graduates in Vietnam prefer to continue their education at college rather than do something else (Dang & Le, 1999); consequently, they are fully prepared to attend private tutoring classes to get admitted to college.

Despite the widespread nature of private tutoring, to date there is little quantitative research into the causes of the popularity of private tutoring, and its impact on a student's academic performance using nationally representative survey data. This paper is the first study that uses a nationally representative household survey to investigate the determinants of expenditure on private tutoring, and the effects of expenditure on private tutoring on a child's academic performance in Vietnam. Methodologically, this paper contributes to the available estimation techniques by developing a joint Tobit-ordered probit econometric model from the simultaneous Tobit equations of Amemiya (1974) to test for the possible endogeneity of spending on private tutoring. The paper's main findings are that private tutoring is a necessity in the household budget for primary and lower secondary students in Vietnam, and the trend to attend private tutoring is stronger at higher education levels. Private tutoring is found to significantly increase a student's schooling performance.

This paper begins by briefly reviewing the literature on the determinants and impact of private tutoring in Section 2. Section 3 describes the data and the private tutoring situation in Vietnam. Section 4 describes the econometric framework for analysis. Empirical results are then discussed in Section 5 and Section 6 concludes.

2. Background on the demand and impact of private tutoring

There have been few quantitative studies on the determinants and impact of private tutoring, and even fewer studies seem to employ adequately rigorous econometric models to evaluate the impact of private tutoring on a student's academic performance. To further complicate matters, most of the data employed so far are not nationally representative data. Lack of official statistics or researchers' attention may be two reasons for this situation. A third reason is that private tutoring can be a sensitive issue; some governments may be reluctant to make public the data for fear of political pressure. Full-time teachers and parents may also want to keep private tutoring a secret, for various reasons. Gordon and Gordon (1990) document that in the United Kingdom the reasons for limited information about private tutoring can be teachers' fear of harming their school's image, their promotion prospects or tax avoidance purposes, or parents' fear of their children's school teachers misinterpreting private tutoring as a lack of confidence in their abilities.

Among the existing studies on the determinants of private tutoring, private tutoring was found to be a good with income elasticity ranging from highly inelastic in Greece (Psacharopoulous & Papakonstantinou, 2005) to unit elastic in Turkey (Tansel & Bircan, 2006). The common pattern is that richer and more educated households in urban areas spend more on private tutoring classes compared to other households in more remote areas (Ha & Harpham, 2005; Kim & Lee, 2004; Tansel & Bircan, 2006).

There have been mixed results among the few studies seeking to determine the effects of private tutoring on students' academic achievement. For a sample of 8-year-old children in Vietnam, after controlling for other characteristics, Ha and Harpham (2005) find that although private tutoring

does not significantly increase the children's writing and multiplication test scores, it does double these children's reading test scores. However, contrary evidence is found for Singapore where private tutoring is found to have a negative effect on secondary students' grades (Cheo & Quah, 2005).[1]

Nevertheless, only two of the above-mentioned studies (Kim & Lee, 2004; Tansel & Bircan, 2006) use nationally representative data. Furthermore, Cheo and Quah (2005) did not explicitly test for the possible endogeneity of private tutoring; neither did Ha and Harpham (2005). It is therefore clear that more research needs to be done on this topic.

3. Data description and private tutoring situation in Vietnam

3.1. Data

This paper mainly uses data from the 1997–1998 Vietnam Living Standards Survey (VLSS), which is a nationally representative household survey conducted by Vietnam's General Statistical Office (GSO) with technical support from the World Bank. Part of the 1992–1993 VLSS is also used to calculate the nutritional status of the children in the panel data between the two surveys.

The 1997–1998 VLSS uses 5 questionnaires: household, commune, price, school, and clinic, covering 6000 households from all areas of Vietnam. In addition to providing information regarding each individual's previous and current schooling, the education section in the household questionnaire provides detailed and separate components of expenditure on education such as tuition fees, contribution to parent associations, cost of books, transportation costs, and private tutoring expenditure for each student. One unique point of the 1997–1998 VLSS compared to other household surveys in Vietnam is that it collects information about a student's academic performance or GPA-type ranking in the previous grade. This information is collected from either the student himself/herself or other household members, with slightly more than half of the students self-reporting. This academic ranking variable has four values excellent, good, average or poor.[2] The commune and school questionnaires collect information such as community infrastructure, school facilities, school teachers' qualifications, and school finances and fees.[3]

However, one limit with the 1997–1998 VLSS is that it only asks for expenditure on private tutoring for each student, without specifying what type of private tutoring classes the student has had. Thus, it may not be possible to exactly separate the impact of private tutoring in academic subjects taught and tested at mainstream schools compared to that of private tutoring in subjects not taught (and tested) at school, which may be pursued simply for entertainment or further human development such as fine arts or martial arts. However, as can be seen later on in the context of widespread tutoring in Vietnam, it is reasonable to assume that most of the spending on private tutoring is to supplement academic subjects taught and assessed by examinations at school.

3.2. Private tutoring situation in Vietnam

Primary education in Vietnam includes grades 1–5 (for children age 6–10). Secondary education consists of lower secondary education (grades 6–9 for age 11–14), and upper secondary education grades 10–12 for age 15–17). Students have to take examinations at the end of each school level to have the respective graduation diploma.[4] To gain admission into some specialized upper secondary schools or college, students must also take an entrance examination. There is strict rationing at the tertiary level: over the school years 1993–1994 to 1997–1998, approximately 1 in 5 students who took the

[1] Another study shows that in Korea, both short-term and long-term tutoring have no impact on grade point averages for secondary students even after other factors are controlled for (Lee, Kim, & Yoon, 2004). However, from the description of the sampling procedure (p. 28), this study does not appear to account for self-selection bias by students into taking private tutoring or not. Thus the results of the study should be taken with the appropriate caution.

[2] While some concern may be raised about the validity of this self-reported information, it should be noted that in Vietnam, a student's test score or GPA is rarely kept secret. Students usually know about their friends' grades, and the teacher usually lets all the class know who scored higher on the test to encourage students to emulate each other. There is some anecdotal evidence that in some cases, the names of students who score lowest on the test may also be mentioned so that they feel embarrassed enough to put more effort into their studies. Furthermore, it is hard to imagine children misreporting their GPA in the presence of their adult household members.

[3] See Vietnam Living Standards Survey 1997–1998 (World Bank, 2000) for further details.

[4] However, according to the most recent Law on Education 2005, currently only senior secondary student have to take examinations to obtain the high school diploma.

Table 1
Household expenditure on private tutoring classes, 1997–1998

	All Vietnam	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Mean hh. exp. on private tutoring (VND)	138,641	16,216	46,122	68,934	152,724	446,797
Distribution of hh. with exp. on private tutoring as percent of total expenditure						
0%	65.7	85.9	74.3	67.6	58.1	45.2
1–5%	31.0	13.9	24.7	31.4	37.2	45.8
5–10%	2.9	0.2*	0.9*	1.0*	4.0	7.8
10% or higher	0.4*	–	0.1*	–	0.7*	1.2*
Total	100	100	100	100	100	100
No. of households	3769	630	676	756	789	918

Note: * less than 20 observations.
Source: Author's calculation from the 1997–1998 VLSS.

university entrance examinations were admitted (MOET, 2006). In the recent years 2000–2002, the government's expenditure on education and training was approximately 12% of total expenditures (GSO, 2005).

There has been much public debate about the widespread private tutoring situation in Vietnam. The topic has come up not just in the media, including television broadcasting and newspapers and journals, but also in the National Assembly's hearings of the Minister of Education and Training.[5] Indeed, private tutoring has become so serious a problem that the Vietnamese government has issued several legal documents at the ministerial levels prohibiting compulsory and mass-scale extra classes at school (Decree No. 242, OPM, 1993), and stipulating the ranges for extra class fees that schools can charge students (Circular No. 16, MOET & MOF, 1993). However, after the promulgation of these regulations, private tutoring classes still developed such that the Ministry of Education and Training (MOET) had to issue some more legal documents regulating it, notably among them Circular No. 15 (MOET, 2000) providing guidance on urgent measures to be taken to control private tutoring. It is interesting in this context to examine the private tutoring situation in Vietnam.

Table 1 shows that around 34% of the households with children in school send their children to private lessons and the majority of them (90%) allocate between 1% and 5% of the total household expenditure on private tutoring. However, richer households in Vietnam appear to spend more on private tutoring than poorer households: the percentage of households with a positive expenditure on private tutoring almost quadruples from 14% in the poorest (1st) consumption quintile to 55% in the richest (5th) consumption quintile. The difference is even more striking in terms of real expenditure with the mean household expenditure on private tutoring for the richest households almost 30 times higher than that for the poorest households.

More students attend private tutoring classes at higher school levels. This trend is shown in Table 2 with the numbers steadily increasing across Vietnam from 31% at primary school to 56% at lower secondary school, and 77% at upper secondary school. While there is a large difference in private tutoring attendance for students in urban and rural areas, as well as for students belonging to the ethnic majority group Kinh-Hoa and ethnic minority group, these gaps become convergent as the school levels progress. However, this trend can be indicative of more need for students to pass the level-graduation and the entrance examinations, as well as the selection process into higher education by family income.[6]

[5]Private tutoring classes became so common in Vietnam that it was recently reported that even some students preparing to enter grade 1 also take these classes (VnExpress, 2006). Results from a small survey in Vietnam indicates that the top three obvious reasons that both parents and teachers, as well as the students themselves, use to explain why students go to private tutoring are making up for poor ability and keeping up with the class, studying to pass the examinations and bettering one's education, and not understanding the lessons (Mac, 2002).

[6]The mean years of schooling completed for people age 15 or older are 5.2, 6.8 and 9.1 for individuals in households in quintiles 1, 3, and 5 of the distribution of per capita expenditure, respectively (Author's calculations from the 1997–1998 VLSS). See Dang (2005) for the decomposition of the difference in years of schooling completed between ethnic majority and ethnic

Table 2
Percentage of students attending private tutoring classes by school level, 1997–1998

Level	All vietnam	Urban	Rural	Ethnic majority	Ethnic minority
Primary	31.1	54.7	27.4	37.0	7.1
Lower secondary	55.9	76.1	50.6	60.7	19.0
Upper secondary	76.7	82.3	73.7	78.0	55.9

Source: Author's calculation from the 1997–1998 VLSS.

4. Econometric framework

There are two equations of interest; the first is the determinants of expenditure on private tutoring and the second is the impact of expenditure on private tutoring on student academic performance. The demand equation for a student's quantity of schooling—here represented by expenditure on private tutoring—is modeled in reduced form as a function of individual, household, and community (and school) factors (Glewwe, 2002). The academic achievement equation for the student can also be derived in a similar way, but is a different function of individual, household, and community factors.

It is likely that there are characteristics observed and unobserved to the econometrician that affect both spending on private tutoring and student performance at school. Such characteristics include parental concern for their children's education and the student's innate ability, both of which are almost impossible to measure in practice. Parents with strong preferences for their children's education may do many things to help their children succeed in school, such as spending time helping them with their homework, reading stories for them to develop their appreciation of literature, and spending money to send them to private tutoring classes, and they may do all these things simultaneously. Likewise, a student's innate ability can have a positive correlation with his/her school performance, and either a positive or negative correlation with the expenditure on private tutoring. The correlation is positive when the household wants to spend more on the gifted child, and negative when parents try to equalize educational outcomes across children of different ability. These unobserved characteristics usually end up in the regression error terms, causing expenditure on private tutoring in the second equation to be an endogenous variable. If the endogeneity of private tutoring expenditure is not controlled for in regression analysis, it can lead to inconsistent parameter estimates.

To address this issue, this paper uses a simultaneous framework consisting of a joint Tobit and ordered probit econometric model which is developed from the simultaneous Tobit model of Amemiya (1974).[7] Since one dependent variable is censored (around 66% of the households have zero expenditure on private tutoring) and the other is discrete and ordered (academic ranking), this model is the appropriate estimation method. See the Appendix for the full model.

The instrumental variable in the academic performance equation for expenditure on private tutoring is the tutoring fees charged by the schools in the commune. These fees are regulated by government rules (although the regulations also stipulate a range within which the local education officials can set the tutoring fees, taking into account local living standards). While students can also attend other private tutoring classes besides these classes organized by the local schools, these school fees can represent at least the "official" price of private tutoring in the community.[8]

(*footnote continued*)
minority students. Unless noted otherwise, all the calculations from the 1997–1998 Vietnam Living Standards Survey are author's calculations.

[7] See, for example, Glick (1999) for an application of Amemiya's model in estimating the supply of market and home work by women. Related models have been used in a variety of fields such as consumer demand (Hanemann, 1984), contraceptive use and desired family size (Bollen, Guilkey, & Mroz, 1995), and the labor supply and schooling decision of school children (Assaad, Levison, & Dang, 2005).

[8] While general tuition fees can directly affect school progress, it can be argued that once the students decided to continue attending school tuition fees may only influence their academic performance indirectly. Furthermore, private tutoring fees are generally optional and not required as other tuition fees. An informal test is implemented by running an ordered probit regression of a student's academic ranking on the log of expenditure on private tutoring classes and the log of private

Although the 1997–1998 VLSS provides information on four categories for academic ranking (poor, average, good and excellent), the top two categories (good and excellent) are combined into one category to simplify the likelihood function to avoid convergence problems. The reason these two categories, but not the last two categories for instance, are combined is that a student may not be allowed to progress to the next grade if he/she falls into the category of poor performance in most schools in Vietnam. To reduce heteroscedasticity, private tutoring expenditure, as well as household expenditures and private tutoring fees, are transformed to the logarithmic scale. Since there are a number of students with zero expenditure on private tutoring or communes with zero private tutoring fees, a value of one is assigned in the place of zero for these cases.

The explanatory variables are at the individual, household, school, community, and regional levels. There are several model specifications, depending on the inclusion of different personal, household, and community characteristics, to provide some comparison as well as a range of estimates for the variables of interest. Separate regressions are run for primary school and lower secondary school students. However, since the 1997–1998 VLSS provides information on expenditure on private tutoring classes and students' academic rankings in the previous year, students in the first grade at each school level are dropped.[9] The private tutoring situation with upper secondary students is not examined in the paper because of insufficient data.

Individual-level variables include a student's age, age squared, sex, ethnicity, nutritional status,[10] and the number of years before the last grade in a student's current school level. The age ranges of 6–14 and 11–18 are chosen for primary students and lower secondary students respectively to allow for the fact that some students may go to school late or repeat grade. Household variables include family size, parental education, and household expenditure. Household expenditure per capita is included to capture the income effect on a person's schooling, since household expenditure is generally considered a better measure of household living standards than household income (Deaton, 1997, pp. 29–32).

Community and school variables include the distance to the nearest school and the distance to the town center. The distance to the nearest school is used when there are several schools within a commune. School variables include the share of primary and lower secondary teachers having the qualifications of Vietnam's MOET, the average numbers of book sets as a proportion of students that a school can lend or rent out to each student, and the share of schools with electricity in the commune. However, since the 1997–1998 VLSS does not provide enough information to link a student with the school the student attends, the school-level variables are obtained by averaging across all the schools in the commune. Regional characteristics are approximated by dummy variables for urban or rural areas and for the Northern Uplands, North Central, South Central, Central Highlands, South East, and Mekong Delta regions, with the Red River Delta region serving as the reference category for the geographic location.

5. Estimation results and interpretation

5.1. The determinants of private tutoring

Estimation results of the determinants and impact of expenditure on private tutoring classes for primary school students are shown in Table 3. Model 1 to model 4 applies the joint Tobit-ordered probit framework for analysis. Model 1 only controls for the most basic individual, household, and regional characteristics. While model 2 adds to model 1 the standardized height-for-age z scores calculated from the VLSS 1992–1993, model 3 adds to model 1 the composition of household size. Finally, model 4 adds to model 1 the community and school characteristics. Compared to model 4, while model 2 loses quite a few observations because of the attrition problem with the panel data, model 3

(*footnote continued*)
tutoring fees, controlling for other household, school, community and regional characteristics. The p-value for the coefficient on the log of private tutoring fees is insignificant, but the p-value for expenditure on private tutoring is significant at the 5% level.

[9]The main reason for dropping these students is that for students currently at the first class in each school level, this information reflects their GPA and expenditure in their previous school levels (kindergarten and primary levels respectively for primary and lower secondary students). The other reason is to avoid selection bias for students who continue to the next schooling level, as compared to those who do not.

[10]Height-for-age standard deviation scores are calculated from the panel households that participated in both the 1992–1993 and 1997–1998 VLSSs using the ANTHRO software (Sullivan and Gortein, 1999) which can be downloaded from the Center for Disease Control website. However, there are a large number of missing observations for this panel data, and in any case, the impact of this variable is not very strong.

Table 3
Determinants and impact of expenditure on private tutoring classes for primary school students, 1997–1998

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.
Log of expenditure on private tutoring	0.128**		0.140**		0.134**		0.096*		0.039*	
	(2.44)		(2.40)		(2.56)		(1.69)		(1.90)	
Log of tutoring fees		0.173***		0.186***		0.173***		0.159***		0.158***
		(3.95)		(4.19)		(4.02)		(3.61)		(3.58)
Individual and household characteristics										
Log of hh. expenditure per capita	0.245***	1.524***	0.292***	1.345***	0.243***	1.419***	0.256***	1.263***	0.280***	1.248***
	(2.75)	(4.55)	(2.76)	(4.02)	(2.58)	(4.07)	(3.03)	(3.74)	(3.46)	(3.69)
Year before the last grade	−0.093**	−0.871***	−0.107**	−0.844***	−0.080*	−0.846***	−0.099**	−0.871***	−0.114***	−0.876***
	(2.20)	(4.51)	(2.20)	(4.55)	(1.87)	(4.43)	(2.42)	(4.56)	(2.81)	(4.60)
Age	−0.346**	−1.286*	−0.327*	−1.452*	−0.280*	−1.018	−0.338**	−1.338*	−0.350**	−1.390*
	(2.24)	(1.73)	(1.80)	(1.93)	(1.66)	(1.33)	(2.19)	(1.85)	(2.29)	(1.93)
Age squared	0.011	0.058	0.010	0.067*	0.008	0.046	0.010	0.060*	0.011	0.063*
	(1.45)	(1.60)	(1.11)	(1.80)	(1.01)	(1.25)	(1.40)	(1.73)	(1.47)	(1.81)
Female	0.250***	0.214	0.203***	0.179	0.252***	0.260	0.262***	0.187	0.267***	0.181
	(4.80)	(1.11)	(3.56)	(0.91)	(4.79)	(1.38)	(5.04)	(0.98)	(5.03)	(0.95)
Father's years of schooling	0.054***	0.005	0.064***	−0.046	0.056***	0.002	0.056***	0.012	0.056***	0.014
	(5.44)	(0.13)	(5.36)	(1.06)	(5.57)	(0.04)	(5.44)	(0.31)	(5.52)	(0.34)
Mother's years of schooling	0.019*	0.107**	0.022*	0.152**	0.016	0.072	0.022**	0.082*	0.023**	0.080*
	(1.70)	(2.12)	(1.71)	(2.50)	(1.41)	(1.35)	(1.96)	(1.81)	(2.07)	(1.76)
Ethnic minority	−0.144	−1.321**	−0.114	−1.464**	−0.171*	−1.599***	−0.121	−0.921*	−0.127	−0.929*
	(1.55)	(2.31)	(1.08)	(2.55)	(1.87)	(2.73)	(1.40)	(1.80)	(1.47)	(1.81)
Height for age z scores			0.041*	0.151						
			(1.85)	(1.48)						
No of siblings age 0−5					0.024	−0.353**				
					(0.50)	(1.98)				
No of siblings age 6−11					−0.087**	−0.050				
					(2.50)	(0.32)				
No of siblings age 12−15					−0.068*	−0.528***				
					(1.69)	(3.12)				
No of siblings age 16−18					−0.043	−0.624***				
					(0.96)	(2.84)				
No of siblings age 19 or older					−0.020	−0.009				
					(0.22)	(0.08)				
School & community characteristics										
Share of qualified teachers							0.074	−1.658**	0.046	−1.693**
							(0.37)	(2.28)	(0.23)	(2.33)
Number of book sets per student							0.121	−1.921	0.116	−1.958
							(0.63)	(1.60)	(0.60)	(1.64)

Share of school with electricity							0.181**	0.242	0.193**	0.242
							(1.96)	(0.55)	(2.10)	(0.55)
Share of people with upper secondary education or higher in the commune							−0.164	5.478**	0.062	5.464**
							(0.27)	(2.45)	(0.11)	(2.44)
Distance to school							0.023	−0.200	0.020	−0.193
							(0.58)	(1.08)	(0.53)	(1.05)
Distance to nearest town							0.001	−0.065***	0.001	−0.066***
							(0.25)	(2.68)	(0.14)	(2.70)
Regional characteristics										
Urban	−0.072	2.104***	−0.060	1.892***	−0.123	2.092***	−0.081	1.230*	−0.056	1.229*
	(0.55)	(3.80)	(0.39)	(2.98)	(0.95)	(3.89)	(0.53)	(1.96)	(0.37)	(1.96)
Northern Uplands	0.232	−3.723***	0.209	−3.466***	0.291**	−3.527***	0.172	−3.541***	0.074	−3.559***
	(1.50)	(5.09)	(1.26)	(5.20)	(1.98)	(4.79)	(1.11)	(4.78)	(0.57)	(4.83)
North Central	0.099	−2.066***	0.105	−1.991***	0.126	−1.831***	0.071	−1.833***	0.009	−1.832***
	(0.73)	(3.74)	(0.73)	(3.72)	(0.96)	(3.38)	(0.54)	(3.72)	(0.07)	(3.71)
South Central	0.084	−2.675***	0.263	−3.039***	0.110	−2.562***	0.053	−2.552***	−0.011	−2.534***
	(0.54)	(5.06)	(1.59)	(5.17)	(0.71)	(4.97)	(0.34)	(4.93)	(0.08)	(4.91)
Central Highlands	0.154	−4.905***	0.208	−3.559***	0.196	−4.481***	0.186	−5.418***	0.081	−5.440***
	(0.89)	(7.40)	(1.15)	(2.74)	(1.12)	(6.60)	(0.90)	(7.80)	(0.44)	(7.78)
South East	0.415**	−2.937***	0.492**	−3.311***	0.431**	−2.552***	0.361**	−2.300***	0.287*	−2.283***
	(2.39)	(4.78)	(2.41)	(4.62)	(2.53)	(4.10)	(2.14)	(3.91)	(1.84)	(3.88)
Mekong Delta	0.373**	−4.773***	0.381**	−4.513***	0.420**	−4.597***	0.362**	−4.476***	0.266*	−4.493***
	(2.19)	(7.94)	(2.04)	(7.20)	(2.55)	(7.79)	(2.15)	(7.28)	(1.92)	(7.30)
Alpha 1	−1.740		−1.366		−1.448		−1.480		−1.547	
	(1.48)		(0.97)		(1.15)		(1.24)		(1.31)	
Alpha 2	0.488		0.892		0.791		0.764		0.704	
	(0.41)		(0.63)		(0.63)		(0.64)		(0.59)	
Constant		−2.716		−0.281		−2.552		1.189		1.607
		(0.55)		(0.06)		(0.50)		(0.24)		(0.32)
Sigma		3.449***		3.278***		3.375***		3.364***		3.364***
		(18.21)		(16.16)		(18.14)		(17.83)		(17.84)
Rho	−0.180*		−0.203*		−0.209*		−0.115			
	(1.68)		(1.68)		(1.93)		(1.08)			
Observations	2347		1799		2313		2347		2347	2347
Observations left-censored at 0	1604		1210		1580		1604			1604
Wald chi2	230.82	362.15	226.17	308.95	292.09	390.05	285.47	397.19	279.69	396.49
D.f.	16	16	17	17	21	21	22	22	22	22

Note: 1. *t* statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%.
2. The variances are obtained accounting for clustered sample and using Huber–White method.
3. The two equations in models 1, 2, 3 and 4 are estimated jointly. The two equations in model 5 are estimated separately.

contains some arguably endogenous variables (i.e. household size).[11]

The coefficient on the log of private tutoring fees is highly significant in all models, suggesting that this is a good instrument. Further examination of the results shows that the coefficients on individual and household characteristics are rather similar across the four models, particularly the coefficients on parental education.

The estimation results show that endogeneity of expenditure on private tutoring may not be a serious issue for this population. The coefficient on the correlation term ρ between the errors of the two simultaneous equations is marginally significant at the 10% level in models 1 and 2, but it is statistically insignificant for model 4, which controls for community and school characteristics. Although ρ is almost significant at the 5% level under model 3, the number of siblings in a household is argued to be endogenous, depending on the "taste" of the parents in raising their children. Thus there is little evidence against the hypothesis of no endogeneity with expenditure on private tutoring for this population, after controlling for individual, household and community characteristics. However, this argument heavily relies on the validity of the instrument used, which appears to be a good one both theoretically and empirically. Hence, there may not be much use in estimating the equations simultaneously when the estimation can be done separately. Model 5 in Table 3 presents separate estimates of model 4 by running two separate Tobit and ordered probit regressions.

Joint estimation for the determinants and impact of expenditure on private tutoring classes for lower secondary school students is also done, but the coefficient on the correlation term ρ is never significant under any model.[12] Consequently, Table 4 only shows results for the two regressions run separately in each model. The coefficients are again rather similar across the models, showing that our estimation results are fairly robust to alternative specifications. Given the discussion about the different models above (and the low statistical significance of nutritional status on student academic performance), the main models for analysis are thus model 5 in Table 3 and model 4 in Table 4.

The marginal effects of the determinants of expenditure on private tutoring classes are calculated (based on model 5 in Table 3 and model 4 in Table 4) and shown in Table 5. Because expenditure on private tutoring classes, as well as household expenditure per capita, is in log form, the coefficient on household expenditure per capita can be roughly interpreted as the income elasticity of private tutoring (for all households). These elasticities are less than one for both primary students and lower secondary students, indicating that private tutoring is a necessity for primary and lower secondary students in Vietnam.

Households' concern of student performance during the final grade of each level of schooling is seen very clearly in the highly significant coefficient on the variable indicating the number of years before the last grade of each level. One year nearer to the last grade brings a 30% increase in spending on private tutoring at the primary level and a 66% increase at the lower secondary level.

Age has decreasingly negative effects on both spending on private tutoring and academic performance for a student in primary and lower secondary school in Vietnam. This means that, controlling for other factors, older students are less likely to attend private tutoring, and less likely to perform well in school compared to younger students. One possible reason besides the cohort effects is that older students may have other concerns to worry about besides studying (e.g. earning income to support their family), and those who do return to school when much older tend to have much motivation, as well as financial stability, to study.

There appears to be no gender discrimination in spending on private tutoring in Vietnam, ceteris paribus. While mothers' education has a positive impact on private tutoring at the primary level, it has no impact at the lower secondary level. In contrast, fathers' education has an insignificant effect at the primary level, but a significant effect at the lower secondary level. One more year of schooling for the father increases spending on private tutoring classes at the lower secondary level by 5%, the corresponding number at the

[11]There is much debate about the effect of family size on a child's education. While a number of studies have found a significant negative effect of family size on a child's education, for example in Vietnam (Truong, Knodel, Lam, & Friedman, 1998) and Thailand (Knodel & Wongsith, 1991), some economists argue that family size is likely to be endogenous. According to this argument, parents may decide on the quality and quantity of their children at the same time, and the fewer number of siblings could be due to the fact that the parents want to concentrate more resources per child, thus reflecting a higher taste for child quality (Becker, 1991; Becker & Lewis, 1973), which is not an observed variable in the regression.

[12]Estimation results can be obtained upon request.

Table 4
Determinants and impact of expenditure on private tutoring classes for lower secondary school students, 1997–1998

	Model 1		Model 2		Model 3		Model 4	
	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.
Log of expenditure on private tutoring classes	0.071***		0.070***		0.068***		0.065***	
	(3.24)		(2.98)		(3.08)		(2.97)	
Log of tutoring fees		0.151***		0.217***		0.139***		0.131***
		(3.01)		(3.67)		(2.98)		(2.65)
Individual and household characteristics								
Log of hh. expenditure per capita	0.187**	0.983***	0.210**	1.232***	0.160	0.660**	0.152	0.836***
	(2.05)	(3.16)	(2.01)	(3.48)	(1.61)	(2.18)	(1.62)	(2.82)
Year before the last grade	−0.223***	−1.019***	−0.240***	−1.089***	−0.209***	−0.979***	−0.221***	−1.040***
	(3.33)	(5.29)	(3.14)	(5.05)	(3.11)	(5.12)	(3.27)	(5.61)
Age	−0.747**	−2.603**	−1.032**	−2.664*	−0.701*	−2.343*	−0.723*	−3.017**
	(1.97)	(2.05)	(2.41)	(1.78)	(1.76)	(1.80)	(1.90)	(2.37)
Age squared	0.019	0.087**	0.029*	0.088*	0.018	0.079*	0.018	0.101**
	(1.44)	(1.96)	(1.92)	(1.68)	(1.29)	(1.74)	(1.37)	(2.28)
Female	0.311***	−0.035	0.306***	−0.111	0.311***	−0.006	0.312***	−0.105
	(4.31)	(0.19)	(3.75)	(0.54)	(4.23)	(0.03)	(4.30)	(0.60)
Father's years of schooling	0.029*	0.077*	0.035*	0.074	0.028*	0.088**	0.032*	0.076*
	(1.76)	(1.81)	(1.88)	(1.56)	(1.66)	(2.05)	(1.94)	(1.84)
Mother's years of schooling	0.030**	0.014	0.024	−0.008	0.036**	0.003	0.025*	−0.009
	(2.18)	(0.33)	(1.44)	(0.17)	(2.31)	(0.06)	(1.78)	(0.22)
Ethnic minority	−0.377***	−1.633**	−0.398***	−1.067	−0.395***	−1.549*	−0.375***	−1.294
	(3.02)	(1.97)	(3.21)	(1.28)	(3.19)	(1.93)	(2.65)	(1.51)
Height for age z scores			0.013	−0.060				
			(0.31)	(0.57)				
No of siblings age 0–5					−0.081	−0.282		
					(0.87)	(0.82)		
No of siblings age 6–11					−0.002	−0.331**		
					(0.04)	(2.26)		
No of siblings age 12–15					−0.052	−0.426**		
					(0.82)	(2.25)		
No of siblings age 16–18					0.006	−0.303		
					(0.10)	(1.59)		
No of siblings age 19 or older					0.013	−0.036		
					(0.45)	(0.47)		
School and community characteristics								
Share of qualified teachers							−0.093	0.338
							(0.35)	(0.35)
Number of book sets per student							−0.051	−0.330
							(0.50)	(0.93)

Table 4 (*continued*)

	Model 1		Model 2		Model 3		Model 4	
	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.	Aca. per.	Log of exp. on pri. tut.
Share of school with electricity							0.113	0.872*
							(0.82)	(1.71)
Share of people with upper secondary education or higher in the commune							1.158*	6.118**
							(1.83)	(2.12)
Distance to school							−0.031	0.202
							(1.06)	(1.62)
Distance to nearest town							0.002	0.006
							(0.34)	(0.24)
Regional characteristics								
Urban	−0.128	1.036*	−0.262	0.944	−0.123	1.026*	−0.300*	0.433
	(0.80)	(1.76)	(1.26)	(1.45)	(0.78)	(1.79)	(1.68)	(0.62)
Northern Uplands	0.458***	−1.010	0.459***	−0.973	0.430***	−1.009	0.499***	−1.299*
	(3.50)	(1.56)	(3.57)	(1.41)	(3.20)	(1.60)	(3.75)	(1.91)
North Central	−0.044	−0.161	−0.035	−0.095	−0.074	−0.065	−0.034	−0.214
	(0.30)	(0.30)	(0.24)	(0.18)	(0.47)	(0.13)	(0.22)	(0.38)
South Central	−0.092	0.592	0.012	0.258	−0.083	0.853	−0.018	0.552
	(0.57)	(0.90)	(0.05)	(0.33)	(0.49)	(1.31)	(0.10)	(0.74)
Central Highlands	0.088	−3.240***	0.106	−4.300**	0.099	−2.701**	0.179	−3.062***
	(0.57)	(2.91)	(0.58)	(2.15)	(0.57)	(2.41)	(1.06)	(2.90)
South East	0.367*	−1.953**	0.395	−2.506***	0.361*	−1.648**	0.474**	−1.964**
	(1.74)	(2.46)	(1.51)	(2.87)	(1.67)	(2.05)	(2.16)	(2.18)
Mekong Delta	0.346**	−2.341***	0.362*	−2.235***	0.326*	−2.235***	0.496***	−2.300***
	(2.01)	(3.81)	(1.89)	(3.30)	(1.82)	(3.64)	(2.62)	(2.91)
Alpha 1	−7.291**		−9.185***		−7.066**		−7.304**	
	(2.51)		(2.78)		(2.37)		(2.48)	
Alpha 2	−4.672		−6.621**		−4.424		−4.688	
	(1.61)		(2.00)		(1.48)		(1.58)	
Constant		14.300		12.608		15.305		17.083*
		(1.47)		(1.09)		(1.57)		(1.77)
Sigma		3.098***		2.95***		3.03***		3.03***
		(17.35)		(15.13)		(16.87)		(17.12)
Observations	1193	1193	936	936	1173	1173	1179	1179
Observations left-censored at 0		534		416		520		522
Wald chi2	112.14	153.48	90.15	164.36	121.43	179.71	136.63	197.85
D.f.	16	16	17	17	22	22	22	22
Pseudo R2	0.090		0.091		0.090		0.096	

Note: 1. *t* statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%.

2. The variances are obtained accounting for clustered sample and using Huber-White method.

3. The two equations in all the models are estimated separately.

Table 5
Marginal effects of the determinants of expenditure on private tutoring classes for primary and lower secondary students, 1997–1998

	Primary students	Lower secondary students
Log of tutoring fees	0.054***	0.082***
Individual and household characteristics		
Log of hh expenditure per capita	0.428***	0.526***
Year before the last grade	−0.301***	−0.655***
Age	−0.477*	−1.900**
Age squared	0.022*	0.064**
Female	0.062	−0.066
Father's years of schooling	0.005	0.048*
Mother's years of schooling	0.027*	−0.006
Ethnic minority	−0.319*	−0.815
School and community characteristics		
Share of qualified teachers	−0.581**	0.213
Number of book sets per student	−0.672	−0.208
Share of school with electricity	0.083	0.549*
Share of people with upper secondary education or higher in the commune	1.875**	3.853**
Distance to school	−0.066	0.127
Distance to nearest town	−0.023***	0.004
Regional characteristics		
Urban	0.422*	0.273
Northern Uplands	−1.221***	−0.818*
North Central	−0.629***	−0.135
South Central	−0.869***	0.348
Central Highlands	−1.866***	−1.928***
South East	−0.783***	−1.237**
Mekong Delta	−1.541***	−1.448***

Note: * significant at 10%; ** significant at 5%; *** significant at 1%.

primary level for one more year of mother's schooling is 3%.[13]

Belonging to an ethnic minority groups reduces spending on private tutoring as much as 32% for a primary student. However, there is no difference at the lower secondary level for the two groups in private tutoring spending. Perhaps if an ethnic minority household decides to send their children to lower secondary school, then conditional on this choice, they behave similarly to ethnic majority households and send their children to private tutoring.

Turning to the community and school characteristics, parents seem to turn to private tutoring because of the poor quality of local schools. While raising the share of qualified primary school teachers by 25% decreases spending on private tutoring by around 14% at the primary level, it is puzzling that the household spends more on private tutoring in communes with more schools with electricity at the lower secondary level. Perhaps electricity allows teachers to set up private tutoring classes in the evening. However, one should be cautious in interpreting these variables since they may also indicate the general quality of school in the commune (i.e. there can be other unobserved school characteristics).[14]

Not surprisingly, the share of people with upper secondary education or higher in the commune has a strong impact on expenditure on private tutoring. The impact can come from both the demand and supply sides. On the demand side, living in a community with a higher level of education may give a student more peer pressure to study harder, as well as more inclination toward achieving higher education through possible interaction with the adults. On the supply side, communities with higher educational levels may be able to supply more tutors for the students.

It is remarkable that after all the other characteristics are controlled for, geographic location is more important in determining spending on private tutoring for a primary student compared to a lower secondary student. Living in an urban area or nearer to the town center causes more private tutoring only at the primary level. Perhaps for rural households, once they decide to send their children to a higher education level, they are ready to invest more in their children's future. It may also be possible that a sorting process is happening in both urban and rural areas whereby only the wealthier households can afford the increasing cost of education as their children progress at school.

5.2. The impact of private tutoring

Private tutoring has significant effects on a student's academic performance under all models. This impact is remarkable at the lower secondary

[13]An interaction term indicating the product of parental education was also tried in the regressions. However, this variable was omitted since it was statistically insignificant in both the regressions for primary and lower secondary students.

[14]In general, there is still much to be learned about the effect of school variables on a child's schooling. Hanushek (1997) provides a general review and Glewwe and Kremer (2006) present a recent discussion of the literature.

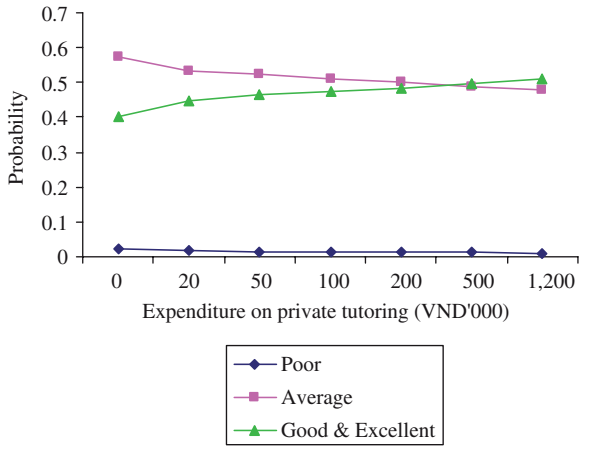

Fig. 1. Predicted probabilities of falling in each academic performance category for primary students.

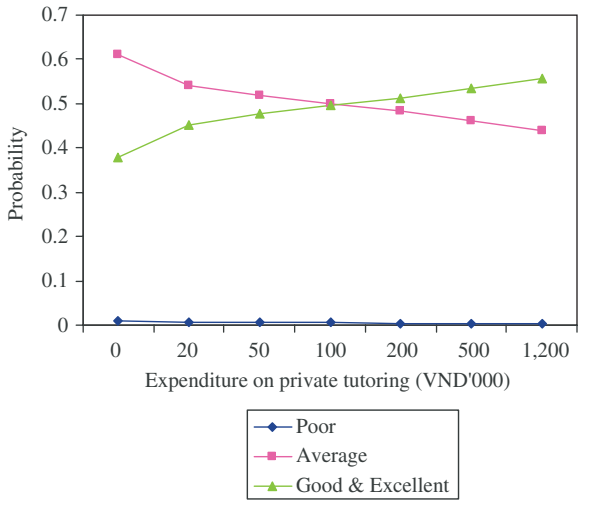

Fig. 2. Predicted probabilities of falling into each academic performance category for lower secondary students.

level where, controlling for community and school characteristics, expenditure on private tutoring classes has a strongly significant impact on a student's academic performance while household expenditure per capita does not. Figs. 1 and 2 plot the predicted probabilities of achieving either one of three academic rankings: poor, average, and good and excellent against expenditure on private tutoring classes, keeping all other characteristics at the mean. The range of expenditure is 0, 20,000, 50,000, 100,000, 200,000, 500,000, and 1,200,000 in the Vietnam currency *dong*,[15] approximately corresponding to the 60th, 67th, 75th, 83rd, 90th, 95th, and 99th percentiles, respectively. (Note from Table 1 that 20,000 VND is about the mean expenditure on private tutoring by households in the poorest consumption quintile in Vietnam).

For both primary and lower secondary students, higher spending on private tutoring decreases the probability that the student falls into either the poor or average performance categories, but increases the probability the student accomplishes the good and excellent academic ranking. However, the impact is much stronger at the lower secondary level compared to the primary level, except for the poor performance category. The slopes of the predicted probability lines are steepest when expenditure on private tutoring increases from 0 to 20,000 VND. After that, the slopes become less and less steep.

Increasing spending on private tutoring from 0 to 20,000 VND decreases the probability of having a poor and average academic ranking respectively for a primary student by around 0.01 and 0.04, but increases the probability of having a good and excellent academic ranking by 0.05. At the same increase in expenditure, the corresponding figures for a lower secondary student are much higher at around 0.01, 0.07, and 0.08, respectively. While raising spending on private tutoring by 10 times from 20,000 VND to 200,000 VND has almost no influence on the probability of having a poor academic ranking for both primary and lower secondary students, it decreases the probability of having an average academic ranking by 0.03 and 0.06, and increases the probability of achieving a good and excellent academic ranking by 0.04 and 0.06 respectively at the primary and lower secondary school level.

6. Conclusion

This paper finds that private tutoring in Vietnam is a necessity in the household budget for primary and lower secondary students, and the trend to attend private tutoring is stronger at higher education levels. There is no evidence of gender discrimination in expenditure on private tutoring. Ethnic minority students spend less on private tutoring at the primary level but not at the lower secondary level, as do students living in rural and remote areas. This can raise some concern about a sorting process exacerbating inequality where only wealthier households can afford the rising cost of sending their children to higher education. However, the results suggest that spending on

[15]The exchange rate in 1998 is around US$1 for 14,000 VND (IMF, 2006).

private tutoring would fall significantly at the primary level if the quality of schools was improved by increasing the qualifications of primary teachers.

Controlling for other characteristics, private tutoring is found to have a significant impact on students' academic performance, but the influence is larger for lower secondary students. Thus if effectively managed by policy makers, private tutoring can help students do better at school.

Promising avenues for future research may include the impact of private tutoring on other outcomes such as school progress and labor market outcomes. If appropriate instruments that affect school performance but not private tutoring expenditure are available, it would also be useful to know the influence of student academic performance on private tutoring expenditure.

This paper extends the simultaneous Tobit model of Amemiya (1974) to a joint Tobit-ordered probit econometric model that allows one to test for the endogeneity of spending on private tutoring. This model may be applied to other research with a similar econometric issue.

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Appendix

The joint Tobit-ordered probit model is defined as follows. Let y_{1i}^* be a latent variable indicating child i's academic performance (academic ranking). The observed schooling variable y_{1i} is an ordered discrete variable with the values 0, 1, and 2. Let y_{2i}^* be a latent variable indicating the expenditure on private tutoring classes for child i. The observed expenditure on private tutoring classes y_{2i} is left-censored at zero. Assume the underlying structure for the latent variables y_{1i}^* and y_{2i}^* take the following forms

$$y_{1i}^* = \theta y_{2i} + \beta_1' x_{1i} + u_{1i}$$
$$y_{2i}^* = \beta_2' x_{2i} + u_{2i},$$

where x_{2i} is a vector consisting of a constant term, all the observed characteristics, including x_{1i}, and the instrument for expenditure on private tutoring; θ, β_1 and β_2 are the parameters to be estimated; u_{1i} and u_{2i} are zero-mean disturbances with a bivariate normal distribution and variance-covariance matrix $\sum = \begin{bmatrix} 1 & \rho\sigma \\ \rho\sigma & \sigma^2 \end{bmatrix}$ with the variance of the u_1 normalized to 1, and the variance of the u_2 being σ^2; ρ is the correlation coefficient of the two disturbance terms u_1 and u_2. If ρ is not statistically different from 0, or the unobserved characteristics may not cause inconsistent estimates, our system of equations can be estimated using the Tobit model and ordered probit model separately. Otherwise, when ρ is statistically different from 0, the concern about the endogeneity of expenditure on private tutoring is justified, and the two equations should be jointly estimated.

The likelihood function for the model is then

$$L = \prod_1 \int_{-\infty}^{\alpha_1-\theta y_{2i}-\beta_1' x_{1i}} f(u_1,u_2)\,du_1 \prod_2 \int_{-\infty}^{\alpha_1-\theta y_{2i}-\beta_1' x_{1i}} \int_{-\infty}^{-\beta_2' x_{2i}} f(u_1,u_2)\,du_2\,du_1 \prod_3 \int_{\alpha_1-\theta y_{2i}-\beta_1' x_{1i}}^{\alpha_2-\theta y_{2i}-\beta_1' x_{1i}} f(u_1,u_2)\,du_1 \prod_4 \int_{\alpha_1-\theta y_{2i}-\beta_1' x_{1i}}^{\alpha_2-\theta y_{2i}-\beta_1' x_{1i}} \int_{-\infty}^{-\beta_2' x_{2i}} f(u_1,u_2)\,du_2\,du_1$$

$$\prod_5 \int_{\alpha_2-\theta y_{2i}-\beta_1' x_{1i}}^{\infty} f(u_1,u_2)\,\mathrm{d}u_1$$
$$\prod_6 \int_{\alpha_2-\theta y_{2i}-\beta_1' x_{1i}}^{\infty} \int_{-\infty}^{-\beta_2' x_{2i}} f(u_1,u_2)\,\mathrm{d}u_2\,\mathrm{d}u_1$$

$$= \prod_1 \int_{-\infty}^{\alpha_1-\theta y_{2i}-\beta_1' x_{1i}} f(u_1, y_{2i}-\beta_2' x_{2i})du_1$$
$$\prod_2 \int_{-\infty}^{\alpha_1-\beta_1' x_{1i}} \int_{-\infty}^{-\beta_2' x_{2i}} f(u_1,u_2)\,\mathrm{d}u_2\,\mathrm{d}u_1$$
$$\prod_3 \int_{\alpha_1-\theta y_{2i}-\beta_1' x_{1i}}^{\alpha_2-\theta y_{2i}-\beta_1' x_{1i}} f(u_1, y_{2i}-\beta_2' x_{2i})du_1$$
$$\prod_4 \int_{\alpha_1-\beta_1' x_{1i}}^{\alpha_2-\beta_1' x_{1i}} \int_{-\infty}^{-\beta_2' x_{2i}} f(u_1,u_2)\,\mathrm{d}u_2\,\mathrm{d}u_1$$
$$\prod_5 \int_{\alpha_2-\theta y_{2i}-\beta_1' x_{1i}}^{\infty} f(u_1, y_{2i}-\beta_2' x_{2i})du_1$$
$$\prod_6 \int_{\alpha_2-\beta_1' x_{1i}}^{\infty} \int_{-\infty}^{-\beta_2' x_{2i}} f(u_1,u_2)\,\mathrm{d}u_2\,\mathrm{d}u_1.$$

Let $-\theta y_{2i}-\beta_1' x_{1i}=A$, $y_{2i}-\beta_2' x_{2i}=B$, $-\beta_2' x_{2i}=D$, and assuming $(u_1, u_2) \sim N_2(0, 0, 1, \sigma^2, \rho)$, the log likelihood function is[16]

$$\begin{aligned}
\ln L = &\sum_1 \left\{ -\ln(\sigma) + \ln\,\phi\left(\frac{B}{\sigma}\right) \right.\\
&\left. + \ln\,\Phi\left(\frac{\alpha_1 + A - \rho B/\sigma}{\sqrt{1-\rho^2}}\right)\right\}\\
&+ \sum_2 \left\{ \ln\,\Phi_2\left(\alpha_1 + A, \frac{D}{\sigma}, \rho\right)\right\}\\
&+ \sum_3 \left\{ -\ln(\sigma) + \ln\,\phi\left(\frac{B}{\sigma}\right)\right.\\
&+ \ln\left[\Phi\left(\frac{\alpha_2 + A - \rho B/\sigma}{\sqrt{1-\rho^2}}\right)\right.\\
&\left.\left. -\Phi\left(\frac{\alpha_1 + A - \rho B/\sigma}{\sqrt{1-\rho^2}}\right)\right]\right\}\\
&+ \sum_4 \ln\left[\Phi_2\left(\alpha_2 + A, \frac{D}{\sigma}, \rho\right) - \Phi_2\left(\alpha_1 + A, \frac{D}{\sigma}, \rho\right)\right]\\
&+ \sum_5 \left\{ -\ln(\sigma) + \ln\,\phi\left(\frac{B}{\sigma}\right)\right.\\
&\left. + \ln\left[1 - \Phi\left(\frac{\alpha_2 + A - \rho B/\sigma}{\sqrt{1-\rho^2}}\right)\right]\right\}\\
&+ \sum_6 \ln\,\Phi_2\left(-\alpha_2 - A, \frac{D}{\sigma}, -\rho\right).
\end{aligned}$$

[16] See Dang (2006) for the proof and the general case where y_{1i} has m categories. The log likelihood function is maximized using the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm in Stata 9 (StataCorp, 2005).

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