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SLEEP AND TIME ALLOCATION AMONG COLLEGE STUDENTS: THE CASE OF UNIVERSIDAD DEL ATLÁNTICO

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Abstract

A current debate in economics is whether the time spent sleeping responds to economic incentives. In this paper it is investigated the demand for sleep using a sample of 88 undergraduate students of Universidad del Atlántico in Barranquilla, Colombia. It is examined how these students allocate their time for different activities, what factors determine the hours they spent sleeping, and what factors affect their productivity regarding their grade point average. The results reveal an inverse relationship between the amount of sleep that undergraduates get each night and their grade point average. In addition, it is found differences of age, gender, origin, and school background on time allocation and academic productivity among these students.

Key words: Consumer economics: theory, time allocation, human capital formation, labor productivity.

JEL Classification: D11; D61; J22; J24

Introduction

Although people devote to sleep about a third of their lives, the issue of sleep time allocation has received relatively little attention in economics[1]. This topic has been usual in psychology research, especially in medical sciences. The latter established that sleep affects productivity and overall quality of life. However, it is relevant to underline that while sleep contains a biological component (genetic), individual choice is a crucial factor in its allocation.

[1] The sleep is defined as the use of time spent sleeping. It represents the hours devoted to sleep at night.

Sleep influences the behavior of people and labor productivity. Authors like Dement and Vaughan (1999), Van Dongen *et al.* (2003), Turner *et al.* (2007) show that sleep is associated with cognitive performance, decision making, reasoning, memory, problem solving, attention and even accidents. In the college context, Lima *et al.* (2002), Rosales *et al.* (2008) and Pilcher and Ott (1998) show how the allocation of time spent sleeping can affect the health of students.

Despite the importance of sleep on human activities there are few studies that frame its analysis in economic theory and even more if it is considered the college environment. Stolzar (2006) and Eide and Showalter (2007) found that decisions about sleep are closely related to academic performance and health of college students in the United States. Meanwhile, in Latin America there are no studies that directly analyze the allocation of time among college students taking as relevant variables such as the time devoted to sleep and academic performance[2].

This research aims to demonstrate that decisions about sleeping of students of the Universidad del Atlántico are based on academic incentives[3]. In particular, it is estimated econometrically how college students allocate their time of sleep, and other uses of their available time. To that end, this study makes a partial extrapolation of the methodology used by Stolzar (2006). However, because of the specific characteristics of the context in which the research study is developed, it was necessary to modify some variables incorporated by this author.

This article consists of five sections, including this introduction. In Section 1 we review the literature concerning the allocation of sleep time. Section 2 explains how the data were obtained on different uses of time between college students and the methodology used in the research. Section 3 identifies the factors that influence

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[2] However, Di Gresia and Porto (2004), although not intended to analyze the sleep time, estimate the determinants of student achievement associated with the number of credits approved per year, average grade and a combination of these two measures.

[3] Academic incentive refers to the desire of the student to acquire skills and achieve a high GPA in college, thus enhancing their human capital in the labor market.

the sleep time allocation between the students and the variables that affect the obtaining a high GPA. Section 4 deals with a model of time allocation among undergraduate students in order to establish differences in age, gender, origin and school background[4] in the allocation of time and academic productivity. At the end, we present our conclusions.

1. Literature Review

The model of individual choice between work and leisure represented a first step in the modeling of time allocation, summarizing non-working activities into a single category called leisure. This model assumes that consumer preferences and the budget constraint determine working hours (labor supply) and consumption. Thus, the optimal allocation of time is found where the marginal rate of substitution (MRS) between consumption and leisure equals the wage rate.

In this sense, the neoclassical economic theory shares the assumption that the consumption of market goods directly alters the consumer utility. However, there are goods purchased that do not generate direct utility to the consumer but they can be listed as inputs in the production of commodities[5] that shape directly the system of preferences (Becker, 1971).

Becker (1965) assumes that households are productive units that maximize their own utility. Every home combines time and market goods through a production function of commodities and choose the best combination to maximize their respective utility function. For instance, Becker (1965, p. 495) notes that: "*One such commodities is the seeing of a play, which depends on the input of actors,*

[4] The school background is the academic record that corresponds to the type of high school (public or private) from which a college student graduated.

[5] Conventional economic analysis separates consumer theory of production theory. In this way, consumers get utility or satisfaction through goods and services purchased in the market. In the approach of Becker (1965), consumers derive utility only from the consumption of commodities. These are goods produced by the consumer (or families conceived as small domestic factories) by combining market goods and their own time. For details, see Febrero and Schwartz (1995).

script, theater and the playgoer's time; another is sleeping, which depends on the input of a bed, house (pills?) and time. "

The approach of Becker (1965) has become a source of proliferation of studies related to the allocation of unused time at work, including time spent sleeping. This analysis has been used both to model the allocation of non-work time as well as to prove it empirically. Indeed, one of the contributions of Becker (1965) has been precisely the development of a ductile method to all kinds of non-working activities that allows applying economic analysis to the allocation of time[6] (Pollak, 1999, p. 7).

Under the influence of this view, the allocation of time spent sleeping has been modeled and applied to various sleep-related issues. These include sleep analysis as an input in the production of health[7] (Contoyannis and Jones, 2004) and in the production of human capital (Grossman, 1972).

El Hodiri (1973)[8] assumes that individuals maximize a utility function that depends on the daily consumption and the fraction of hours a day in bed. By solving this maximization problem, El Hodiri (1973) found that each individual, given their hourly wage, choose sleep 8 hours a day. With this methodology, Bergstrom (1976) formulates a model of utility maximization in which the average man spends about 9.23 hours in bed (8 hours sleeping, 1.23 hours devoted to activity X).[9]

In the same direction, Hoffman (1977) introduces a different utility function and a different budget constraint in order to clarify the existence of the activity X. According to Hoffman (1977, p. 647), El Hodiri (1973) and Bergstrom (1976)

6 Note that subsequent contributions to that of Becker (1965) have also laid the foundation of numerous theoretical and empirical works related to the use of time in various areas of knowledge. In this regard, see Lancaster (1966) and Muth (1966).

7 Health is the level of individual welfare state in which human beings normally exerts all its vital functions.

8 Cited by Bergstrom (1976, p. 411).

9 The activity X refers to a use of time in bed spent on any activity other than sleep.

models lose consistency for two basic reasons: they do not consider the female perspective in formulating their models and do not include payment to women´s domestic work.

Biddle and Hamermesh (1990) present the main empirical reference regarding the relationship between time spent working and time dedicated to sleep. The central conjecture these authors postulate is that sleep is a time-intensive good that contributes simultaneously to the utility and to the productivity of the individual. Biddle and Hamermesh (1990) also showed that there is an inverse relationship between wages and time spent sleeping.

Szalontai (2006), according to Biddle and Hamermesh (1990), finds that in South Africa the sleep demand responds to economic incentives. Specifically, this author shows that there is a negative relationship between sleep duration and income per capita. Furthermore, Cardon et al. (2008) developed the first dynamic model of intertemporal choice demand of sleep. The idea of these authors was to investigate the interaction between individual choice and the inherent need for sleeping, the productivity and the human capital development in time, among other topics relating to sleep.

Sleep has been also considered as a source of energy available in limited quantities. Asgeirsdottir and Zoega (2008) model the decision to sleep as an investment decision and the consumption level of alertness enjoyed during the day. Based on this formulation, Asgeirsdottir and Zoega (2008, p. 15-16) show that the economics of sleep is intimately associated with the economics of natural resource extraction.

In order to determine the causal effect of sleep on educational outcomes, Eide and Showalter (2007) explored the relationship between sleep patterns of adolescents and their academic achievement. Meanwhile, Stolzar (2006) examined in a sample of 81 university students the incentives that determine the hours they choose to sleep, obtaining an inverse relationship between the amount of hours of sleep per night for these students and their grade point average (GPA). Additionally, this author finds that college women sleep less than their male counterparts.

Based on the evidence described, in the following sections we develop a series of econometric models with the aim of testing the following hypotheses:

1) The sleep time of the average college student decreases when there is an increase in the price of his/her time awaken or the time that he/she is not asleep.[10]
2) On average, undergraduates with high marginal utility per additional unit of GPA will sleep less than those congeners with low marginal utility per additional unit of GPA.
3) The different ways in which college students allocate their time depend on the opportunity cost per hour.
4) On campus women sleep less than men.[11]
5) There are significant differences in age, gender, origin and school background in the allocation of time in relation to the opportunity cost and the productivity per hour-student.

2. Methodology

Data on time allocation of students were obtained through a survey to students at Universidad del Atlántico. All respondents were enrolled in undergraduate

[10] Economists routinely measure the price of people´s awaken time through its opportunity cost in the labor market (wage). However, the problem here is to measure such a value in terms of the opportunity cost of studying While student status means "giving up a salary" in order to qualify for increasing its future value in the labor market, it is not convenient to take the wage as a measure of the opportunity cost of the student as many of these lack a paid work. For this reason, in this context is taken the GPA as an approximation to the opportunity cost (price of time) of college student.

[11] Biddle and Hamermesh (1990) show that although women sleep more than men when including gender differences such as employment status and weekly hours worked, once these factors are held constant, women sleep less than 20 minutes than their male counterparts. Also Stolzar (2006) found that at Stanford University, where male and female students have similar workloads and the same conditions regarding the calculation of their grade point average, men sleep more than women.

programs in the first half of 2009. These students were not required to disclose their names and it was explained that the survey was not a university´s official business so they did not have incentives to distort their responses [12]. According to Juster and Stafford (1986 and 1991) it is common the existence of bias regarding the collection of data on time allocation of respondents. For this reason, for these authors it is convenient that respondents should keep a record of the time spent on each activity performed during the day[13].

Juster and Stafford (1991) also point out that obtaining information regarding the use of time is required when dealing with responses related to daily working hours, that is to say, "regular hours", since it minimizes potential measurement errors. Thus, these measurement errors are minimized by considering the data collected on the time allocation of students. These students previously know their weekly class schedule and adjust it based on their time spent on other activities.

Firstly, the data were broken down in percentages in terms of gender, origin and educational background among college students. The sample consisted of 69% of students from the city, so-called urban student.[14] Likewise, a 72% of these students graduated from public high schools, and the number of men and women were equal. Surveyed students filled daily a schedule stating how they assigned each hour of their day during the week between Sunday 17 and Sunday May 24, 2009. These students began to complete the survey from 6:00 am Sunday of the week above mentioned and ended at 6:00 am the following Sunday. The survey contains a list of nine applications of time which include: (1) sleeping (2) attend classes, (3) study (outside the classroom), (4) run errands, housework, personal care, (5) work (paid), (6) unpaid extracurricular activities (being part of a sports

[12] It is worth noting that the present investigation is a cross-sectional study which surveyed 100 students, chosen randomly from the list of students enrolled in the first half of 2009.

[13] However, some studies (see for example, Mulligan, Schneider and Wolfe 2000; Marcenaro and Navarro, 2006) show that this kind of data collection skews the sample to the extent that it interferes much in the normal course of life of respondents.

[14] In this research, urban student refers to people from the cities which are capitals of Colombian departamentos.

team, do volunteer work, joining clubs, etc..), (7) food (meals and snacks), (8) meeting friends / family / others (9) idle activities (other than all the above activities). Additionally, respondents had the option (10) Others, in which the student described in his/her own words uses of time that he/she considers not included in the list. All these "others" were reassigned among the nine original uses of time. Table 1 illustrates with examples how were classified some of these uses of time called "others".

Table 1. Classification of "other" uses of time

Examples of "others"	**Classification**
Attending church	Extracurricular Activity
Video Games	Leisure activities
Go to the gym [15]	Leisure activities
Medical Appointment	Personal Care
Job Interview	Paid Work
Party	Leisure activities

These data on time allocation were organized on daily average, according to the prevailing time use of every hour of the respondent. In this sense, the data are estimates because students selected time uses with regards to that prevailing activity during the respective hours. For example, if Tuesday from 4:00 to 5:00 pm a student devoted 45 minutes to school and 15 minutes to run an errand, he/she will be allocated an hour to study and zero hours on errands. Additionally, students provided information about sleep habits of their parents.

Some respondents did not take into account the instructions outlined in the survey and chose two uses of time per hour instead of one. In this case, the following method was used: if a respondent spent half an hour at a specific activity, for example, meet friends for several days a week, we proceeded to list those half

[15] It could be argued why the activity "go to the gym" was considered a leisure activity and not a personal care activity. The reason for this classification tries to avoid the ambiguity that may arise from individuals whose primary goals are aesthetic and not health itself.

hours and then group every two half hours and form completed hours devoted to this activity.[16] In few surveys occurred that half hours grouped ended in odd groups, for example, five and a half hours sleeping and two and a half hours dedicated to serving friends. In this case, we proceeded as follows: we subtracted the half hour of meeting friends and it was reassigned to the predominant activity for a result of six hours devoted to sleep and two to meet friends.

3. Empirical Regularities

After removing poorly answered surveys, it results a sample of 88 students[17]. First, conventional descriptive statistics were computed: arithmetic mean, standard deviation and minimum and maximum values of the nine uses of time between the 88 students, using STATA 10 (Table 2). They reported an average of 8.4 hours of sleep per night (about a third of 24 hours a day), 2.3 hours of daily study and two hours of leisure per day. Since the data are measured in hours per day, the average number of hours per day of students, based on the nine uses of time, sums 24.

Table 2. Statistical results of the use of time

Use of Time (hours)	Observations	Mean	Std. Dev.	Min	Max
Sleep	88	8.37	1.28	5.57	12
Attend Classes	88	3.98	1.64	0	7.29
Study	88	2.31	1.41	0	6.14
Run errands / Personal Care	88	1.48	1.22	0	5
Work (Paid)	88	1.36	2.20	0	8.14
Extracurricular activities	88	0.67	1.11	0	5.57
Food / Snacks	88	2.27	0.68	0	4.14
Friends / Family / Others	88	1.46	0.91	0	4.57
Leisure	88	2.09	1.45	0	5.71

When comparing the averages obtained here with those found in the Stanford University (see Table 3), which correspond to 7.9 hours of sleep per night, 4.5 hours of daily study and 3.5 hours of leisure per day, it seems evident that in

[16] This is because the study is based on time intervals measured in hours.

[17] These 88 respondents accounted for 0.68% of the total of 13,027 undergraduate students enrolled in the first half of 2009.

countries with high per capita income people tend to sleep less. This comparison would support the results found by Szalontai and Wittenberg (2004). These authors show that, in contrast to the study of Biddle and Hamermesh (1990) which finds that in the United States the time spent in sleeping is 8.2 hours per day on average, in South Africa it reaches an average of 9.6 hours per day devoted to sleep and other activities related. Also in Table 3 it is shown that Stanford University students are relatively idler yet academically more dedicated and sleep less than the students at Universidad del Atlántico.

Table 3. Comparison with previous research

Study	Hours of sleep per day	Hours of leisure per day	Hours of study per day
Biddle and Hamermesh (1990)	8.2	-	-
Szalontai and Wittemberg (2004)	9.6	-	-
Stolzar (2006)	7.9	3.5	4.5
Trujillo and Iglesias (2010)	8.4	2	2.3

Next, we reduce the nine uses of time to three variables to eliminate some of them and merge others. These variables are: *sleep, leisure,* and *schoolwork* (attend classes + study outside the classroom). We then proceed to estimate econometrically the following multiple linear regression models of sleep time allocation: sleep (demand of sleep), leisure (demand of leisure), and schoolwork (supply of schoolwork) among college students:

Sleep Demand Model

Sleep $= \beta_o + \beta_1$(GPA) $+ \beta_2$ (Age) $+ \beta_3$ (Male) $+ \beta_4$ (Urban) $+ \beta_5$ (Public) $+ \beta_6$ (Sleepfather) + u_i

Leisure Demand Model

Leisure $= \beta_o + \beta_1$(GPA) $+ \beta_2$ (Age) $+ \beta_3$ (Male) $+ \beta_4$ (Urban) $+ \beta_5$ (Public) $+ \beta_6$ (Sleepfather) + u_i

Schoolwork Supply Model

Schoolwork $= \beta_o + \beta_1$ (GPA) + β_2 (Age) + β_3 (Male) + β_4 (Urban) + β_5 (Public) + β_6 (Sleepfather) + u_i

The explanatory variables that make up these three models are as follows: *GPA*, *age*, *male*, *urban*, *public* and *sleepfather* or the number of hours per day that sleep the father of a student[18]. Conventional descriptive statistics of these explanatory variables are summarized in Table 4.

Table 4. Statistical results of no-choice variables

Variable	Observations	Mean	Std. Dev.	Min	Max
Age	88	21.330	3.132	17	37
Male	88	0.500	0.503	0	1
Urban	88	0.693	0.464	0	1
Public High School	88	0.727	0.448	0	1
Sleep Mother[19]	88	7.123	1.126	5	11
Sleep Father	88	7.527	1.310	5	12
GPA	88	3.647	0.418	1.6	4.50

Table 5 summarizes the regressions of each of the previous models. In the column Sleep of Table 5, the negative coefficient of the variable *male* states that, *ceteris paribus*, male students sleep on average about 0.6 hours less than women in the campus. The estimated coefficient corresponding to *urban* indicates that, assuming constant the other explanatory variables, a city student sleeps about half an hour less than a student coming from a different territorial demarcation. In turn, the

[18] We selected *sleepfather* instead of *sleepmother* because the former is statistically more significant. Additionally, these two variables reported a high collinearity with one another. Probably the high multicollinearity is due to what Hoffman (1977, pp. 647-648) called The Third Condition for Marital Stability, whereby, in the presence of love, married couples agree on the time spent on the activity X: "… *on the assumption that the wife (w) and the husband (h) have the same tastes and preferences of consumption (x) and fraction of 24 hours per day spent in bed (y)… When love exists, each spouse's marginal utility from x depends on both one's own and one's spouse's consumption and hours in bed… This certainly must be a significant reason for the widespread popularity of marriage.*"

[19] Maternal sleep is the hours devoted to sleep at night for the mothers of the students surveyed.

estimator of *sleepfather* indicates, *ceteris paribus*, that for each additional hour the student's father sleeps, it will increase the average daily hours the student sleeps in about 0.17. Additionally, the estimated coefficient of the variable GPA indicates that, *ceteris paribus*, for each point of increase in GPA (student´s price of time), it is reduced by about 0.4 the average daily hours slept by the student.

Table 5. Robust linear regressions with explained variables: *sleep, leisure y schoolwork*[20]

Variable	***Sleep***	***leisure***	***schoolwork***
GPA	-0.371 (0.319)	-0.02 (0.345)	1.291 (0.460)*
age	-0.017 (0.036)	-0.053 (0.038)	-0.222 (0.069)*
Male	-0.623 (0.267)**	0.723 (0.348)**	-0.179 (0.419)
Urban	-0.522 (0.299)***	0.378 (0.332)	-0.354 (0.415)
Public	-0.308 (0.305)	-0.006 (0.352)	-0.021 (0.479)
Sleepfather	0.165 (0.087)***	-0.042 (0.131)	0.202 (0.152)
Constant	9.745 (1.731)*	3.007 (1.817)	5.132 (2.521)**
R^2	0.141	0.103	0.202
Observations	88	88	88

* Statistically significant at 1%
** Statistically significant at 5%
*** Statistically significant at 10%

On the other hand, in the column leisure, the estimator of *male* indicates that on campus, *ceteris paribus*, male students get about 0.72 hours of leisure more than their female counterpart. The estimated coefficient on the variable age establishes that for each additional year of student´s life, he/she will devote 0.053 hours less for leisure. The negative sign of the estimator of GPA implies that the higher the student´s GPA, the lesser will be the hours he/she will devote to his/her leisure.

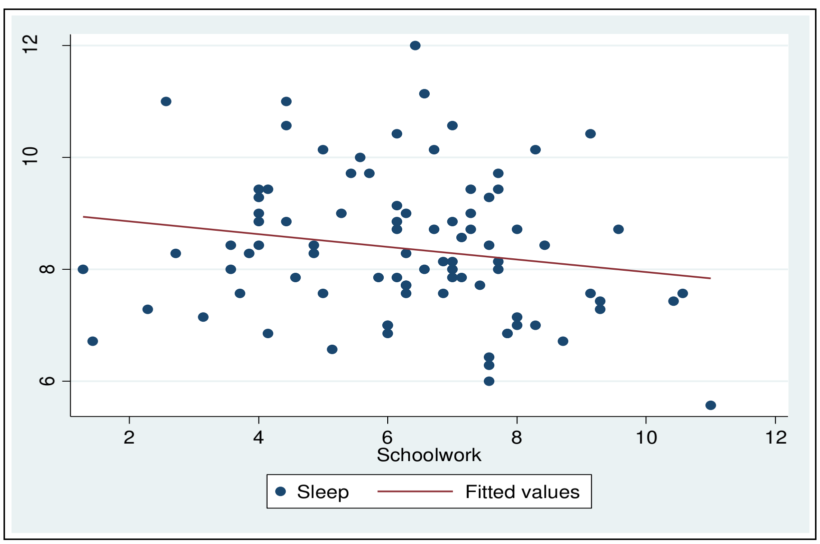
In relation to the column schoolwork, the estimated coefficient of GPA states that, ceteris paribus, each additional point in the student´s GPA will increase in 1.3 hours the student´s daily schoolwork. The estimator of *age* shows that, ceteris

[20] In Tables 5, 6, 7 and 8 robust standard errors appear in parentheses.

paribus, for each additional year of age, the student drops his/her schoolwork in about 0.2 hours. On the other hand, the estimated coefficient of *male* reveals that men perform 0.47 hours less of schoolwork than women. Finally, the coefficient of *sleepfather* indicates that an extra hour of sleep by the average student's father increases the student´s schoolwork by about 0.18 hours daily.

In order to clarify the previous regressions, we relate the explained variables *sleep*, *schoolwork* and *leisure.* Figure 1 shows a scatterplot of *sleep* and *schoolwork*. It is observed a negative correlation between *sleep* and *schoolwork* (slope ≈ -0.11). This correlation supports the negative sign of the GPA coefficient in the regression of *sleep*. Thus, we evidenced the result found by Stolzar (2006) as opposed to the Biddle and Hamermesh model (1990), which assumes that sleep increases productivity.[21] In this sense, it follows that on campus students who hold higher GPAs are more willing to substitute one hour of sleep for one hour of schoolwork. Hence, students with better academic performance get fewer hours of sleep.

Figure 1. Hours of sleep and Hours of schoolwork



[21] This means that, for college students, sleeping extra hours does not contribute to their productivity associated with the GPA.

Figure 2 shows the same scatter plot but with leisure and sleep. As noted, there is a slightly negative relationship between the two variables (slope ≈ -0.05).[22]

Figure 2. Hours of sleep and hours of leisure

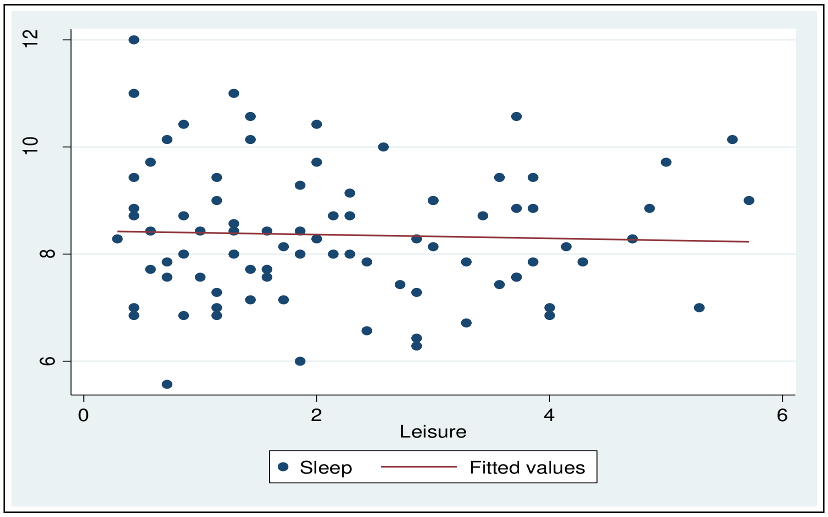
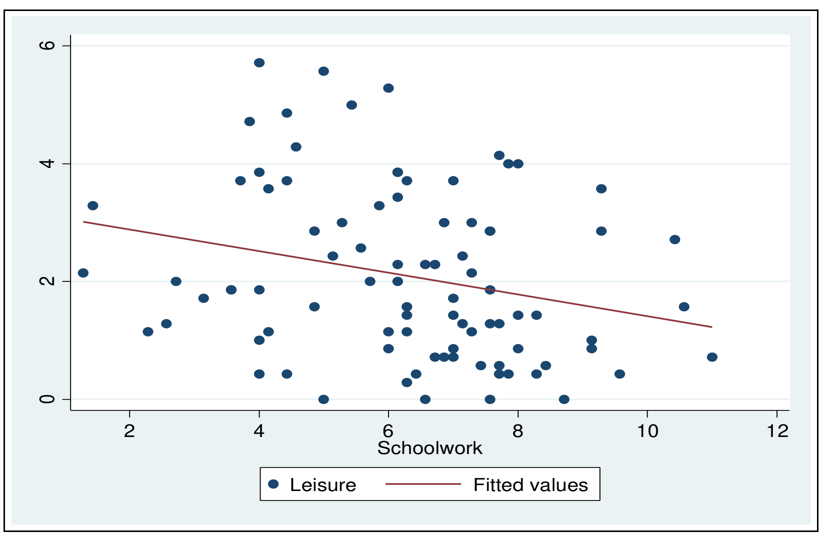


Figure 3 shows that the slope is steeper in the graphical relationship between leisure and schoolwork (≈ -0.18). This scatterplot illustrates that those students who made greater schoolwork demand less leisure, and those who perform less schoolwork demand more leisure.

Figure 3. Hours of Schoolwork and hours of Leisure



[22] In contrast to the finding of Stolzar (2006), in which there is a direct relationship between leisure and sleep, the results found here suggest that, on average, students who demand greater amounts of leisure do not necessarily get extra hours of sleep.

Figure 4. Student Type 1 (schoolwork lover)

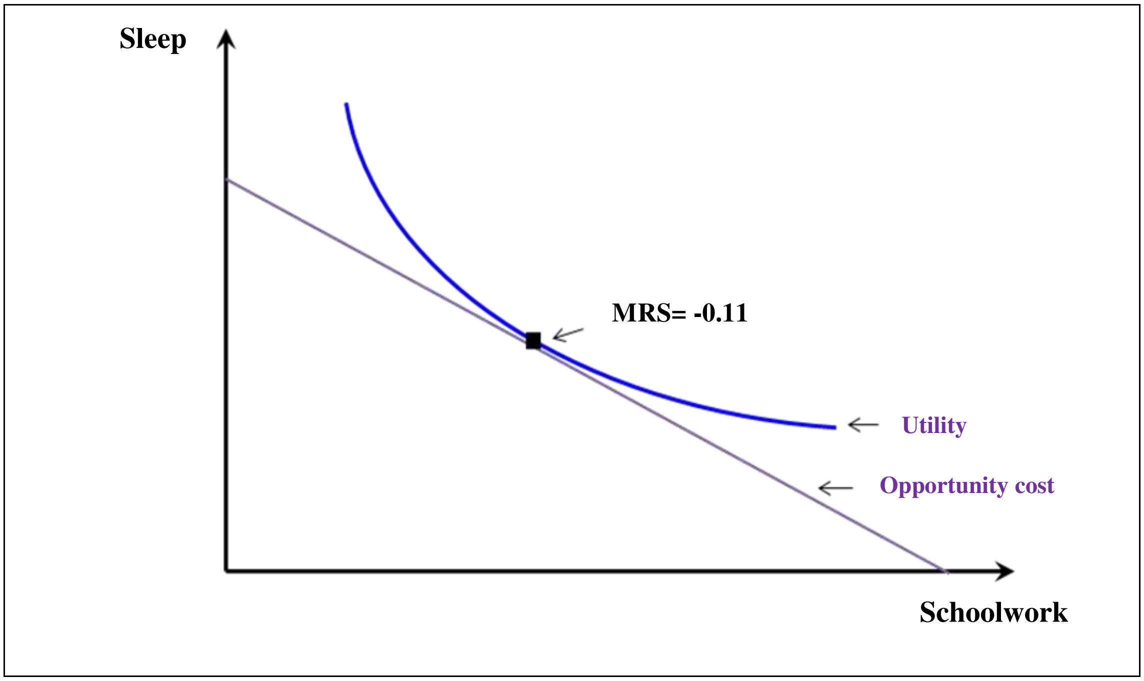
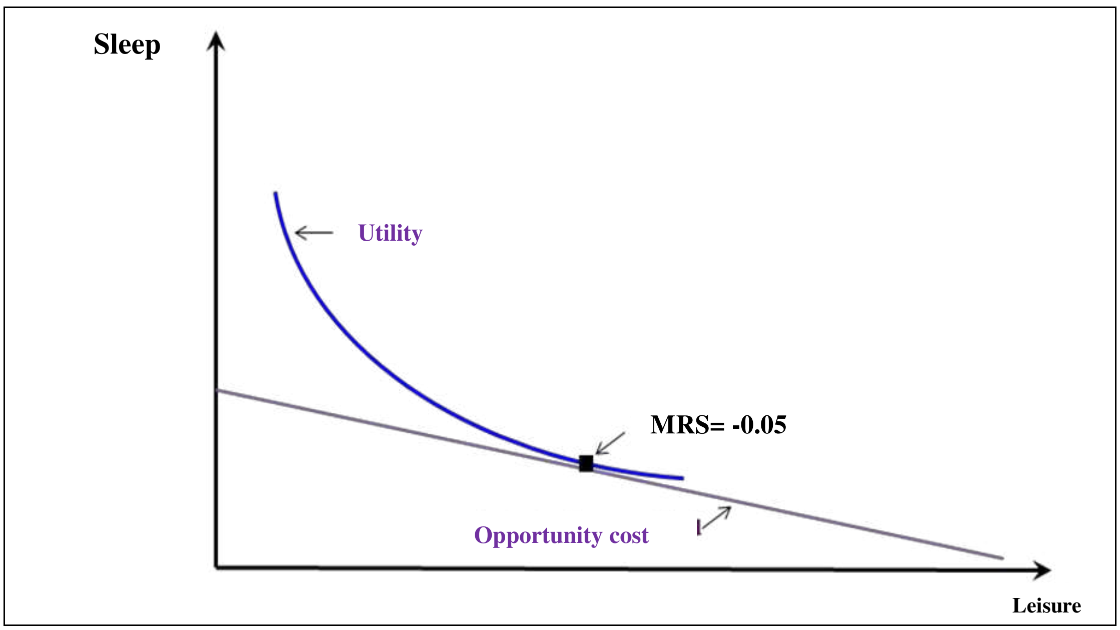


Figure 5. Student Type 2 (leisure lover)



The above results show that on-campus students are classified into two types: type (1), schoolwork lovers, and type (2), leisure lovers. Student type (1) may have low amounts of leisure and sleep at a time and is willing to substitute 0.11 hours of sleep and/or 0.18 hours of leisure in exchange for an additional hour of schoolwork (see Figure 4). On the other hand, the student type (2) is willing to sacrifice only 0.05 hours of sleep to obtain an additional hour of leisure (Figure 5).

In line with what is established in the previous analysis, a first explanation arises linked to marginal analysis called "economic explanation".[23] This indicates that the willingness of student type (1) to sacrifice sleep for additional schoolwork is much higher than the willingness of student type (2) to substitute sleep for extra leisure.

However, there are also genetic factors that play an important role in the decisions about sleep.[24] In this regard, Dement and Vaughan (1999) have suggested that the loss of sleep is cumulative and similar to a monetary debt that must be paid. That is, if a person sleeps less than what the body needs (need for sleep) he/she will incur in a "sleep debt", as it is deduced from the position of these authors: "…*the important thing is that the size of the sleep debt and its dangerous effects are definitely directly related to the amount of lost sleep.*" (Dement and Vaughan,1999, p. 60). Because of this phenomenon, this study provides the incidence of biological factors[25] in the inverse relationship between *sleep* and *GPA*.

There is a second explanation with regards to the students´ alternatives to bedtime, so-called "genetic explanation". [26] This suggests that there are two groups of students. A group with a relatively lower sleep need and a group with a relatively higher sleep need. The former have an academic edge over the latter because they have a greater allocation of time to study. In short, the "genetic explanation"

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[23] The "economic explanation" refers to the understanding of an issue or event from the perspective of Economics.

[24] Genetic factors are elements or circumstances related to the inheritance of characteristics or qualities that determine the behavior of a human being.

[25] Biological factors are elements or circumstances related to the biology that determine the behavior of a human being.

[26] The "genetic explanation" refers to the understanding of an issue or fact based on genetic criteria.

supposes that the hours of sleep required by the student are due to genetics. To account for this, we create the explanatory variable "sleep need". This explanatory variable is the average of the hours of sleep per night of students´ parents. To calculate it, we assumed that the hours devoted to sleep for both mother and father are approximately equal to their sleep need, and the sleep need of their children is proportional to the average between both parents.

Additionally, we generated the explanatory variable "sleep deviation" which measures the difference between the students´ hours of sleep per night minus their sleep need. This variable represents the choice of sleep for each student. In Table 6, we estimated the following model:

$$GPA = \beta_o + \beta_1 \textit{(Sleep need)} + \beta_2 \textit{(Sleep deviation)} + \beta_3 \textit{(Age)} + \beta_4 \textit{(Male)} + \beta_5 \textit{(Urban)} + \beta_6 \textit{(Public)} + u_i$$

Table 6. Robust linear regression with explained variable *GPA*

Variable	Coefficient
sleep need	-0.057 (0.043)
sleep deviation	-0.041 (0.041)
age	0.016 (0.009)
male	-0.248 (0.103)**
urban	0.003 (0.095)
public	-0.006 (0.101)
constant	3.9 (0.447)**
R^2	0.101
Observations	88

** Statistically significant at 5%

Then we examine the hypothesis $\beta_1 = \beta_2$. First, the “genetic explanation” establishes that if $|\beta_1| > |\beta_2|$ then the “sleep need” is a higher indicator of GPA tan the choice of sleep hours. Conversely, the “economic explanation” suggests that if $|\beta_2| > |\beta_1|$ then the choice of sleep hours turns out to be the higher indicator of GPA.

Based on Table 6, it is shown that = -0.06, indicating that for each additional hour of sleep need, the GPA is reduced by about 0.06. This coefficient is almost three quarters more than the value of β_2 (-0.04), indicating that for each additional hour of sleep chosen above the sleep need, the student´s GPA decreases by 0.04. Therefore, it is not possible to reject the hypothesis: $|\beta_1| > |\beta_2|$. This hypothesis suggests that, for the GPA of students, is much more damaging an increase in sleep need than to choose additional hours of sleep over their respective sleep need. However, the genetic explanation (β_1) as well as the economic explanation (β_2) are valid if we take into account the negative sign of both estimators.

Table 6 also shows that the variable *male* has an estimated coefficient of -0.248. This coefficient indicates that, holding other factors constant, at the Universidad del Atlántico, male students obtained 0.25 points less on their GPA than female students. The estimated coefficient of the variable *age* (0.02) indicates that, *ceteris paribus*, the older the student the higher will be his/her GPA.

As to gender, empirical evidence suggests that, on average, women sleep more than men when including gender differences such as employment status, hours worked and potential wage. However, when these factors are kept constant the result gets inverted (Biddle y Hamermesh, 1990, p. 928). In turn, Stolzar (2006) corroborates the finding of Biddle and Hamermesh establishing significant differences regarding sleep time between women and men, in behalf of the latter. Conversely, we found that, among college students, women sleep more than men.

4. College Student Academic Productivity Model

We define a representative student that maximizes a utility function subject to two constraints (budget and time). In this model, the student´s utility is a function of his/her health, entertainment[27] and academic performance. Suppose that Z_1 is an indicator of the health of the student, Z_2 an indicator of their level of entertainment and Z_3 an indicator of their academic performance. In formal terms, the utility is expressed as

$$U\,(Z_1, Z_2, Z_3) \qquad (1)$$

[28]

Each of these Zj (where j = 1, 2, 3) is generated by a production function that combines two inputs (market goods and time). The budget constraint implies that each student has a fixed M such that

$$M = \sum p_j\, x_j \qquad j = 1, 2, 3 \qquad (2)$$

where x_1, x_2 and x_3 represent the goods used in the production of health, entertainment and academic performance, respectively, and p_1, p_2 and p_3 are the respective unit prices of each good. The time constraint is denoted as:

$$T = t_1 + t_2 + t_3 \qquad (3)$$

where T is the student´s endowment of total time, t_1 the hours devoted to sleep, t_2 those devoted to leisure, and t_3 those devoted to schoolwork.

Each student has a "conventional production function" of the form:

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27 Entertainment is the level of fun or recreation that makes more enjoyable people´s time.

28 $\partial U/\partial Z_j > 0$ (for j= 1, 2, 3), so any increase in Zj increases overall utility and, $\partial^2 U/\partial Z_j^2 < 0$ (for j= 1, 2, 3), indicating the compliance with the law of diminishing marginal utility.

$$\left.\begin{array}{l} Z_1 = f_1\,(t_1, x_1) \\ Z_2 = f_2\,(t_2, x_2) \\ Z_3 = f_3\,(t_3, x_3) \end{array}\right\} \qquad (4)$$

First, we assume that the hours spent sleeping (t_1) do not directly affect entertainment (Z_2) and academic performance (Z_3) production functions. Also, the hours devoted to leisure (t_2) do not directly affect health (Z_1) and academic performance (Z_3) production functions. Finally, the schoolwork (t_3) does not directly affect the production of health (Z_1) or the production of entertainment (Z_2).

From the viewpoint of mathematical programming, the representative student solves the following primal problem:

Max U (Z_1, Z_2, Z_3)
Subject to ($M = \sum p_j\, x_j$) y ($T = \sum t_j$)

The Lagrangian is:

£ = £ (t_1, t_2, t_3, x_1, x_2, x_3, λ, μ) = U [$f_1\,(t_1, x_1)$, $f_2\,(t_2, x_2)$, $f_3\,(t_3, x_3)$] + λ ($M - \sum p_j\, x_j$) + μ ($T - \sum t_j$), where λ y μ are Lagrange´s multipliers.

The first order conditions are:

$$\frac{\partial £}{\partial x_j} = \left(\frac{\partial U}{\partial Zj}\right)\left(\frac{\partial f_j}{\partial x_j}\right) - \lambda\, p_j = 0 \qquad j = 1, 2, 3$$

$$\frac{\partial £}{\partial t_j} = \left(\frac{\partial U}{\partial Zj}\right)\left(\frac{\partial f_j}{\partial t_j}\right) - \mu = 0 \qquad j = 1, 2, 3$$

$$\frac{\partial £}{\partial \lambda} = M - \sum p_j\, x_j = 0$$

$$\frac{\partial £}{\partial \mu} = T - \sum t_j = 0$$

From the first order conditions, it follows that time is allocated between health and entertainment so that:

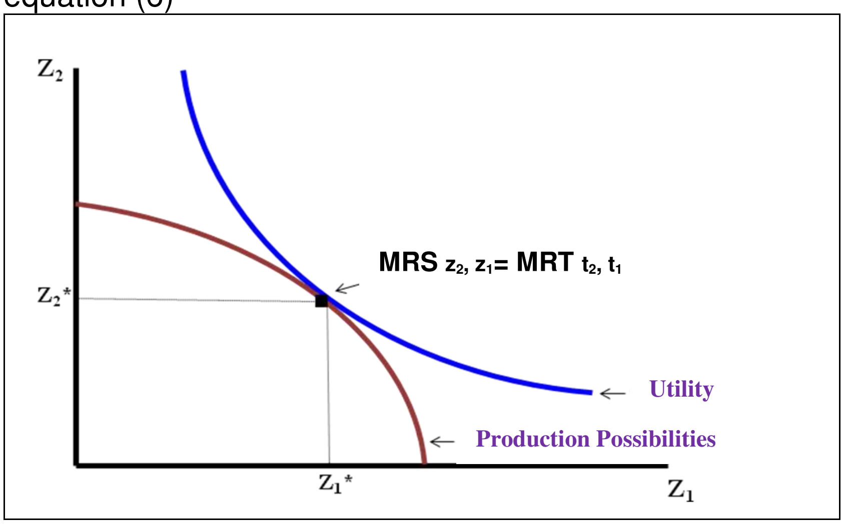
$$\left(\frac{\partial U}{\partial Z_1}\right)\left(\frac{\partial f_1}{\partial t_1}\right) = \left(\frac{\partial U}{\partial Z_2}\right)\left(\frac{\partial f_2}{\partial t_2}\right) \qquad (5)$$

Rearranging (5) in terms of the marginal utilities we have,

$$\left(\frac{\partial U}{\partial Z_1}\right)\Big/\left(\frac{\partial U}{\partial Z_2}\right) = \left(\frac{\partial f_2}{\partial t_2}\right)\Big/\left(\frac{\partial f_1}{\partial t_1}\right) \qquad (6)$$

Equation (6) shows that the ratio of marginal utilities (MRS) between health (Z_1) and entertainment (Z_2) should be equal to the ratio of marginal productivities or marginal rate of transformation (MRT) between leisure (t_2) and sleep (t_1).

Figure 6. Hypothetical graphical representation of the tangency condition given by equation (6)



To understand the differences in the allocation of time among the students we will assume that they will face the same market prices (*p_1, p_2* and *p_3*). However, it may happen that:

1) M is different for each student, and
2) The production functions $Z_j = f_j\ (t_j, x_j)$ vary among students.

Here we explore the validity of possibility (2). This means that to produce one unit of Z_j it is required a fixed amount of x_j and t_j. It follows that the production function Z_j corresponds to a specification of fixed proportions[29] as follows:

$x_j / a_j = Z_j$ y $t_j / b_j = Z_j$ for j = 1, 2, 3.

Thus, the ratio of marginal productivities between leisure and schoolwork is:

$$\left(\frac{\delta f_3}{\delta t_3}\right) \Big/ \left(\frac{\delta f_2}{\delta t_2}\right) = \frac{b_2}{b_3}$$

Assume that a_j and b_j vary among college students so that the student time allocation is reduced to the following three equations:

$t_{1i} = \varepsilon_{1i}\ (a_{1i}, a_{2i}, a_{3i}, b_{1i}, b_{2i}, b_{3i}, M_i)$ for i= 1, …, N
$t_{2i} = \varepsilon_{2i}\ (a_{1i}, a_{2i}, a_{3i}, b_{1i}, b_{2i}, b_{3i}, M_i)$ for i= 1, …, N
$t_{3i} = \varepsilon_{3i}\ (a_{1i}, a_{2i}, a_{3i}, b_{1i}, b_{2i}, b_{3i}, M_i)$ for i= 1, …, N

where the subscript i indicates the ith student and N is the total number of university students. Assuming that students face the same market prices (*p_1, p_2* and *p_3*), we proceed to evidence hypothesis 5. Since the fact that with the data obtained we cannot find health indicators (Z_1) and entertainment (Z_2), we only applies Leontief production function to academic achievement (Z_3). To do this, we assume that the GPA is a ratio of Z_3 ($Z_3 = \psi_i\ (GPA)_i$). In this sense, it follows that $Z_3 = (t_3/b_3)$.

[29] A fixed proportions specification represents a Leontieff production function.

The essential purpose is to determine how b_3 (productivity of schoolwork in the production of GPA) varies among college students in line with their gender, origin and school records. Thus, we estimate the equation after making the following algebraic simplifications:

$\psi * PA = (t_3 / b_3)$

$PA = (t_3/ (b_3 * \psi))$

$\ln (PA) = \ln (t_3) - (\ln (b_3) + \ln (\psi))$

$\ln (PA) – \ln (t_3) = - (\ln (b_3) + \ln (\psi))$

$\ln (PA/ t_3) = - \ln (b_3) - \ln (\psi)$

where $- \ln (b_3)$ is estimated as:

$\beta_0 + \beta_1(Age)_i + \beta_2(Male)_i + \beta_3(Urban)_i + \beta_4(Public)_i$

and $-\ln (\psi_i) = u_i$, where u_i is the stochastic error term.

We estimate the following regression:

$ln(GPA/schoolwork)_i = \beta_0 + \beta_1(Age)_i + \beta_2(Male)_i + \beta_3(Urban)_i + \beta_4(Public)_i + u_i$,

Additionally, we asume that $b_3 = e^{-\varphi}$, where

$\varphi = \beta_0 + \beta_1(Age)_i + \beta_2(Male)_i + \beta_3(Urban)_i + \beta_4(Public)_i$

If β_x (where x = 1, 2, 3, 4) is positive, it means that an increase in the corresponding explanatory variable reduces b_3. The lower b_3 the most productive will be an hour of schoolwork (t_3) in production of GPA. Therefore, a $\beta x > 0$ indicates that the corresponding explanatory variable has a positive effect on the marginal productivity of GPA per hour of schoolwork. In the previous estimations the following categories serve as reference groups: female, provincial students[30] and attendance to private high schools.

Table 7. Robust regression with explained variable ln(GPA/schoolwork).

Variable	**ln(GPA/schoolwork)**
age	0.043 (0.014)*
male	-0.073 (0.083)
Urban	0.108 (0.079)
public	0.050 (0.081)
constant	-1.519 (0.335)*
R^2	0.152
Observations	88

* Statistically significant at 1%

As seen in Table 7, the estimated coefficient of the variable age indicates that, assuming other factors fixed, the older the student the higher will be his/her productivity of schoolwork in the production of GPA. Similarly, for each additional year of age, the student will devote less hours of schoolwork (see the column schoolwork in Table 5). Therefore, younger students produce fewer units of GPA per hour of schoolwork, since they spend more hours to the latter[31].

As for the estimated coefficient of the variable *male* (-0.073), this indicates that, ceteris paribus, college women produce more units of GPA per hour of schoolwork than their male counterparts (since b_3 is higher in this case). This result, along with the fact that on campus women spend more hours of schoolwork than men (please, see again the column schoolwork in Table 5) reflects the fact that, on average, the former group obtain greater GPAs than the latter.

[30] In this research, provincial student refers to students who do not come from departmental city capitals.

[31] In this sense, the marginal productivity per hour of schoolwork indicates that it operates the law of diminishing marginal returns in the production of GPA.

In order to extend the interpretation of the productivity of schoolwork, it should be considered that the schoolwork is the outcome of two components: hours of school and hours of study. Thus, we examine the productivity of each of these two types of schoolwork in the production of GPA. In Table 8, it is shown the estimations of ln(GPA/classes) and ln(GPA/study) respectively, on the variables *age, male, urban, public*. In these regressions, attending classes is a better indicator of growth in the GPA rather than to study outside the classroom.

Table 8. Robust regressions with explained variables ln(GPA/classes) and ln(GPA/study).

Variable	**ln(GPA/classes)**	**ln(GPA/study)**
Age	0.039 (0.019)**	0.045 (0.021)**
Male	- 0.087 (0.099)	-0.025 (0.179)
Urban	0.126 (0.099)	0.154 (0.172)
Public	0.147 (0.100)	-0.138 (0.211)
Constant	-1.036 (0.438)	-0.239 (0.577)
R^2	0.099	0.047
Observations	88	88

** Statistically significant at 5%

Regarding the variable *public*, it passes from positive in the column ln (GPA / classes) to be negative in the column ln (GPA / study). In the regression ln (GPA / classes) of Table 8, the estimated coefficient of *public* indicates that those college students who graduated from a public high school are more productive in an hour of classes than those students who come from a private high school. However, the productivity of one hour of study by students from public high schools is smaller in relation to their peers graduated in private high schools.

Finally, in the regression ln (GPA / classes) the estimated coefficient of *urban* (0.13) indicates that, *ceteris paribus*, urban students are more productive per hour of class in producing GPA. However, provincial students attend more classes than urban students.[32] Under these conditions, provincial students have, on average, higher GPAs than urban students.[33] In this case, class attendance contributes more to the productivity per hour of classes in the production of GPA.

5. Conclusions

The current debate on the impact of incentives on the allocation of time spent sleeping can find answers in the field of economics. In this study, we observed that for each additional point in the GPA of a student at the Universidad del Atlántico his/her average hours of sleep per night is reduced by two fifths. If we compare this result with that obtained in Stanford University we would have the following demand functions of sleep:

- Demand of sleep for students at Universidad del Atlántico, *ceteris paribus:*
  Sleep* = a – (2/5) *GPA

- Demand of sleep for students at Stanford University, *ceteris paribus*:
  Sleep* = *s* – (24/25) *GPA

where ***a*** and ***s*** are the *y*-intercepts.

From the demand functions above, it follows that there is a sleep opportunity cost for college students: in this case, higher for the Stanford´s representative student. Still, both functions show an unhealthy result considering that students with better average sleep less. Indeed, previous research suggests that sleep loss adversely affects the ability to perform simple and complex tasks, creativity, memory and even cognition (Dement and Vaughan, 1999; Van Dongen *et al*., 2003; Turner *et al*., 2007).

[32] Provincial students attend classes 4.37 hours a day on average, while urban students attend only 4.07.

[33] The arithmetic mean of provincial students´ GPAs is 3.73, while that of urban students is approximately 3.55.

However, the results found here indicate that obtaining a high GPA means sacrificing sleep hours. Hence, part of the college student´s decision to sleep depends on the academic incentives he/she possesses. From an economic perspective, college students must get a quantity of sleep (sleep optimal choice) such that the marginal utility of their health equals to the marginal utilities of their entertainment and academic performance. Therefore, the optimal choice of sleep for students at the Universidad del Atlántico is between 5.57 and 12 hours per day.

Additionally, we found differences in age, gender, origin and educational background in the allocation of time in relation to the opportunity cost per hour-college student. According to the findings, the productivity of an hour of schoolwork in the production of GPA depends on age (less for the younger) and gender (higher for women). This phenomenon corresponds to the fact that college women boast higher GPAs compared to men. It should be noted, however, that college women spend, on average, more hours of schoolwork, sacrificing their leisure hours instead of sleep hours. Thus, the relation between the number of hours of schoolwork and higher productivity per hour of schoolwork would explain the fact that women show evidence of higher academic performance.

It should be emphasized that this research did not consider other variables that may influence the allocation of time spent sleeping by college students. In future studies on this subject it would be appropriate to include explanatory variables such as income level, socioeconomic status, type of career, etc…

In summary, we have shown that sleep time is an activity, like others, that could be analyzed within the framework of economic theory. Indeed, a fraction of the allocation of time spent sleeping depends on rational individual choice. Furthermore, considering that sleep time covers approximately a third of people´s lifetime, the time spent on other activities becomes relatively scarce. This implies that sleep is a resource from which college students can extract time when making valuable other uses of their time.

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