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# Microeconomic Policy for Development:
# Essays on Trade and Environment, Poverty and Education

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*To my princesses:*
*Mariangela, Amanda and Elizabeth*

*To my loved parents*

# Contents

# Abstracts

This thesis contains three papers analyzing different issues

***Paper 1: "Do Countries with Lax Environmental Regulations Have a Comparative Advantage in Polluting Industries?"***

We study whether lax environmental regulations induce comparative advantages, causing the least-regulated countries to specialize in polluting industries. We seek to improve three areas in the empirical literature based on the Heckscher-Ohlin-Vanek's factor content of trade, more specifically in Tobey's (1990) approach: the measurement of environmental endowments, the possible endogeneity due to an omitted variable that has not been considered, and the influence of the industrial level of aggregation. For the econometrical analysis, we use a cross-section of 71 countries to examine the net exports in the most polluting industries in the year 2000. As a result, we find that industrial aggregation matters and we find some evidence in favor of the pollution-haven effect.

***Paper 2: "Poor Areas or Poor People: Decomposing differences in living standards and poverty"***

Several studies report large and persistent differences in standards of living and poverty within a country. In this paper, we study whether the observed differences in poverty incidence in urban areas are due to differences in the attributes of the population living in these zones or come from differences in the value of these attributes in the different areas. For this purpose, we apply decomposition analysis. We illustrate the

methodology comparing urban areas in 13 Chilean regions for the year 2003. We found that even after controlling for an ample set of household characteristics, differences in the parameters are an important determinant of household income and poverty within a country.

***Paper 3: "Absenteeism and Time-Inconsistent Behavior. Should we make lecture attendance compulsory?"***

We investigate the problem of absenteeism in an educational program with time-consistent and naïve time-inconsistent students and the effect that mandatory attendance has on the behavior and well-being of the students. We observe that time-inconsistent students tend to postpone lecture attendance such that they are more likely to be absent from lectures located in the first part of the term while they later show up in the second part of the course. Absenteeism rates are not necessarily lower for naïve time-inconsistent vis-à-vis time-consistent students; nevertheless, the performance of time-inconsistent students is worse in any case. We showed that the well-being of myopic time-inconsistent students could be dramatically reduced because of the shortcoming in their intertemporal preferences. Therefore, it seems as mandatory attendance could benefit these students in the classroom, although there is some possibility of harming the time-consistent. The outcome depends on the distribution of the benefits and costs of lecture attendance along the term, which requires empirical evaluation.

# Preface

First of all, I would like to express my sincere gratitude to my thesis supervisors Thomas Sterner and Renato Aguilar for their continuous guidance, encouragement and support. I am deeply indebted to Thomas without his help and patience especially in the last stage of this work I might have not come back to the academic world.

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Miguel Quiroga

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# Introduction

The papers of this thesis analyze three different issues at three different scopes or aggregation levels. The papers range from the analysis of the international trade at the country level to the analysis of lecture attendance at the individual level, passing through the analysis of geographic poverty differences within a country. Nevertheless, the analysis of the interaction between economic theory and economic policy serves as a common element tying together these pieces of work. They investigate the relation between environmental regulation and international trade, regional policy and geographic poverty differences, and mandatory attendance and absenteeism in an educational program.

In the first paper, we study whether lax environmental regulations induce comparative advantages, causing the least-regulated countries to specialize in polluting industries. The subjacent hypothesis asserts that environmental policies could modify the environmental endowment of a country and that differences in environmental endowments among countries influence their comparative advantage. Thus, for instance, lax environmental standards extend the availability of environmental inputs in the production process, reducing environmental control costs and increasing net exports in "pollution-intensive" sectors — the so-called "pollution-haven effect" described by Copeland and Taylor (2003, 2004). The Heckscher-Ohlin-Samuelson (HOS) theorem is a natural framework for analyzing whether changes in the availability of environmental endowments influence the comparative advantage in a country. Scholars use Vanek's factor-content prediction (HOV) to study input services — say capital, labor, land, or natural resources — included in a country's net exports. We seek to improve three areas in the empirical literature based on the Heckscher-Ohlin-Vanek's factor content of trade, more specifically in Tobey's (1990) approach: the measurement of environmental endowments, the possible endogeneity due to an omitted variable that has not been considered, and the influence of the level of aggregation of the industries studied. For the econometric analysis, we use a cross-section of 71 countries to examine the net exports in the most polluting industries in the year 2000. As a result, we find that industrial aggregation matters and we find some evidence in favor of the pollution-haven effect.

The second paper is motivated by the observation that several studies report large and persistent regional differences in poverty incidence within a country. These geographic differences in household ability to reach minimum living standards motivate governments and aid organizations to allocate resources according to the location of the households and productive units. Nevertheless, the arguments in favour of policy that targets poor areas are not clear. On the one hand, geographic differences for poverty and living standards could be attributed to the co-localization of households with similar characteristics. In equilibrium, if there were no restrictions to household mobility, households could enjoy the same welfare wherever they lived and it would be a better policy to directly target the attributes that cause these households to remain poor. On the other hand, in certain contexts, regional or local attributes could influence household living standards and the probability of being poor in such a way that the same household might face different income prospects based on where they live. In some cases, interactions between geographical capital and household attributes provide the mechanism in a context of limited household mobility. The same household could experience a higher living standard in a richer local environment. Public goods, knowledge spillovers, and favorable agro-climatic conditions among other factors, may generate such a favorable environment. Other models consider market imperfections that arise from local externalities that could hurt poor households more severely. In this paper, we study whether the observed differences in poverty incidence in urban areas are due to differences in the attributes of the population living in these zones or come from differences in the value of these attributes in the different areas. For this purpose, we propose a methodology for comparing living standards and poverty incidence in different regions using a cross-section of household micro-data. The objective is to distinguish whether differences in living standards and poverty incidence come from the concentration of poorly endowed households or come from differences in the influence that household attributes have on the standard of living among regions.We illustrate the methodology comparing urban areas in 13 Chilean regions for the year 2003. We found that even after controlling for an ample set of household characteristics, differences in the parameters are an important determinant of household income and poverty within a country.

In the third paper, we assume that the lessons or lectures held by a teacher or instructor are an important component of a course. Therefore, we investigate the consequences that self-control problems have on lecture absenteeism. We examine the effect that mandatory attendance has on well-being and behavior of the students as well. Our approach combines a human capital model and a signaling model. We assume that attendance to lessons increases productivity. Attendance is important for passing the exam and achieving a higher academic qualification. Firms observe whether workers were successful in their studies; they know whether they graduate or not. This information is a signal to firms about the expected productivity of each worker. Furthermore, firms have access to the grades obtained by graduated students. Based on this information, firms remunerate workers based on the results that they achieved in the courses. The results show that lecture absence could be a severe problem for students with time-inconsistent intertemporal preferences. Time-inconsistency reduces the well-being of these students and affects their performance in the course, but how does it influence absenteeism? The answer is ambiguous. The presence of time-inconsistency could even reduce student absenteeism under certain circumstances. Mandatory attendance could increases the well-being of the time-inconsistent students, but it could reduce the well-being of time-consistent students as well. The convenience of this policy depends on how mandatory attendance modifies the absenteeism profile of time-inconsistent students. This is associated to the severity of the time-inconsistency, the distribution of benefits and the costs of lecture attendance along the term, and the number of lectures in a course. The negative effect that compulsory attendance produces on time-consistent students is associated to the magnitude of the benefits and costs that make them deviate optimally from a perfect attendance register.

All three chapters may be thought of as belonging to the classical core of economics. We study in what way unregulated market outcomes may deviate from an optimal or desirable state and analyze the possible contribution that some form of regulation may provide. The range of subjects is broad: the sources of market imperfection come from external effects, inconsistencies in our preference structure and geographic features but many underlying principles are similar.

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# Paper I

# Do Countries with Lax Environmental Regulations Have a Comparative Advantage in Polluting Industries?*

*Miguel Quiroga*

**Abstract**

We study whether lax environmental regulations induce comparative advantages, causing the least-regulated countries to specialize in polluting industries. We seek to improve three areas in the empirical literature based on the Heckscher-Ohlin-Vanek's factor content of trade, more specifically in Tobey's (1990) approach: the measurement of environmental endowments, the possible endogeneity due to an omitted variable that has not been considered, and the influence of the industrial level of aggregation. For the econometrical analysis, we use a cross-section of 71 countries to examine the net exports in the most polluting industries in the year 2000. As a result, we find that industrial aggregation matters and we find some evidence in favor of the pollution-haven effect.

**Key Words:** trade, comparative advantage, pollution haven, environmental endowment, environmental regulation, Porter hypothesis, factor content, aggregation bias, non-homothetic preferences.

**JEL Classification:** F18, Q56

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* Research collaboration on this paper with Martin Persson and Thomas Sterner is gratefully acknowledged. They suggested this subject and had even done some exploratory work before I was involved. I have however had the main responsibility for the development of both the theoretical analysis in its present form as well as the current empirical analysis.

## 1. Introduction

In the last two decades, environmental concern has emerged as a relevant issue in trade liberalization. The debate stems from the fear that countries use less stringent environmental policies to gain a comparative advantage in polluting industries.

We investigate to what extent differences in environmental policy among countries provide a source of comparative advantage. The subjacent hypothesis asserts that the environmental endowment of a country could be modified using environmental policies and that differences in environmental endowments among countries influence the comparative advantage of a country. Thus, for instance, lax environmental standards extend the availability of environmental inputs in the production process, reducing environmental control costs and increasing net exports in pollution-intensive sectors — the so-called “pollution-haven effect” described by Copeland and Taylor (2004). Although some theoretical research supports this proposition (see Chilchilnisky 1994; Copeland and Taylor 1994; McGuire 1982; Siebert 1977; Pethig 1976), empirical studies have not found robust results corroborating the hypothesis.[1]

The Heckscher-Ohlin-Samuelson (HOS) theorem is a natural framework for analyzing whether changes in the availability of environmental endowment influence the comparative advantage in a country. Scholars use Vanek’s factor-content prediction (HOV) to study input services — say capital, labor, land, or natural resources — included in a country’s net exports. In an offshoot of this literature, Tobey (1990) accommodated the comprehensive empirical study published by Leamer (1984) to analyze whether differences in the stringency of environmental regulations influence the comparative advantages in five pollution-intensive industries. Tobey’s

[1] The literature has been reviewed by Jaffe et al. (1995), Rauscher (1997), and recently by Copeland and Taylor (2004).

research was based on a cross-section analysis of net exports in these industries, with country measures of factor endowments and a qualitative measure of environmental stringency as explanatory variables. He did not find evidence that environmental regulation determined net exports in any of the industries. The study, however, was constrained by the low number of degrees of freedom (Copeland and Taylor 2004). In response, most contemporaneous studies increased the number of observations in the estimations. For instance, Murrell and Ryterman (1991) include East European economies, and Cole and Elliott (2003) use a more updated dataset that includes 60 countries for 1995.

The endogeneity of the variable measuring strictness of environmental regulations has also been a concern in the literature, as countries could reduce the stringency of environmental policy when net exports are threatened by international competition.[2] As recognized by Cole and Elliot (2003), however, it is improbable that this problem could be serious in Tobey's framework, since net exports in a specific industry are not likely to influence environmental regulation at a country level. Even so, Cole and Elliot (2003) estimated the net exports in a polluting industry and the stringency of the environmental regulation using simultaneous equations. Evidence of pollution-haven effect has not been found in any of these extensions of Tobey.

In this paper, we aim to address three areas in which we believe there is room for improvement in Tobey's (1990) approach: the measure of environmental endowments, endogeneity due to dissimilarity in the consumption patterns across countries, and the level of aggregation of the industries considered in the analysis.

[2] Governments could use the environmental policy as a second-best trade policy when they face limitations on pursuing trade goals using trade policy (e.g., Trefler 1993; Ederington and Minier 2003).

Leamer's (1984) empirical analysis uses endowment of productive factors as controls for analyzing comparative advantages. Furthermore, models that link natural resources and production usually consider emissions of pollutants as one of the factors in the production process (Ayres and Kneese 1969). Therefore, if firms in a country face stricter environmental regulations (if they are obligated to reduce emissions), then the shadow price of the emission unit will rise and it will be necessary to increase the amount of other inputs to keep the level of production. Tobey (1990) and subsequent studies have not used a measure of pollution or emission directly when they control for environmental endowment. They use a proxy variable measuring the stringency of the environmental regulations instead. The index relates to a country's efforts in environmental protection, e.g., legislation, expenditures on environmental research, and pollution abatement and control, among others.[3] However, the shadow price of a unit of emission does not only depend on the stringency of regulations "on paper," but also on the natural advantage, nature of enforcement, gains in efficiency (e.g., Porter and van de Linde 1995), and offsetting subsidies supporting pollution-intensive industries (see Baumol and Oates 1988; Eliste and Fredriksson 2002). As a result, Jaffe et al. (1995, page 144) claim that the meager evidence of pollution haven "…could be due to no more than the failure of the ordinal measure of environmental stringency to be correlated with true environmental control costs." We believe that the direct measure of pollutants or emissions might be a better measure. They take into account not only the stringency, but also the enforcement of environmental regulations and of any subsidy or domestic policy offsetting some of the effects of stricter regulations. Therefore, in this study we incorporate a measure directly based on emissions to capture the environmental

[3] See Walter and Ugelow (1979), Tobey (1990) and Murrell and Ryterman (1991). The index developed by Dasgupta et al. (2001), used in the empirical work of Cole and Elliott (2003), is also based almost exclusively on input-oriented indicators.

endowment in the empirical analysis. We expect that a more stringent environmental policy will reduce environmental endowments available for use in production and emissions. Reduced availability of environmental services will increase the use of primary factors for controlling pollution, increasing production costs and reducing the net exports of goods that use environmental services intensively.

The second area in which we believe we can contribute is linking this literature to more recent research on the factor content of trade in international economics. The factor content of trade claims that international trade is an indirect way of exchanging factors (Vanek 1968). Recently, Trefler and Zhu (2005) formulated a more general definition of the factor content of trade that allows trade in intermediate input and variation in technology across countries. The authors show that this definition is not consistent with Vanek's factor content prediction. In our paper, we use this result to show that even when it is assumed that technology is the same across countries, the less restrictive definition of the factor content of trade includes a dissimilarity consumption term that researchers have not been controlling for. We believe that the consumption condition could be positively correlated with the environmental endowment, which could make the Ordinary Least Square (OLS) parameters downward biased, reducing the ability to identify evidence of a pollution haven. We therefore use Instrumental Variables (IV). To the best of our knowledge, this source of endogeneity has not been empirically analyzed previously.[4]

The third aspect we address is the level of aggregation. Earlier studies examine trade in aggregate commodity groups. As these groups include a wide array of industries with different pollution intensities and levels of environmental control costs, the effect of environmental policy

[4] Although another source of endogeneity could come from the fact of using emissions as explanatory variables, we believe that this problem is not serious because we are considering national emissions as explanatory variable but net export in a particular industry.

on trade might not be detected because control costs could be canceled out when heterogeneous units are pooled. Thus, aggregation may mask shifts in the division of labor between polluting and non-polluting activities within an industrial sector. In this paper, we estimate the empirical specification at a more disaggregated level to see if aggregation is of significance.

Our empirical analysis is based on a cross-section of 71 developed and developing countries in 2000.[5] Previously published studies used cross-sections of countries for the years 1995 or 1975 (Cole and Elliott 2003; Murrell and Ryterman 1991; Tobey 1990). The fact that we use more up-to-date data is an important advantage because considerable progress has been made recently in tariff reduction and reduced barriers to trade around the world. According to the World Trade Organization (WTO) (http://www.wto.org), developed countries have cut their tariffs on industrial products by 40 percent between 1995 and 2000. The value of the imported industrial products rose from 20 to 44 percent, and the proportion of imports facing tariff rates above 15 percent fell from 7 to 5 percent. This stresses the importance of trade and comparative advantage as determinants of the pattern of trade. This is illustrated by the world's openness to trade, i.e., the sum of exports and imports as a percentage of gross domestic product (GDP). In 1975, trade openness was 33 percent, but in the following 20 years it increased to 42 percent, and finally to 49 percent from 1995 to 2000 (World Bank's website, 2006). We believe that this dramatic increase in world trade (as well as increases in environmental regulation) might increase the

[5] Countries included in the analysis: Algeria, Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Denmark, Ecuador, Egypt, El Salvador, Ethiopia, Finland, France, Gabon, Germany, Ghana, Greece, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Ireland, Italy, Japan, Jordan, Kenya, Republic of Korea, Luxembourg, Macau, Madagascar, Malaysia, Mauritius, Mexico, Morocco, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Portugal, Senegal, Singapore, Slovak Republic, South Africa, Spain, Sweden, Switzerland, Syrian Arab Republic, Thailand, Tunisia, Uganda, United Kingdom, United States, Uruguay, Venezuela, and Zimbabwe.

probability of finding evidence of pollution havens, especially if polluting industries have been more affected by barriers to trade in the past.

We choose to analyze the most polluting industries and to work at a more disaggregated (3-digit) level.[6] We estimated a model in which the net exports were regressed on the endowments of inputs, including two environmental variables based on emissions of sulfur dioxide ($SO_2$) and organic matter in wastewater, measured as biological oxygen demand (BOD).

Preliminary analysis of this data at the aggregate level using OLS finds evidence of the pollution-haven effect only in the non-metallic minerals sector. Some of the other subsectors even exhibited evidence in the opposite direction. Such positive effects of environmental regulation are known in the literature as the Porter hypothesis, interpreted as the result of technological innovation triggered by regulation (Porter and van de Linde 1995). In this case, the stricter environmental policy increases profitability and net exports for the industries concerned. Many economists find that the Porter hypothesis flouts logic since it is not clear why companies fail to undertake profitable improvements before being forced by the regulator (e.g., Palmer, Oates, and Portney 1995). To scrutinize the evidence we disaggregate data and use Instrumental Variables (IV) to correct for endogeneity. As we will see, this modifies the results.

In the following section, we present the conceptual framework. In the third section, we discuss our empirical strategy. In the last two sections, we present an analysis of the results and conclusions.

[6] The industries are classified according to the Standard International Trade Classification (SITC) revision 3.

## 2. Conceptual Framework

Trefler and Zhu (2005) showed that if we include intermediate trade inputs and allow technologies to vary across countries, factor services exchanged through international trade will contain differences in endowment and consumption patterns across countries. Equation 1 summarizes this relationship. $F_i^{T-Z}$ is the *K*x1 vector of net factor services exported by country *i*. $V_i$ denotes the *K*x1 vector of factor endowments, and $C_{ij}$ is the Gx1 vector of country *i* consumption of goods produced in country *j*. Subscript *w* symbolizes the variable aggregated at the world level. $\phi_i$ is country *i*'s share of world consumption. The *K*x*G* factor intensity matrix $A_j$ describes the production technology for country *j*.[7]

$$F_i^{T-Z} = \left(V_i - \varphi_i V_w\right) - \sum_{j=1}^{N} A_j \left(C_{ij} - \varphi_i C_{wj}\right) \tag{1}$$

In general in environmental economics, studies directly consider emissions of pollutants as one of the factors in the production process. The basis for introducing the environment as an input in the production process comes from a seminal paper written by Ayres and Kneese (1969). The pollution and its control are interpreted as a material balance problem in a closed economy. They added intermediate inputs to the Walras-Cassel general equilibrium model and obtained a specification where the production of residuals or emissions is part of the production and consumption process. Later on, Rauscher (1997) and Copeland and Taylor (2003) elaborated a model in which emissions are inputs in the net production function of the firm. In this model, the firm jointly produces goods and emissions and must assign a proportion of its input to abatement

[7] The *k*-input requirement per unit of product *g*, denoted $\alpha_{kg}$, is a generic element of $A_j$. It includes the direct and indirect factor requirements to produce *g* in country *j*. The direct factor requirements are the primary factors used in the production of *g*, and the indirect factor requirements are the primary factors used in the production of intermediate inputs employed in the elaboration of *g*.

of emissions. Copeland and Taylor (2003) assumed that abatement activities and production activities use inputs in the same proportion and that a convenient relationship exists between abatement activity and emissions.[8] In contrast, Rauscher (1997) used the material-balance relationships to achieve a linear relationship between emissions and production.

Thus, environmental services included in country *i*'s net exports ($E^z$) are, employing equation (1), the result of two factors: abundance of environmental inputs and differences in the pattern of consumption (see equation 2).[9]

$$E^z = e^{'} F_i^{T-Z} = \left(E_i - \varphi_i \, E_w\right) - \sum_{j=1}^{N} \sum_{g=1}^{G} \alpha_{egj} \left(C_{gij} - \varphi_i C_{gwj}\right) \tag{2}$$

Therefore, a country is a net exporter of environmental services if and only if $E^z > 0$ which is decided by the sum of two components. The first is the conventional requirement that the country's share in the world environmental endowment must be larger than its share in the world expenditure of income $\left(E_i / E_w > \phi_i\right)$. The second term is a measure of consumption similarity. In this less constrained framework, the abundance of environmental endowments does not determine by itself the comparative advantage of a country; heterogeneity in the consumption patterns across countries also plays a role in the factor content of trade.

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8 Dean et al. (2005) extend this model to include agglomeration economies.

9 E symbolizes the endowments of environment inputs. *e'* denotes the transpose of a *K*x1 vector that contains only zeros, but the *e*th element, the environment, is equal to 1. $\alpha_e^{'}$ denotes the transpose of a *G*x1 vector, which indicates the *environment*-requirements per unit of product *g*.

### 2.1 Empirical Specification

It is possible to obtain the equation that has been estimated in the literature starting from equation 1 and adding two standard assumptions in HOV model: similar production technology across countries and identical homothetic preferences everywhere. Let us start with the first of these assumptions and assume that countries have similar factor intensity matrices, such that $A_j = \tilde{A} \ \forall j$, to get equation 3. In this equation, $T_{ij}$ is the *G*x1 vector of net exports from country *i* to country *j*.

$$F_i^{T-Z} = \tilde{A}\sum_{j=1}^{N} T_{ij} = \tilde{A}T_i^c = \left(V_i - \varphi_i\, V_w\right) - \tilde{A}\left(\sum_{j=1}^{N} C_{ij} - \varphi_i \sum_{j=1}^{N} C_{wj}\right) \tag{3}$$

In addition, if we assume that the number of goods is equal to the number of factors (*G*=*K*) and $\left|\tilde{A}\right| \neq 0$, then the factor intensity matrix, $\tilde{A}$, could be inverted. Afterward, the net export of a country can be expressed in terms of excess endowment supplies and deviation from the average in the patterns of country *i*'s consumption such as in equation 4.

$$T_i^c = \tilde{A}^{-1}\left(V_i - \varphi_i\, V_w\right) - \left(C_i - \varphi_i C_w\right) \tag{4}$$

Hence, we obtain the net export of good *g* from country *i*, as in the equation 5, premultiplying $T_i^c$ by the transpose of a Gx1 vector, denoted *t*, that contains only zeros, but the *g*th element is equal to 1.[10]

$$T_{ig} = t^{'}T_i^c = \sum_{k=1}^{K} \beta_{gk}\left(V_{ik} - \varphi_i\, V_{wk}\right) - \left(C_{ig} - \varphi_i C_{wg}\right) \tag{5}$$

10 $C_{gi}$ and $C_{gw}$ represent country *i* and world consumption of good *g*, respectively.

The elements in the inverted matrix, denoted $\beta_{gk}$, are called Rybczynski coefficients. They could be interpreted as the derivative of the product *g* with respect to the factor *k* (see Leamer 1984). According to this equation, net exports of good *g* from country *i* are a linear function of factor endowments minus country *i*'s importance in the consumption of good g. The last component is a "consumption adjustment", denoted *q* (where $q = C_{ig} / C_{wg} - \phi_i$), that reflects deviation of the country *i*'s share in the consumption of good *g* from its share in the world consumption.

Finally, equation 5 could be expressed as a linear function of factor endowments as well (see Appendix A). The coefficient $\gamma_{kg}$ is interpreted as the effect that an increment in the endowment of the input *k* will have on the exports of good *g*, *ceteris paribus*.

$$T_{gi} = \sum_{k=1}^{K} \gamma_{kg} V_{ki} - \left( C_{gi} - \varphi_i C_{gw} \right) \tag{6}$$

As a result, the empirical work can be based on two alternative specifications: Net exports of the good *g*, adjusted by *q*, are a linear function of the excess supply factors on equation 5 or are linearly related to the factor endowments in equation 6. As Leamer (1984) highlights in his book, it is possible that one or more factors might not be observed, or are being measured imperfectly resulting in errors with finite variance. In this case, empirical estimation based on excess factor endowments can yield biased and inconsistent estimators because the stochastic component of the empirical model could be correlated with the explanatory variables. This is because the remuneration to the inputs is integrated in the consumption share of the country in the world output (see equation 5a in Appendix A), and unobserved inputs might be correlated with the explanatory variables through its effect in this variable. As a result, the empirical equation based on factor endowments (equation 6) should be preferred over equation 5.

Equation 6 looks very similar to the empirical specification that has been estimated by Leamer (1984), Tobey (1990), Murrell and Ryterman (1991) and Cole and Elliott (2003), except for the term capturing differences in patterns of consumption, *q*. This factor has not appeared in those studies because the assumption of identical homothetic preferences in HOV models is a sufficient condition to make $C_{gi} / C_{gw} = \phi_i$ (Trefler and Zhu 2005). Nonetheless, Hunter (1991) and, more recently, Yan (2007) show that the null of homothetic preferences is statistically rejected. Furthermore, nonhomothetic preferences could explain up to one-quarter of inter-industry trade flow (Hunter 1991) and improve the performance of HOV prediction (Yan 2007). We will discuss the consequences of nonhomothetic preferences in the analysis of the results.

### 2.2 Industrial Aggregation

Earlier studies have used highly aggregated data which might have hidden any evidence of pollution havens. To illustrate this point, consider equation 7 which shows equation 6 expressed at an arbitrary industrial level.

$$T_{iI} = \sum_{g \in I} T_{ig} = \sum_{k=1}^{K} \left( \sum_{g \in I} \gamma_{gk} \right) V_{ik} - \left( \sum_{g \in I} C_{ig} - \varphi_i \sum_{g \in I} C_{wg} \right) \qquad (7)$$

The coefficient $\gamma_{Ik}$, which can be interpreted as the effect of an increment in the endowment of input *k* on the exports of industry *I*, will be the sum of the coefficients associated to each good that belongs to *I*. Clearly, if one of the coefficients for one good is large, but not the others, there could be an effect in the single sub-sector that is significant, though it might not show up at the aggregate level[11].

### 3. Empirical Strategy

We estimated the parameters of equation 8, which is based on equation 6, for a subset of highly polluting industries. $E_k$ stands for the variables measuring environment endowments, $V_k$ denotes other endowment variables, and ε is the error term.

$$T_g = \alpha + \sum_{k=1}^{P} \gamma_{gk} V_k + \sum_{k=P+1}^{Q} \delta_{gk} E_k + \varepsilon \tag{8}$$

Positive values of the parameters are associated to factors that determine a comparative advantage for the industry. In contrast, negative coefficients represent factors whose abundance generates a comparative disadvantage for the industry. The main hypothesis is that the parameters associated to environmental endowments can be estimated as positive at a reasonable level of statistical significance. We conduct three independent estimations based on equation 8. These are intended to illustrate what we perceive as unresolved issues from previous studies. First, we estimate the empirical specification used by previous studies as a benchmark[12]. In the next step, we assume $q$ is not zero and correlated with the environmental endowments such that the parameters estimated using OLS are inconsistent. We assume there is no variable to control for dissimilarities in the consumption condition and thus we use IV estimation to get consistent

[11] Moreover the industrial aggregation might also be related to the endogeneity problem discussed above.

[12] This means that we assume the error term is iid, normally distributed, with finite and constant variance; therefore, we can use OLS on a cross-section of countries. We assume countries fulfill the consumption similarity condition ( $q = 0$ ), or, if they do not, this condition is not correlated with the regressors.

estimates in the HOV equations. In the third and final step, we make the same estimations at a more disaggregated level.

### 3.1 Environmental Variables

A suitable indicator of environmental endowment, based on pollution, should at least fulfill the following criteria: (i) be emitted as a result of production; (ii) be subject to regulation due to its direct effects on humans or the environment; (iii) have well-known abatement technologies available for implementation; and (iv) have data available for a wide set of developed and developing economies. Two pollutants that satisfy these criteria are atmospheric $SO_2$ and BOD.

$SO_2$ is a precursor for acidification and urban smog. The main source of $SO_2$ emissions is combustion of coal and oil, accounting for about 85 percent of global anthropogenic emissions (UNDP 2000, page 64). It is possible to reduce $SO_2$ emissions by various well-known methods (fuel substitution, desulfurizing, flue gas scrubbing, etc.). A country's emissions of $SO_2$ mainly depend on: the GDP of the country, the energy intensity of its production, the share of the fossil combustibles in the country's total energy use, the sulfur content of those fuels, and the use of abatement technologies.[13]

Organic matter and chemicals, emitted through wastewater, are by-products of various industrial activities and are a major source of surface water pollution. The released organic material is consumed by naturally occurring bacteria, using up the oxygen dissolved in the water. With high enough releases of organic matter, the oxygen levels in the waters may drop to levels

[13] Finally, our measure of environmental endowment is the country's $SO_2$ emissions from fossil fuel use, divided by the share of coal and oil in the country's total energy use. This indicator corrects for the fact that some countries have very low emissions simply because they derive a large share of their energy use from natural gas, hydro or nuclear power.

so low that fish and other aquatic organisms perish. A low oxygen level is often considered the single most important factor when determining the extent of pollution in a water body (Nemerow and Dasgupta 1991, page 4).

The rate at which the oxygen is consumed can be measured in various ways; one common method is BOD. Organic matter can quite easily be reduced through end-of-pipe treatment of the wastewater which removes more than 90 percent of original BOD. The technologies are well developed and readily available, although at noticeable cost.

### 3.2 Other Endowment Variables Considered in the Estimation

This study adopts a model with endowments in capital, labor, land, and natural resource endowments. We have tried to follow the endowments considered in the basic studies first conducted by Leamer (1984). Labor endowment is split into three groups based on level of education: illiterate workers, literate workers with secondary education, and professional and technical workers. Information about land is divided into tropical and non-tropical forest areas, and cropland. The natural resource endowments include production of minerals (copper, iron, lead, and zinc) and solid fuels (coal and liquid and gaseous fuels—i.e. crude oil and natural gas). A more detailed description of the sources of information is given in Table 1. Table 2 provides summary statistics.

## 4. Results

We first estimate benchmark parameters of equation eight for each aggregate industry using OLS, see Table 3. Because the hypothesis of homoscedasticity was rejected in some industries, we use White standard errors to estimate heteroscedasticity-robust t statistics.[14]

As mentioned earlier, two alternative assumptions are consistent with this method of estimation. Either that countries fulfill the consumption similarity condition ($q = 0$) and net exports are determined by abundance of their endowment factors,[15] or q is uncorrelated with the regressors.

Several explanatory variables are highly correlated, and various diagnostic tests suggest that multicollinearity is severe in our estimations (e.g., the mean variance inflation factor is 48 and the condition number 68). Part of this problem may be because we have redundant variables characterizing the skills of labor force. One of these variables is the number of literate non-professional workers. This variable is not statistically different to zero in any of our regressions. Moreover, when we drop this variable, we do not observe any change in the signs or the level of significance of the main variables, and the severity of the multicollinearity is considerably reduced (the mean variance inflation is 13 and the condition number 26). Therefore, the reported results do not include this variable. The sign of the parameters looks reasonable, and the sign and the significance of the parameters associated to the environmental endowment are robust to

[14] The White standard errors were multiplied by $n/(n-k)$. This degrees-of-freedom adjustment, suggested by Davidson and MacKinnon (1993), improves the White estimator for OLS in small samples. Furthermore, this modus operandi guarantees to get the usual OLS standard errors if the variances of the disturbances were constant across observations.

[15] Although this seems restrictive, Trefler and Zhu (2005) show that there are many models consistent with this condition — models with taste for variety or ideal variety; North-South models with differences in technology; and models consistent with production specialization as Heckscher-Ohlin, scale returns, and failures of factor price equalization.

changes in the data and in the specification of the regression model. For instance, most of the industries considered in the analysis are based on natural resources, and we should expect that these factors could be a source of comparative advantage. This is exactly what we observe in these sectors. The production of iron has a direct influence on the net exports of the iron and steel industry. The production of copper and zinc determines a comparative advantage in the nonferrous metals.[16] Finally, the exports in the pulp and paper industry are considerably influenced by the availability of forest and negatively influenced by areas of cropland.

In general, we observe a rather high coefficient of determination in our results despite the fact that we use a cross-section sample. The independent variables explain a high percentage of the variation in the net exports. The exception is the chemical industry, where we can explain only half of the variation in net exports. An analysis of these results by sector shows that industries differ considerably in their sources of comparative advantage. In most cases, net exports are directly influenced by the abundance of unskilled workers and, in others, by the abundance of capital. Summing up, our estimation results look quite reasonable and are a good starting point for our analysis.

Table 3 shows that only in non-metallic minerals do we find evidence of a pollution haven; the statistically significant positive coefficient associated with BOD suggests that a higher level of organic water pollutant emissions will increase the exports in this industry. In the other cases, the parameters show that the availability of environmental amenities does not influence the exports of a country — or that the effect goes in the opposite direction. In effect, emissions of $SO_2$ in the nonferrous metal, chemical, and pulp and paper industries (as well as BOD in the

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[16] Lead has a counterintuitive sign. However, this is only because different subsectors coexist in nonferrous metals. In a more disaggregate analysis, lead net exports are directly influenced by lead production, although the coefficient is not statistically different to zero.

chemical industry) negatively affect industrial exports. This can be seen as support for the Porter hypothesis that stricter environmental policy will increase net exports of these industries.

### 4.1 Endogeneity and IV Estimation

As mentioned earlier, we believe that if countries do not fulfill the consumption symmetry condition, and we do not control for *q*, then the estimated parameters could be inconsistent if the omitted variable is correlated with some of the explanatory variables. We suspect that *q* could be correlated with the environmental endowments because both variables could be negatively correlated with the income of the countries. We believe that the share of total consumption of the good produced by the industries considered in the study is reduced by increases in the per capita income because they are not luxury goods. In this case, reduction in the share of the consumption of good *g* in world consumption due to higher levels of income could be associated with a lower level of pollution. Then, environmental endowments could be positively correlated to *q*. In this case, the formula $p\lim \hat{\delta}_{gk} = \delta_{gk} - Cov(E_k, q)/Var(E_k)$ shows the plim of the OLS estimated parameters. It is easy to see that using OLS we underestimate the true value of the parameters, and the asymptotic bias could be negative (thus a bias against evidence of pollution havens and in favor of the Porter hypothesis). Our hypothesis is that OLS parameters are inconsistent and thus we use IV estimation.

To perform IV estimation we need instrumental variables and our candidate instruments are the number of fish species (fishno), the number of fish species threatened (fishthrea), total road network (road), and the number of vehicles per thousand people (vehicles).[17] First, we

[17] The instruments were highly correlated with the environmental endowments. In some cases, they could reflect the effect that high levels of pollution can have on biodiversity and in others,the influence that mobile sources of pollution have on our environmental endowments. We tried other instruments as well, but they were irrelevant.

evaluated the relevance of the instruments using the first-stage regressions reported in Table 4. The Shea partial $R^2$ suggests that the instruments have the adequate relevance to explain all the endogenous regressors, and the Anderson canonical correlation likelihood-ratio test indicates that we reject the hypothesis that the model is under-identified.[18] The comparison of the Cragg-Donald statistic with the critical value reported in Stock and Yogo (2004, Table 2) does not allow us to reject the null of weak instruments. As a consequence, weak instruments could result in size distortion of at least 20 percent (*ibid.*). To overcome the weakness of our instruments, we use a Limited Information Maximum Likelihood estimator (LIML) instead of Two Stages Least Squares (2SLS), because LIML has proven to be less affected by weak instruments. In our case, the maximal size distortion is below 10 percent when we use LIML (Stock and Yogo 2004, Table 2).

The lack of consistency in OLS estimations when we suspect that some of the regressors are endogenous has to be balanced with the loss of efficiency when we use IV. A common practice is to check the endogeneity of the regressors. We tested the hypothesis that BOD and $SO_2$ are exogenous, making use of different versions of Durbin-Wu-Hausman's test of endogeneity. The outcomes were robust to the choice of the statistic.[19] The results of one of these tests are in the penultimate row of Table 5. In chemical and pulp and paper industries, and in non-metallic mineral production, it was not possible to reject the exogeneity of the environmental explanatory variables.

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[18] The rule of thumb in this literature indicates that the instruments are weak at explaining all the endogenous variables if the value of the partial $R^2$ is large, but the Shea partial $R^2$ is small.

[19] If we could not reject the assumption of conditional homoscedasticity, a special form of the test was calculated.

Furthermore, in choosing the estimator, we must consider whether or not the assumption of homoscedasticity is valid, as the Generalized Method of Moment (GMM) provides a more efficient estimation in the presence of heteroscedasticity of unknown form. If the variance is not constant, IV estimators will be consistent, but less efficient, and OLS will be less efficient than GMM. Therefore, if we reject the hypothesis of homoscedasticity and the regressors are endogenous, we will make use of the orthogonality conditions to estimate the GMM generalization of the LIML estimator to allow for heteroscedasticity. It is called "continuously-updated GMM" estimator (HLIML-GMM). On the other hand, if the regressors are exogenous and heteroscedasticity is present, we estimate a Heteroscedastic OLS estimator (HOLS). It uses the additional moments available to generate the OLS residuals that will constitute the first-step in the feasible two-step GMM (Wooldridge 2002). Appendix B contains the scheme that we follow to estimate IV with weak instruments.

Table 5 displays the results of our estimations when we consider the possibility of endogenous regressors and apply methods that are more efficient when disturbances are not homoscedastic. Only in the iron and steel and nonferrous metals sectors did we reject the hypothesis of exogeneity of the environmental variables. However, in the chemical industry and pulp and paper sector, we employed the HOLS estimator, because when we estimated the HOV equation using OLS we rejected the assumption of homoscedasticity (see Table 3). Over-identification tests suggest that the instruments were valid. They are exogenous,i.e., uncorrelated with the error term.

The results show, as expected, that there is a downward bias in the OLS parameters when regressors are endogenous. We can see this if we compare the parameters associated with the environmental variables in the iron and nonferrous industries in Tables 3 and 5. In almost all the cases, the value of the parameters was larger if we use instrumental variables to control for the endogeneity of the regressors.

Employing these more efficient and consistent methods of estimation we found additional evidence of pollution havens in the iron and steel sector. Therefore, the net exports in the iron and steel industry and in the non-metallic minerals production are directly influenced by lax environmental regulations, while evidence supporting the Porter hypothesis is now only found in the chemical industry.

### 4.2 Disaggregated Analysis

In this section, we analyze the influence that the industrial level of aggregation has on our results. We follow the same procedure as in the previous section to estimate the HOV equation at a more disaggregated level employing methods that are consistent when regressors are endogenous and more efficient in the presence of heteroscedasticity. Table 6 summarizes the effect of environmental endowments on the net exports in all the industries.[20]

We detected a more extended presence of the endogenous regressors in the analysis. Moreover, we found more evidence of pollution havens. Most of this evidence comes from the variable measuring water pollution, which suggests that more stringent water pollution regulations that are effective in reducing water contamination will reduce the net exports in the industries where the BOD estimated coefficient is positive and statistically different from zero. Only in three disaggregated industries: semi-finished products of iron and steel (672), glassware (665), and pottery (666), did we find evidence that lax air pollution regulations will increase

[20] Tables 7(a-d) report detailed results for each industry.

exports in these industries. There was however more evidence of the Porter hypothesis from the variable capturing air pollution regulations.

## 5. Conclusions and Discussion

The main goal of this study was to understand the effect that differences in environmental policy have on trade. Consistent with previous literature based on the HOV equation and the Tobey (1990) approach, we use more updated cross-section country data on net exports in the most polluting industries. The controls are the factor endowments of the country. The purpose has been to investigate the hypothesis that lax environmental regulations could constitute a source of comparative advantage, causing the least-regulated countries to "specialize" in polluting industries. Previous studies have utilized an indicator of the stringency of environmental regulation as a proxy variable for the environmental endowment. We use two measures of pollution as direct measures of environmental endowment, instead. However, consistent with previous studies, we did not find much evidence of pollution haven. Nevertheless, we sought to scrutinize two other issues that have not been investigated in this literature: the consequence of non-homothetic preferences and the level of aggregation of the industries.

We show that if preferences are non-homothetic, there is an omitted variable that previous studies have not considered. This variable captures the differences in consumption patterns among countries. We suspect that the omitted variable could be positively correlated with the environmental endowment generating a downward bias in the estimation of environmental endowment parameters using OLS. In this study, we use an instrumental variables approach to deal with this trait. Our empirical results were consistent with this intuition. We found evidence of endogeneity in several industries. The evidence of what is called Porter hypothesis turns out to be weaker and we found more evidence of a pollution haven effect.

Finally, Feenstra and Hanson (2000) discuss the issue of aggregation bias in the factor content of trade literature. They found that the aggregation bias was substantial, but could not explain the missing trade. In our paper, we wanted to see whether the level of industrial aggregation is of importance for evidence of a pollution haven. We estimate the same empirical model at a more disaggregate industrial level. We found that aggregation matters. At a disaggregate level, there is more evidence of pollution havens. However, the level of disaggregation for considering these studies is still an open question. We have the impression that considering industries at a more disaggregate level could change our results still more.

Empirically the evidence remains mixed. Using more advanced methods and recent data still do not yield a very clear picture. We do find, however, that the introduction of instrumental variables to deal with the bias caused by consumption asymmetries together with more disaggregated data analysis extends the number of cases in which we find the pollution haven, while the evidence in favor of the Porter hypothesis only remains in the chemical industry and for air pollution regulations.

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## Appendix A. Derivation of equation 6

Starting from equation 5, the participation of the country in world income is illustrated explicitly in the equation 5a. $\omega_k$ is the remuneration to the input *k*.

$$T_{ig} = \sum_{k=1}^{K} \left( \beta_{gk} V_{ik} - \frac{\sum_{k=1}^{K} \omega_k V_{ik}}{\sum_{k=1}^{K} \omega_k V_{wk}} \beta_{gk} V_{wk} \right) - \left( C_{ig} - \varphi_i C_{wg} \right) \tag{5a}$$

Now, we can define world income, denoted $Y_w$, as the sum of the rents gained from all world factor endowments to get the equation 5b.

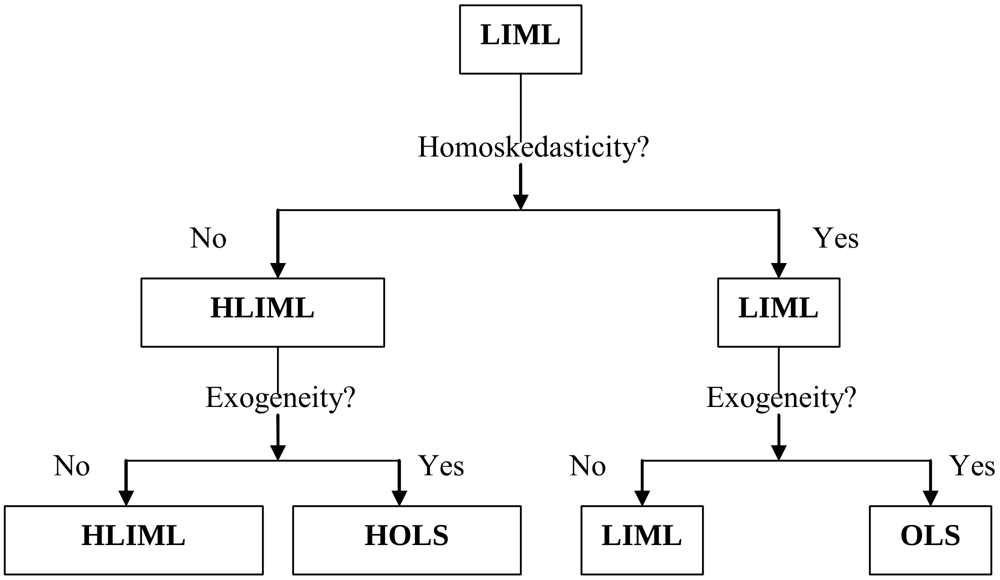
$$T_{ig} = \sum_{k=1}^{K} \left( \beta_{gk} - \sum_{k=1}^{K} \beta_{gk} V_{wk} \frac{\omega_k}{Y_w} \right) V_{ik} - \left( C_{ig} - \varphi_i C_{wg} \right) \tag{5b}$$

But we can define $\sum_{k=1}^{K} \beta_{gk} V_{wk}$ as the world output of good *g*, denoted $Q_{wg}$, arriving at 5c.

$$T_{ig} = \sum_{k=1}^{K} \left( \beta_{gk} - Q_{wg} \frac{\omega_k}{Y_w} \right) V_{ik} - \left( C_{ig} - \varphi_i C_{wg} \right) \tag{5c}$$

Finally, equation 6 is obtained when we define $\beta_{gk} - Q_{wg} \frac{\omega_k}{Y_w} = \gamma_{gk}$ .■

**Appendix B. Outline of IV Estimation with Weak Instruments**




where:

**HLIML** is the heteroscedastic-efficient continuously-updated GMM estimator (it is the GMM generalization of the LIML estimator in the case of possible heteroscedastic disturbance).

**HOLS** is the Cragg's heteroscedastic OLS estimator (HOLS) which is more efficient than OLS in the presence of heteroscedasticity.

Table 1: Definitions and Data

| Variable | Definition and Source |
|---|---|
| **Net Export** | Thousands U.S. dollars of net export year 2000, *UN Comtrade Database* (2000). |
| **Capital** | Physical capital stock, thousand of millions of dollars, year 2000. The sum of annual GDI, (average life of 15 years and constant depreciation rate of 13.3%), *World Development Indicators* 2004. |
| **Labor** | Economically active population (thousands) year 2000, *Ibid.* |
| **Illiteracy** | Illiteracy adult rate year 2000[a], *Ibid.* |
| **Tertiary** | Professional and technical workers (% of labor force) year 2000 or the closest year with information available. International Labour Office (various years), *Yearbook of Labour Statistics.* |
| **Qualified labor** | Labor*Tertiary. |
| **Illiterate labor** | Illiterate workers (thousands) are calculated as: Labor*(100- Illiteracy)/100. |
| **Tropical** | Millions hectares of tropical forest year 1996, *World Resources Institute*. *Earth Trends*: The Environmental Information Portal, http://earthtrends.wri.org. |
| **Crop** | Thousands of square kilometers of cropland years 1992-1993, *Ibid.* |
| **Nontropical** | Millions hectares of non-tropical forest year 1996, *Ibid.* |
| **Copper, Iron, Lead, and Zinc** | Thousands metric tons of mine production for each of these metals year 2000, *US Geological Survey*, Commodity statistics and information, 2004. |
| **Coal** | Coal production (millions short tons) year 2000, Energy Information Administration (Official Energy Statistics from the US Government), *International Energy Annual* 2003, table 25. |
| **Gasoil** | The sum of world production of crude oil, NGPL, and other liquids (thousand barrels per day) and world dry natural gas production (trillion cubic feet) year 2000, million tonnes of oil per year, *Ibid,* table G.1. |
| **BOD** | Organic water pollutant (BOD) emissions (thousands of kg per day) year 2000. *World Development Indicators* 2004. |

| Variable | Definition and Source |
|---|---|
| **$SO_2$** | Sulfur emissions divided by share of oil and coal in total energy. Sulfur emissions compiled by Stern, D. (available on http://www.rpi.edu/~sternd/datasite.html). |
| **Fish-diversity** | Fish species, number, refer to the total number of freshwater and marine fish identified, documented, and recorded in a particular country or region. Total numbers include both endemic and non-endemic species. Most marine fish are excluded from country totals, years 1992-2003, *World Resources Institute*. *Earth Trends*: The Environmental Information portal, http://earthtrends.wri.org. |
| **Fish-threat** | Fish, number threatened, includes all species of both freshwater and marine fish that are recorded as threatened and that are known to occur in the territory of a given country, year 2004, *Ibid.* |
| **Vehicles** | Total number of vehicles per 1000 people, year 1996, *Ibid.* |
| **Road** | Total road network, thousands kilometers, includes motorways, highways, main or national roads, and secondary or regional roads, year 2000, but they come primarily from 1999, *Ibid.* |

[a] For purposes of calculating, a value of 1% was applied to Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Japan, Luxembourg, Netherlands, New Zealand, Norway, Slovak Republic, Sweden, Switzerland, United Kingdom, and United States.

Table 2. Summary of Statistics, Year 2000

| Variable | Observations | Mean | Stan. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| **Capital** | 71 | 630 | 1819 | 3 | 1,07e+04 |
| **Qualified labor** | 71 | 4605 | 11589 | 17 | 85424 |
| **Illiterate labor** | 71 | 6465 | 26396 | 2 | 192763 |
| **Tropical** | 71 | 13 | 40 | 0 | 301 |
| **Crop** | 71 | 145 | 326 | 0 | 1753 |
| **Nontropical** | 71 | 14 | 58 | 0 | 404 |
| **Copper** | 71 | 153 | 593 | 0 | 4602 |
| **Iron** | 71 | 12677 | 42250 | 0 | 223000 |
| **Lead** | 71 | 41 | 132 | 0 | 739 |
| **Zinc** | 71 | 112 | 322 | 0 | 1780 |
| **Coal** | 71 | 57 | 208 | 0 | 1314 |
| **Gasoil** | 71 | 52 | 125 | 0 | 902 |
| **BOD** | 71 | 280 | 795 | 2 | 6204 |
| **$SO_2$** | 71 | 792 | 1946 | 2 | 12197 |

Table 3: HOV Estimation Results using Robust Ordinary Least Square

(Dependent variable: thousands of U.S. dollars of net export in 2000)

| | Iron and Steel | Nonferrous Metals | Industrial Chemical | Pulp and Paper | Non-metallic Minerals Products |
|---|---|---|---|---|---|
| **Capital** | 1 (0,2) *** | -0,4 (0,2) ** | 0,6 (0,2) *** | -0,1 (0,1) | 0,3 (0,3) |
| **Qualified labor** | -105 (97) | -39 (69) | 140 (140) | -31 (43) | -213 (119) * |
| **Illiterate labor** | 42 (19) ** | 11 (11) | -35 (38) | 45 (16) *** | 20 (11) * |
| **Tropical** | -1 (6) | -11 (5) ** | -42 (24) * | 21 (9) ** | 3 (6) |
| **Crop** | -4 (2) | -0,7 (1) | 2 (4) | -5 (2) *** | 0,3 (1) |
| **Nontropical** | -2 (5) | 0,8 (6) | -46 (31) | 60 (13) *** | 1 (6) |
| **Copper** | 98 (221) | 1574 (190) *** | 864 (343) ** | 526 (156) *** | -192 (281) |
| **Iron** | 27 (7) *** | 31 (7) *** | 46 (28) | -1 (11) | -4 (11) |
| **Lead[a]** | -6 (7) | -15 (8) * | -76 (41) * | 14 (15) | 4 (10) |
| **Zinc[a]** | 2 (3) | 7 (3) ** | 28 (16) * | -7 (6) | -0,5 (4) |
| **Coal[a]** | -2 (5) | 6 (4) | 27 (9) *** | 4 (5) | -8 (6) |
| **Gasoil[a]** | -4 (2) * | 5 (3) * | 6 (5) | -6 (4) | -3 (2) |
| **BOD** | 0,4 (0,8) | -0,7 (0,6) | -5 (3) * | 1 (1) | 2 (0,8) *** |
| **$SO_2$** | -541 (561) | -1396 (483) *** | -2550 (907) *** | -1098 (374) *** | 322 (755) |
| **Const[a]** | 215 (186) | 310 (106) | 573 (347) | 373 (221) * | 101 (164) |
| **$R^2$** | 0,85 | 0,91 | 0,48 | 0,76 | 0,84 |
| **Observations** | 71 | 71 | 71 | 71 | 71 |
| **Homocedasticity[b]** | 0,03 | 4,32** | 34,88*** | 8,60*** | 0,08 |

Notes: Heteroscedasticity-robust standard deviation is reported in parentheses. *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively.
[a]Coefficients and standard deviation are expressed in thousands. [b]It reports the Breusch-Pagan/Cook-Weisberg test for heteroscedasticity (with one degree of freedom), the null hypothesis ($H_0$) is constant variance.

Table 4: First-stage Regressions of Instrumented Variables BOD and $SO_2$

| | (1) OLS BOD | | | (2) OLS $SO_2$ | | |
|---|---|---|---|---|---|---|
| **Capital** | 0,2 | (0,0) | *** | -0,0 | (0,0) | |
| **Qualified labor** | 16 | (11) | | 0,0 | (0,0) | * |
| **Illiterate labor** | 3 | (4) | | -0,0 | (0,0) | |
| **Tropical** | -2 | (1) | | -0,0 | (0,0) | |
| **Crop** | 1 | (0,2) | *** | 0,0 | (0,0) | ** |
| **Nontropical** | -2 | (1,3) | * | -0,0 | (0,0) | ** |
| **Copper** | 13 | (10) | | 0,4 | (0,0) | *** |
| **Iron** | -0,3 | (4) | | 0,0 | (0,0) | |
| **Lead** | -4590 | (2164) | ** | -6 | (3) | ** |
| **Zinc** | 1621 | (662) | ** | 2 | (0,7) | *** |
| **Coal** | 3373 | (510) | *** | 4 | (0,9) | *** |
| **Gasoil** | 328 | (267) | | 2 | (0,8) | ** |
| **Fish-diversity** | 41 | (46) | | -0,4 | (0,1) | *** |
| **Fish-threat** | 544 | (1068) | | 8 | (3) | ** |
| **Road** | -795 | (137) | *** | 0,3 | (0,2) | |
| **Vehicles** | 268 | (106) | ** | -0,0 | (0,2) | |
| **Constant** | -34058 | (23544) | | 36 | (52) | |
| **Observations** | 69 | | | 69 | | |
| **Partial $R^2$** | 0,59 | | | 0,33 | | |
| **Shea Partial $R^2$** | 0,54 | | | 0,30 | | |
| **Anderson canonical correlation likelihood-ratio test**[a] | 21,2*** | | | | | |
| **Test of weak instruments**[b] | 4,7 | | | | | |

Notes: Heteroscedasticity-robust standard deviation is reported in parentheses. *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a]Distributed Chi-sq(3). [b]Cragg-Donald statistic (critical values are reported in (Stock and Yogo 2004)).

Table 5: HOV Estimation Results under Hypothesis of BOD and $SO_2$ Endogenous

(Dependent variable: thousands of U.S. dollars of net export in 2000)

| | Iron and Steel | Nonferrous Metals | Industrial Chemical | Pulp and Paper | Non-metallic Minerals Products |
|---|---|---|---|---|---|
| **Method** | LIML | LIML | HOLS[e] | HOLS | OLS |
| **Capital** | 1 (0,2) *** | -0,6 (0,2) *** | 0,6 (0,2) *** | -0,1 (0,1) | 0,3 (0,3) |
| **Qualified labor** | -38 (97) | -26 (89) | 103 (99) | -61 (55) | -213 (119) * |
| **Illiterate labor** | 32 (17) * | 17 (15) | -25 (19) | 53 (19) *** | 20 (11) * |
| **Tropical** | 12 (9) | -0,3 (6) | -35 (11) *** | 24 (8) *** | 3 (6) |
| **Crop** | -4 (2) * | -2 (1) | 2 (2) | -6 (2) *** | 0,3 (1) |
| **Nontropical** | 4 (6) | 11 (6) * | -37 (12) *** | 61 (10) *** | 1 (6) |
| **Copper** | 60 (303) | 1410 (244) *** | 770 (290) ** | 342 (159) ** | -192 (281) |
| **Iron** | 50 (15) *** | 36 (14) ** | 36 (14) ** | -6 (23) | -4 (11) |
| **Lead**[a] | -2 (9) | -2 (10) | -63 (16) *** | 19 (14) | 4 (10) |
| **Zinc**[a] | -2 (4) | 1 (4) | 23 (6) *** | -8 (5) * | -0,5 (4) |
| **Coal**[a] | -7 (5) | -3 (4) | 24 (5) *** | 0,2 (4) | -8 (6) |
| **Gasoil**[a] | -5 (2) ** | 3 (3) | 5 (5) | -7 (3) ** | -3 (2) |
| **BOD** | 1 (0,7) * | 0,6 (0,7) | -4 (1) *** | 1 (0,9) | 2 (0,8) *** |
| **$SO_2$** | -585 (729) | -1004 (606) | -2311 (741) *** | -503 (362) | 322 (755) |
| **Const**[a] | 87 (188) | 149 (118) | 521 (193) *** | 146 (138) | 101 (164) |
| **Centered $R^2$** | 0,85 | 0,91 | 0,48 | 0,76 | 0,84 |
| **Observations** | 69 | 69 | 69 | 69 | 71 |
| **Overidentification**[b] | 1,1 | 0,2 | 0,3[h] | 2,4[h] | |
| **Exogeneity**[c] | 13,5*** | 18,5*** | 0,4 | 1,1 | 1,1 |
| **Homocedasticity**[d] | 8,4 | 5,5 | 14,61 | 7,3 | 8,6 |

Notes: All the estimations have a correction due to small samples. Heteroscedasticity-robust standard deviation is reported in parentheses. *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a]Coefficients and standard deviation are expressed in thousands. [b]Anderson-Rubin statistic of overidentification of all instruments [chi-sq (2)]. Superscript h indicates that Hansen J statistic was reported instead. [c]C-statistic, test of exogeneity/orthogonality of suspect instruments [chi-sq (2)]. [d]IV heteroscedasticity test, Pagan-Hall general test of homoscedastic disturbance using levels of IVs only [chi-sq (16)]. [e]It uses fishno and road as additional moment conditions.

Table 6: Effect of the Environmental Endowment on Net Export

| Industry | Environmental Endowment | | Sub-sector | Environmental Endowment | |
|---|---|---|---|---|---|
| | BOD | $SO_2$ | | BOD | $SO_2$ |
| Iron and Steel | + | 0 | 671 | ++ | 0 |
| | | | 672 | 0 | + |
| | | | 673 | 0 | 0 |
| | | | 674 | 0 | - |
| | | | 676 | +++ | 0 |
| | | | 677 | +++ | -- |
| | | | 678 | 0 | 0 |
| | | | 679 | +++ | 0 |
| Nonferrous Metals | 0 | 0 | 681 | +++ | 0 |
| | | | 682 | 0 | 0 |
| | | | 683 | + | - |
| | | | 684 | 0 | -- |
| | | | 685 | 0 | - |
| | | | 686 | +++ | 0 |
| | | | 687 | +++ | 0 |
| | | | 689 | +++ | 0 |
| Chemical | --- | --- | 512 | 0 | -- |
| | | | 513 | 0 | 0 |
| | | | 514 | 0 | -- |
| | | | 581 | --- | -- |
| Pulp and Paper | 0 | 0 | 251 | -- | 0 |
| | | | 641 | ++ | 0 |
| | | | 642 | 0 | 0 |
| Non-metallic Minerals Products | +++ | 0 | 661 | +++ | 0 |
| | | | 662 | 0 | 0 |
| | | | 663 | +++ | 0 |
| | | | 664 | 0 | 0 |
| | | | 665 | ++ | +++ |
| | | | 666 | +++ | + |
| | | | 667 | ++ | 0 |

Notes: The sign indicates the impact of the variable on net exports: "+" indicates "pollution haven effect" and "-" denotes "Porter hypothesis". The number of signs in a cell specifies the level of confidence of the parameter in the econometric analysis: 99%, 95% and 90%. "0" indicates that the variable is not statistically different from zero.

Table 7a: HOV Estimation Results under Hypothesis of BOD and $SO_2$ Endogenous

(Dependent variable: thousands of U.S. dollars of net export in 1996)

| *Sector* | *Primary Iron and Steel* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Subsector** | **671** | **672** | **673** | **674** | **676** | **677** | **678** | **679** |
| **Method** | **LIML** | **LIML** | **LIML** | **LIML** | **OLS** | **OLS** | **HOLS[d]** | **HOLS[d]** |
| **Capital** | -0,1 | 0,1 | 0,2 ** | 0,2 *** | 0,1 *** | 0,01 *** | 0,02 ** | 0,2 *** |
| **Qualified labor** | -41 | -39 | 23 | 21 | -25 | -0,6 | -3 | -17 |
| **Illiterate labor** | 7 | 4 | 11,2 * | 6 | 6 *** | 0,2 | 1 * | -0,9 |
| **Tropical** | 4 * | 2 | 2 | 0,2 | -0,1 | -0,2 * | 0,5 * | 1 |
| **Crop** | -1 * | -0,4 | -1 * | -0,6 | -0,4 ** | -0,02 | -0,1 | 0,2 |
| **Nontropical** | 2 | -0,4 | 0,5 | 0,5 | 0,9 | -0,01 | 0,5 | 0,4 |
| **Copper** | -66 | -143 ** | 179 | 122 * | -7 | 4 * | -7 | -50 |
| **Iron** | 2 | 7 | 9 | 5 | 2 | 0,1 | 1,0 | 3 |
| **Lead** | 2307 | 240 | -268 | -848 | 720 | -46 | 253 | 833 |
| **Zinc** | -1247 | -167 | -328 | 12 | -156 | 32 | -143 | -498 |
| **Coal** | 5 | -3380 ** | 734 | 860 | -1550 * | -15 | -369 * | -2095 *** |
| **Gasoil** | 112 | -217 | -403 | -143 | -900 * | -56 | -164 | -1648 *** |
| **BOD** | 0,4 ** | 0,2 | 0,1 | -0,1 | 0,4 *** | 0,03 *** | 0,04 | 0,4 *** |
| **$SO_2$** | 152 | 360 * | -508 | -369 * | -51 | -14 ** | 9 | 82 |
| **Constant** | -1086 | -85011 ** | 54567 | 62787 | 12321 | 987 | -4425 | -22709 |
| **Centered $R^2$** | 0,66 | 0,62 | 0,64 | 0,65 | 0,79 | 0,65 | 0,60 | 0,77 |
| **Observations** | 69 | 69 | 69 | 69 | 71 | 71 | 69 | 69 |
| **Overidentification[a]** | 1,78 | 2,16 | 1,44 | 1,25 | | | 2,81 [h] | 5,87 [h] |
| **Exogeneity[b]** | 20,29*** | 8,69** | 11,13*** | 7,86** | 1,87 | 0,54 | 2,74 | 3,11 |
| **Homoskedasticity[c]** | 3,51 | 7,33 | 7,62 | 6,50 | 14,64 | 6,47 | 3,80 | 8,03 |

Notes: All the estimations have a correction due to small samples. For reasons of space, heteroscedasticity-robust standard deviations have not been reported. Instead *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a]Anderson-Rubin statistic of overidentification of all instruments [chi-sq (2)]. Superscript h indicates that Hansen J statistic was reported instead. [b]C-statistic, test of exogeneity/orthogonality of suspect instruments [chi-sq (2)]. [c]IV heteroscedasticity test, Pagan-Hall general test of homoscedastic disturbance using levels of IVs only (chi-squared with 16 degrees of freedom). [d]The Breusch-Pagan/Cook-Weisberg test rejected the hypothesis of conditional homoscedasticity in OLS.

Table 7b: HOV Estimation Results under Hypothesis of BOD and $SO_2$ Endogenous

(Dependent variable: thousands of U.S. dollars of net export in 1996)

| *Sector* | *Nonferrous Metals* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Subsector** | **681** | **682** | **683** | **684** | **685** | **686** | **687** | **689** |
| **Method** | **HLIML** | **LIML** | **LIML** | **LIML** | **OLS**[f] | **LIML** | **OLS** | **LIML** |
| **Capital** | -0,4 *** | 0,2 ** | -0,1 ** | -0,2 *** | 0,0 | -0,02 | -0,03 *** | -0,04 *** |
| **Qualified labor** | 7 | -6 | 0,3 | -4 | 0,1 | -7 | -0,2 | -4 |
| **Illiterate labor** | -3 | 17 *** | 1 | -0,3 | 0,3 | 2 | -0,3 | 0,03 |
| **Tropical** | -0,2 | 2 | -0,5 | -3 | -0,2 | 0,2 | 1 *** | 0,2 |
| **Crop** | -0,1 | -2 *** | -0,2 | 0,4 | -0,1 | -0,3 * | -0,01 | -0,1 |
| **Nontropical** | 0,5 | 1 | 2 ** | 4 | 0,2 * | 2 ** | 0,2 | 0,7 ** |
| **Copper** | 59 | 1124 *** | 63 | 245 * | 7 | -18 | 16 * | -15 |
| **Iron** | 4 ** | 10 ** | 4 | 15 | 0,4 * | 3 * | -1 *** | 0,1 |
| **Lead** | -87 | -1280 | 1115 | -3710 | 23 | 403 | 399 | 434 |
| **Zinc** | 174 | 365 | -234 | 1197 | 59 | 101 | -69 | -142 |
| **Coal** | -1678 | -1746 | -452 | 3824 | 184 ** | -1258 *** | 59 | -258 |
| **Gasoil** | 377 | -1221 * | 1004 * | 3776 ** | -82 | -128 | 31 | -150 |
| **BOD** | 0,5 *** | -0,1 | 0,2 * | -0,5 | 0,02 | 0,2 *** | 0,1 *** | 0,1 *** |
| **$SO_2$** | -130 | -112 | -181 * | -746 ** | -23 * | 10 | -28 | 30 |
| **Constant** | 20347 | 12232 | -19 | 129670 ** | 3254 | -4708 | -3314 | 1175 |
| **Centered $R^2$** | 0,94 | 0,93 | 0,79 | 0,89 | 0,79 | 0,86 | 0,81 | 0,88 |
| **Observations** | 69 | 69 | 69 | 69 | 71 | 69 | 71 | 69 |
| **Overidentification**[a] | 1,74[h] | 3,85 | 1,55 | 2,98 | 13,59*** | 1,89 | | 0,35 |
| **Exogeneity**[b] | 10,78*** | 13,78*** | 17,84*** | 6,77** | 1,90 | 21,61*** | 2,75 | 6,91** |
| **Homoskedasticity**[c] | 4,69[e]* | 8,64 | 10,11 | 13,43 | 9,57 | 9,43 | 2,57 | 14,55 |

Notes: All the estimations have a correction due to small samples. For reasons of space, heteroscedasticity-robust standard deviations have not been reported. Instead *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a]Anderson-Rubin statistic of overidentification of all instruments [chi-sq (2)]. Superscript h indicates that Hansen J statistic was reported instead. [b]C-statistic, test of exogeneity/orthogonality of suspect instruments [chi-sq (2)]. [c]IV heteroscedasticity test, Pagan-Hall general test of homocedastic disturbance using levels of IVs only (chi-squared with 16 degrees of freedom). [e]The test used fitted value and its square (it is distributed chi-sq (2)). [f]This estimator is employed because the result of the overidentification test rejected the hypothesis that excluded instruments are uncorrelated with the disturbance in the structural equation.

Table 7c: HOV Estimation Results under Hypothesis of BOD and $SO_2$ Endogenous

(Dependent variable: thousands of U.S. dollars of net export in 1996)

| *Sector* | *Industrial Chemical* | | | | *Pulp and Paper* | | |
|---|---|---|---|---|---|---|---|
| **Subsector** | **51** | **52** | **56** | **59** | **25** | **641** | **642** |
| **Method** | **HLIML** | **OLS** | **LIML** | **OLS**[f] | **LIML** | **HOLS**[d] | **LIML** |
| **Capital** | 0,2 | -0,1 *** | -0,01 | 0,3 *** | -0,1 | -0,03 | -0,01 |
| **Qualified labor** | 141 | 1 | -3 | 75 * | -8 | -49 | 23 |
| **Illiterate labor** | -10 | -11 ** | 9 ** | -26 ** | 14 ** | 35 ** | -3 |
| **Tropical** | -34 ** | -3 | 0,2 | -7 | 1 | 19 *** | 0,2 |
| **Crop** | 1 | 0,4 | -1 *** | 3 * | -1 ** | -4 ** | 0,1 |
| **Nontropical** | -29 * | -2 | 6 *** | -14 ** | 18 *** | 39 *** | 1 |
| **Copper** | 1047 ** | 88 | 100 ** | 288 * | 290 *** | 63 | 137 |
| **Iron** | 27 | 3 | -7 * | 7 | -3 | 1 | 1 |
| **Lead** | -45268 * | -4916 | 1327 | -18615 ** | -610 | 16364 | -2374 |
| **Zinc** | 17665 ** | 1575 | -368 | 5725 * | 80 | -6977 * | 476 |
| **Coal** | 15359 | 2494 * | 2669 *** | 12518 *** | 2998 * | -4193 * | 3254 * |
| **Gasoil** | 5944 | 645 | 720 | 2336 | -8 | -4449 * | -579 |
| **BOD** | -2 | 0,1 | -0,1 | -2 *** | -1 ** | 2 ** | -0,1 |
| **$SO_2$** | -2875 ** | -186 | -253 ** | -891 ** | -199 | -281 | -384 |
| **Constant** | 540372 ** | 5539 | 29260 | 36155 | 44364 | 27373 | 62387 |
| **Centered $R^2$** | 0,52 | 0,67 | 0,84 | 0,82 | 0,91 | 0,63 | 0,10 |
| **Observations** | 69 | 71 | 69 | 71 | 69 | 69 | 69 |
| **Overidentification**[a] | 0,29[h] | | 0,34 | 7,68** | 2,85 | 2,65[h] | 1,74[h] |
| **Exogeneity**[b] | 7,02** | 3,35 | 11,13*** | 3,88 | 5,22* | 0,85 | 13,22*** |
| **Homoskedasticity**[c] | 11,96[e]*** | 6,36 | 8,18 | 6,95 | 7,91 | 7,39 | 9,88 |

Notes: All the estimations have a correction due to small samples. For reasons of space, heteroscedasticity-robust standard deviations have not been reported. Instead *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a]Anderson-Rubin statistic of overidentification of all instruments [chi-sq (2)]. Superscript h indicates that Hansen J statistic was reported instead. [b]C-statistic, test of exogeneity/orthogonality of suspect instruments [chi-sq (2)]. [c]IV heteroscedasticity test, Pagan-Hall general test of homoscedastic disturbance using levels of IVs only (chi-squared with 16 degrees of freedom). [d]The Breusch-Pagan/Cook-Weisberg test rejected the hypothesis of conditional homoscedasticity in OLS. [e]The test used fitted value and its square (it is distributed chi-sq (2)). [f]This estimator is employed because the result of the overidentification test rejected the hypothesis that excluded instruments are uncorrelated with the disturbance in the structural equation.

Table 7d: HOV Estimation Results under Hypothesis of BOD and $SO_2$ Endogenous

(Dependent variable: thousands of U.S. dollars of net export in 1996)

| *Sector* | *Non-metallic Mineral Manufactures* | | | | | | |
|---|---|---|---|---|---|---|---|
| **Subsector** | **661** | **662** | **663** | **664** | **665** | **666** | **667** |
| **Method** | **OLS**[f] | **LIML** | **LIML** | **OLS** | **HLIML** | **LIML** | **LIML** |
| **Capital** | -0,02 | 0,1 | 0,1 *** | 0,1 *** | 0,02 *** | -0,1 *** | -0,1 |
| **Qualified labor** | -53 * | -35 | -7 | -4 | -25 * | -13 | -76 |
| **Illiterate labor** | 3 | -6 | 4 * | 3 | -1 | 0,4 | 18 ** |
| **Tropical** | 2 | -1 | 0,8 | 2 ** | 3 ** | 1 | 8 |
| **Crop** | 0,2 | 1 | -0,5 ** | -0,3 | 0,3 | -0,3 * | -1 |
| **Nontropical** | 3 | -4 | 1 | -0,5 | 0,7 | 0,6 | 5 |
| **Copper** | -114 | -163 | 12 | 37 ** | -110 *** | -63 ** | -189 |
| **Iron** | -4 | 4 | 3 * | -1 * | 0,04 | 2 | 16 * |
| **Lead** | 3664 | -4297 | 663 | 571 | 2174 | 1487 | 3193 |
| **Zinc** | -1186 | 1565 | -308 | -252 | -893 | -582 | -1822 |
| **Coal** | -2848 ** | -1248 | -1500 ** | 751 * | -2530 *** | -2264 *** | -6113 ** |
| **Gasoil** | -485 | -1133 | -113 | -195 | -908 ** | -492 *** | -2280 ** |
| **BOD** | 0,6 *** | -0,3 | 0,4 *** | -0,01 | 0,3 ** | 1 *** | 0,8 ** |
| **$SO_2$** | 253 | 350 | -66 | -70 | 270 *** | 122 * | 419 |
| **Constant** | 2030,3 | 21354 | -15186 | 2361 | -52581 *** | -19279 | -24513 |
| **Centered $R^2$** | 0,74 | 0,20 | 0,91 | 0,70 | 0,59 | 0,96 | 0,88 |
| **Observations** | 71 | 69 | 69 | 71 | 69 | 69 | 69 |
| **Overidentification**[a] | 5,18* | 3,77 | 1,64 | | 2,74 | 2,54 | 2,63 |
| **Exogeneity**[b] | 2,36 | 11,69*** | 9,78*** | 1,20 | 6,00** | 31,25*** | 7,26** |
| **Homoskedasticity**[c] | 9,93 | 12,29 | 5,16 | 6,29 | 9,58[e]*** | 8,43 | 3,92 |

Notes: All the estimations have a correction due to small samples. For reasons of space, heteroscedasticity-robust standard deviations have not been reported. Instead *, **, and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a]Anderson-Rubin statistic of overidentification of all instruments [chi-sq (2)]. Superscript *h* indicates that Hansen J statistic was reported instead. [b]C-statistic, test of exogeneity/orthogonality of suspect instruments [chi-sq (2)]. [c]IV heteroscedasticity test, Pagan-Hall general test of homoscedastic disturbance using levels of IVs only (chi-squared with 16 degrees of freedom). [e]The test used fitted value and its square (it is distributed chi-sq (2)). [f]This estimator is employed because the result of the overidentification test rejected the hypothesis that excluded instruments are uncorrelated with the disturbance in the structural equation.

# Paper II

# Poor Areas or Poor People: Decomposing differences in living standards and poverty

*Miguel Quiroga*

**Abstract**

Several studies report large and persistent differences in standards of living and poverty within a country. In this paper, we study whether the observed differences in poverty incidence in urban areas are due to differences in the attributes of the population living in these zones or come from differences in the value of these attributes in the different areas. For this purpose, we apply decomposition analysis. We illustrate the methodology comparing urban areas in 13 Chilean regions for the year 2003. We found that even after controlling for an ample set of household characteristics, differences in the parameters are an important determinant of household income and poverty within a country.

Key Words: living standards, poverty, geography, and decomposition analysis.

JEL Classification: I32, I38, O15, O18.

## 1. Introduction

Several studies report large and persistent regional differences in poverty incidence within a country, even in growing economies facing sustained reduction in poverty. These geographic differences in household ability to reach minimum living standards motivate governments and aid organizations to allocate resources according to the location of the households and productive units. For instance, Jalan and Ravallion (1998) reported evidence of targeting poor areas in China.

Nevertheless, the arguments for policy that targets poor areas are not clear. On the one hand, geographic differences for poverty and living standards could be attributed to the co-localization of households with similar characteristics if there are no restrictions to household mobility. In equilibrium, households could enjoy the same welfare wherever they live and it could be a better policy to directly target the attributes that cause these households to remain poor.[1] On the other hand, in certain contexts, regional or local attributes could influence household living standards and the probability of being poor such that the same household might face different income prospects based on where they live. In some cases, interactions between geographic capital and household attributes provide the mechanism in a context of limited household mobility. The same household could experience a higher living standard in a richer local environment. Public goods, knowledge spillovers, and favorable agro-climatic conditions among other factors, may generate this favorable environment. Other models consider market imperfections that arise from local externalities that could hurt poor households more severely. For instance, Jalan and Ravallion (2002) isolate the importance of externalities stemming from

[1] There is still an argument against targeting poor areas, but it is based on the inability of policy makers to observe the characteristics that trap households in poverty (Ravallion, M., 1993).

"geographic capital" which influence the productivity of a farm household's own capital when mobility of capital is constrained. Dasgupta (2003) describes several mechanisms based on the existence of reproductive and environmental externalities at the spatial level which generate positive feedback between poverty, population growth, and degradation of the natural resource endowment. Externalities originating from slightly distorted individual behavior may produce large negative effects through the influence within the group where he/she participates, e.g. neighborhood, school, gender, race, among others (Bowles, S. *et al.*, 2006). For instance, Borjas (1995) shows evidence of externalities that come from ethnic groups and neighborhoods that reduce income mobility. Most recently, Desmet and Ortuño (2007) show the importance of transfer and assistance in perpetuating poor areas. They model how transfers to poor areas avoid a leapfrogging technological change that would keep the backward region underdeveloped. Rich regions avoid the competition of low-wage areas while poor areas prefer the transfer to a higher but uncertain increase in wages from technological change.

In this paper, we propose a methodology for comparing living standards and poverty incidence in different regions using a cross-section of household microdata. The objective is to distinguish whether differences in living standards and poverty incidence come from the concentration of poorly endowed households or come from differences in the influence that household attributes have in the standard of living among regions. Ravallion and Wodon (1999) pursued a similar objective. They suggest a method, analogous to Oaxaca decomposition, for disentangling the two components. They applied the methodology to a cross-section of six thousand in Bangladesh for a population of 120 million inhabitants. They found that geographic differences account for an important part of the differences in living standards.

Although comparable in intent to the study just cited, this paper has several new features that make it possible to gain a more detailed and robust comprehension of the importance of household attributes and the value of these attributes as a determinant of the standard of living and poverty incidence within a country. We decompose the spatial differences in poverty rate between what we call geographic or structural causes and those generated by the spatial concentration of households with similar attributes. For the poverty decomposition we follow Yun (2004) who shows how to apply the Blinder-Oaxaca decomposition to non-linear functions to obtain a detailed decomposition that is free from path-dependence.[2] This detailed decomposition allows us to identify and quantify the variables influencing living standard heterogeneity and poverty gaps among regions. In addition, we use another contribution of the same author to test the significance of these changes (Yun, M.-S., 2005). These new features contribute to identify individuals who are susceptible to falling into poverty. Therefore, it helps to improve the targeting of resources intended to fight against poverty.

Another distinctive aspect of this paper as compared to Ravallion and Wodon (1999) is the fact that we allow all the coefficients to vary among regions, not only the intercept. Therefore, it is not necessary to assume that the value of an extra year of schooling or the price of another household characteristic has to be the same among regions. Furthermore, the size of the sample is considerably larger, thus increasing the accuracy of our estimations.[3]

Last but not least, most of the literature on decomposition analysis compares two groups. This paper illustrates how to apply this methodology to compare a broader set of economic units.

[2] Usually, contribution of single variables were computed by sequentially substituting the value of the variable in a group with the comparison group. The process was repeated with each variable. However, this method is sensitive to the order of replacement, a flaw known as path-dependency (Ham, J.C. *et al.*, 1998).

[3] It consider 170 000 individuals for a population of 13.6 million inhabitants.

We illustrate the methodology using a cross-section of urban Chilean households for the year 2003.

In the following section, we analyze the determinants of living standards. In Section three, we report the estimation of regional income generating functions in the Chilean economy. We use these results in the decomposition analysis in the following sections. As a benchmark of the proposed methodology, in Section four we report simulations of characteristics and structural profiles following the methodology suggested by Ravallion and Wodon (1999). In Section five, we present the decomposition methodology suggested in this paper. We apply the methodology described in World Bank (2006, Technical Note A.8) and we use the work of Yun (2004) to make a detailed decomposition of the differences in standard of living and poverty incidence among Chilean regions. In the last section, we present the conclusions and the main implications of this research.

## 2. Determinants of Living Standards

There is broad evidence of regions being trapped in low living standards and high poverty levels, even in economies that experience sustained economic progress and rapid poverty reduction.[4] This evidence has attracted considerable attention from researchers and policy makers trying to understand and interpret these facts before designing appropriate instruments and policies to help less-advantaged regions. The measure of poverty incidence has partially

[4] There is evidence of these geographic disparities in China (Fang, C. *et al.*, 2002; Gustafsson, B. & W. Zhong, 2000; Ravallion, M. & S. Chen, 2007), Bangladesh (Ravallion, M. & Q. Wodon, 1999), Chile (Contreras, D., 1996a), India (Kapur Mehta, A. & A. Shah, 2003), to cite some studies.

captured their attention as well, to find better methods for making interpersonal comparisons.[5] Additional research efforts seek to understand why poverty is higher in certain areas, which is the focus of this paper. We assume the measure of living standard (or well-being) and poverty incidence as given, usually the *headcount index*, and then we investigate what causes the differences in poverty levels (for instance: Jalan, J. & M. Ravallion, 2002; Ravallion, M. & Q. Wodon, 1999; Rupasingha, A. & S.J. Goetz, 2007; Wan, G., 2007).

From an empirical point of view, there are two interpretations of these observed disparities. One suggests that observed differences between rich and poor areas reflect differences in the characteristics of the inhabitants such that if we control for the appropriated attributes of these populations, the differences could disappear. The other interpretation proposes that differences in the attributes of the population cannot fully explain these geographic disparities and the gap can be attributed to local factors which determine that the contribution of these characteristics to the household income differ geographically.[6]

In the first case, aspatial characteristics influence living standards such that a household could enjoy the same welfare independent of where they live. Heterogeneity in household living standards reflects household preferences and household endowment of productive assets. Poverty arises because individuals do not accumulate enough human and physical capital. In this case, the persistence of areas with low living standards could be mirroring the co-location of poorly

[5] Precision of poverty measures (Simler, K.R. & C. Arndt, 2007), the effect of premature mortality (Kanbur, R. & D. Mukherjee, 2007), distinction between transient and chronic poverty (Hulme, D. & A. Shepherd, 2003) and multidimensional measures of poverty (Duclos, J.-Y. *et al.*, 2006), among others, have captured interest in recent years.

[6] We cannot disregard the dynamic perspective considering that differences in coefficients reflect temporal disequilibrium coming from shocks that have affected these regions. The convergence on these returns has been a key question in the literature. However, the data set employed in this study to illustrate the methodology does not allow us to answer this question. Nevertheless, this shortcoming could at least partially be tackled by comparing the stability of these results in different periods.

endowed households. Why household endowments differ persistently and why households with the same attributes are sorted into determined areas of residence are key questions in this conceptual framework. The second approach emphasizes the role played by local factors in the return on individual characteristics, such that the same household could benefit from different welfare prospects according to the place of residence.

Equation 1 summarizes the factors that influence living standards. The well-being of household $i$ in region $s$ ($w_{iS}$) is a (linear) function of household characteristics ($x_i$) and characteristics of the region where the household resides ($z_S$). Most of the models that emphasize the influence of local factors on living standard consider that the return on household characteristics is the main channel for transmitting this effect. Parameter $\theta$ captures this relationship, i.e. the interaction of household characteristics and geographic-localized factors. Meanwhile, the parameter $\gamma$ grasps the independent effect that local variables could have in living standards. $\varepsilon_{is}$ is the error term.[7]

$$w_{is} = \alpha + \beta' x_i + \gamma' z_s + \theta'\left(x_i * z_s\right) + \varepsilon_{is} \qquad (1)$$

Therefore, we could estimate the parameters $\alpha, \beta, \gamma$ and $\theta$ in equation 1 assuming that we control for all the relevant household and regional characteristics and some structure for the residual. In this case, the parameters $\left(\beta' + \theta' z_s\right)$ - region-specific – will highlight the effect that household characteristics have on living standards. However, if we fail to control for all the relevant regional attributes it is easy to show that we will estimate biased parameters associated

[7] We do not need to assume any specific structure for the residual at the moment.

with the household characteristics.[8] We assume that we do not observe the geographic characteristics. In this case, we could estimate equation 2 including dummy variables identifying the regions $(d_s)$; or, we might estimate equation 3 for each of the $s$ regions in $S$.

$$w_{is} = \alpha + \sum_{s}^{S-1} \gamma'_s d_s + \beta' x_i + \sum_{s}^{S-1} \theta'_s (x_i * d_s) + \varepsilon_{is} \quad (2)$$

$$w_{is} = \tilde{\alpha}_s + \tilde{\beta}'_s x_i + \varepsilon_{is} \quad (3)$$

Ravallion and Wodon (1999) seek to estimate a function similar to equation 2 to analyze whether the spatial differences in living standard and poverty incidence could be explained by mobile household characteristics geographically correlated. They consider 17 regions in Bangladesh and areas within them. They distinguish between rural and urban zones. They found a considerable effect on welfare and poverty levels coming from the area of residence. However, because the sample size was not large enough, they imposed additive separability between the regional effect and the household characteristics, assuming that only the constant parameter varies among the 34 areas considered, while the parameters associated with the household characteristics change only between rural and urban areas. Specifically, they do not consider interactions between the household characteristics and the dummies identifying the 17 district.[9] To estimate parameters consistently using this strategy, it is necessary to assume that the regional impact in living standard is independent of the household characteristics, which implies a rejection of our conceptual framework that considers that the return on household

[8] We do not have the same problem if we do not consider all the relevant household characteristics, meanwhile the omitted characteristics are not correlated with observed household explanatory variables. In this case, the region-specific constant coefficients - $\left[\gamma' z_s + (\beta_k + \theta_k z_s) x_k\right]$ - will capture the effect of the omitted variable $x_k$.

[9] This is because they end up with few observations for many combinations of districts with household characteristics.

capital (in particular "human capital") is affected by local attributes. Accordingly, the estimated parameters will be biased. In our approach, the size of our sample is enough to allow interaction terms between household characteristics and regional effects. Thus, we allow all the parameters to vary geographically. Therefore, we regress standard of living on household characteristics separately in each region as in equation 3.[10]

## 3. Empirical illustration

We analyze the determinant of well-being and poverty in each of the 13 Chilean regions. The empirical analysis uses a Chilean household survey conducted in 2003. The survey consists of multi-stage random sampling with geographical stratifications (at the regional, provincial and county levels) and clustering (at the neighborhood level). Households were selected randomly within each chosen neighborhood.

Household income is the welfare measure available in the survey. We use it to calculate the per capita monthly household income normalized by the poverty line. The log on this variable is the dependent variable in the income regressions. We call this variable "income scale". This variable reflects the log on the number of times that income surpasses the poverty line in the area where the household resides. The absolute poverty line should reflect the cost of achieving the same standard of living among different geographical partitions within a country.

This measure has been suggested by the World Bank (2006, Technical Note A.8) for analyzing the determinants of poverty, as estimated coefficients and the standard deviation of the error term can be used to calculate the probability of being in poverty assuming that the error

[10] For a review of other approaches see Ravallion (1998).

term is normally distributed. In Chile, official poverty analysis only makes a distinction between urban and rural cost of living, assuming that the cost of living does not vary within these areas.[11] We use the prices of Santiago for valuing the bundle in urban areas. However, Contreras (1996a) showed evidence of a high regional price heterogeneity. The basic bundle is cheaper in central regions, but is more expensive in the extreme northern and southern regions. In this study, we recalculate the poverty line using food prices collected by the Chilean Statistical Institute in 24 cities throughout the country. We assume that these prices are representatives of the second level of administrative division of the country, the provinces. Therefore, we obtain price-adjusted poverty lines at provincial level.[12] Figure 1 illustrates the calculated poverty lines for the 24 cities in relation to the level officially fixed for urban areas. We observe that when we use local prices to value the basic food bundle, poverty line is higher in most of the cities. Thus, official poverty measure underestimates poverty rates in most of the Chilean cities.[13]

Another plausible source of distortion in the measure of poverty line comes from differences in household age composition, as nutritional needs differ between adults and children. There is also evidence of scale economies at the household level, such that an increase in the number of constituents of the household increases the cost of covering basic needs less than proportionally. Contreras (1996b) used the method proposed by Rothbarth to calculate equivalence scales (to add the composition of the household) for the Chilean economy. Using the Chilean Expenditure Survey from 1988, Contreras found that the cost of a child is between 15

[11] The poverty line in urban areas is twice the value of the basic needs food bundle.

[12] The price of the items collected in the cities represents 90 percent of the items included in the national basic need food bundle. When the price of the good was not available in the city, it was kept at the official level.

[13] We allowed the prices to vary across cities, but we kept the bundle fixed among the cities. This assumption is difficult to justify even with similar household preferences. We should consider that local households will adjust their consumption in order to subtitute the consumption of products that are relatively more expensive in the area. Therefore, in this exercise, we are also over-estimating the impact of price heterogeneity in poverty rate.

percent and 43 percent of the cost of an adult.[14] However, he noted that the use of this methodology reduces poverty levels, but does not change the ranking of regions in terms of poverty incidence. In this study, we do not use scale equivalences to correct the poverty lines directly, instead demographic variables were included in the regression analysis to account for this effect.

In summary, income scale (our measure of household living standard and well-being) is the explained variable in the regression analysis. We assume that a linear combination of household characteristics determine income scale. The characteristics account for differences in household demographic composition and in the ability to increase income.[15] We group the independent variables in the following categories. The square of some variables intend to capture the possibility of nonlinear effects

a) **Household Composition:** These variables control for age composition to account for the possibility that welfare-measuring errors (as discussed previously) could be correlated with some of the explanatory variables. In particular, we are concerned about the possibility that human capital variables such as education might be correlated with household composition. In the construction of the controls we follow the Chilean evidence provided for Contreras (1996b) to define the number of babies, children, teenagers and adults.

[14] The cost is 15 percent between age 0-4, 20 percent between age 5-10, and 43 percent between age 11-15.

[15] Because the empirical application is used mainly to illustrate the metodology proposed in this paper, we intend to stick with the variables used by Ravallion and Wodon (1999). Nevertheless, the information collected in our survey and the relevance of some of these variables in the Chilean case reveal some differences.

b) **Other household characteristics:** We incorporate a dummy variable that takes the value of one if the family owns a house. This is the only variable available in the survey to control for physical assets that belong to the household. Moreover, we include two dummy variables to control for the gender and ethnic attribute of the household head. The gender dummy takes the value of one if the household head is male. The other dummy takes the value of one if the household head does not belong to any of the eight indigenous groups that the Chilean law recognizes. The inclusion of the first control is based on the evidence of negative gender gap that affects women in Chilean wage formation (for instance see Dresdner Cid, J. & J. Arteaga, 1997; Ñopo, H., 2007) . The other control is based on a recent study that shows evidence of wage discrimination against indigenous groups in the Chilean labor markets (Zurita Zapata, G. & J. Dresdner Cid, 2007). Finally, we include another categorical variable that distinguishes head with spouse from head without spouse, and among the latter, married, single, or divorced/widowed.

c) **Human Capital:** We use linear spline variables (Greene, W.H., 2003, section 7.2.5) to capture formal investment in education of the head and the spouse. These variables allow us to use the richer information about years of schooling available in the employed survey, but also to capture education as a signaling device. It allows the coefficients to change when primary, secondary, university (or professional education), and post-university education has been completed. We employed years of schooling of the head or spouse and knots at age 8, 12 and 16 to build these variables. Furthermore, we include experience of the household head to account for the learning by doing process of human capital accumulation. We distinguish between general and specific accumulation of human capital. Age is a proxy for general experience and number of years in the current employment is a proxy for specific accumulation of human capital. Finally, we introduce a group of dummy variables that identifies the sector of economic activity where the head is employed. Its inclusion is based on the evidence of inter-industry wage differentials (Abuhadba, M. & P. Romaguera, 1993) and segmentation in the Chilean labor market (Basch, M. & R.D. Paredes-Molina, 1996).

We estimate the income scale function, as in equation 3, for each region using Maximum Likelihood. Apart from the covariance matrix for the coefficients, this method of estimation directly provides the standard deviation of the error term (Bhaumik, S.K. *et al.*, 2006). We use the standard deviation of the error term to calculate standardized coefficients. These are employed to estimate the probability of being in poverty assuming that the disturbances are normally distributed. We utilize frequency weights in the parameter estimation to consider the geographical stratification of the sample.

Furthermore, we allow observations within each neighborhood to be correlated. This allows us to adjust the asymptotic variance matrix to consider the fact that the Chilean survey takes into account a large number of clusters within each stratum of relatively small size. Therefore, we assume observations are correlated within a neighborhood, but that they are independent among neighborhoods. This adjustment is consistent with theoretical models which suggest that there are externalities at the neighborhood level that could make the standard of living correlated spatially, but also with the hypothesis of self-selection of highly endowed households in advantaged neighborhoods.[16]. What is more interesting is the fact that our primary estimations seems to corroborate the importance of positive correlation within neighborhoods. Estimated variances when we assume that observations are i.i.d. are rather small, so the significance of all the coefficients is very high. This characteristic does not change when the observations are independently but not identically distributed and we estimate robust standard errors to correct for heterocedasticity of unknown form. However, the estimated variance increases considerably when we allow correlation within the clusters. Table 1 reports the ratio between variances allowing observations within a neighborhood not to be independent (clusters) and variance when observations are independent but not equally distributed (robust). The cluster variance estimator is hundreds of times larger than the robust variance estimator. This evidence is consistent with the existence of positive correlation within clusters for what is possible to observe when comparing both formulas of variance.

$$\hat{\sigma}^2_{\text{Robust}} = \hat{\sigma}^2_{ML}\left(\sum_{i=1}^{N} u'_i\, u_i\right)\hat{\sigma}^2_{ML} \tag{4}$$

$$\hat{\sigma}^2_{\text{Cluster}} = \hat{\sigma}^2_{ML}\left(\sum_{k=1}^{K} u'_k\, u_k\right)\hat{\sigma}^2_{ML} \quad \text{such that} \quad u_k = \sum_{i=1}^{N_k} u_i \quad \text{and} \quad \sum_{k=1}^{K} N_k = N \tag{5}$$

In equations (4) and (5), $\hat{\sigma}^2_{ML}$ represents the conventional estimator of variance and $u_z$ (with $z = i$ or $k$) is the contribution from the $i^{\text{th}}$ observation or the $k^{\text{th}}$ cluster to the scores $(\partial \ln L / \partial \beta)$. *N*, $N_k$ and *K* are the total number of observations, the number of observations in cluster *k*, and the number of clusters, respectively. Therefore, it is easy to see that the cluster estimator of variance will be larger than the robust estimator of variance if the cluster sums of $u'_k\, u_k$ have more variability than the individual $u'_i\, u_i$. That could happen if some of the variation

[16] Raaum et al. (2006) seeks to disentangle both explanations.

is reinforced when we sum $u'_i u_i$ within a cluster, this is consistent with positive correlation within the clusters.

We also estimate equation 2 including thirteen dummy variables that identify the region and interaction variables between these dummies and all the explanatory variables in the income scale function.[17] Then, we conduct a Wald test of the null hypothesis that estimated coefficients are similar among regions. This hypothesis was rejected. As a result, with a level of confidence higher than 99% percent we can reject the hypothesis that the income scale model is the same among the different regions in the country. Therefore, structural determinants of living standards vary geographically such that the coefficients associated with household characteristics are specific to the place of residence. The methodology proposed in this paper is useful because it provides an idea of the importance of this effect.

This test and other similar tests considering group of variables are reported in Table 2. In addition, we test some of the features that we assume when we model income scale. These Wald tests are in Table 3. We reject the null hypothesis that the impact of an additional member of the household is the same independent of whether this member is a baby, child, teenager, or adult. As well, we reject the null hypothesis that one additional year of schooling of the head does not change the accumulated years of schooling, but it is not possible to reject this hypothesis in the case of the spouse. Finally, we reject the null that Rama does not influence income scale.

Estimated parameters for the Metropolitan region are reported in Table 4. All the parameters have the expected sign and most of them are statistically different from zero. The only result that could cause some concern is the dummy variable identifying a male-headed household. This coefficient is not statistically significant which is not consistent with the

[17] Frequency weights and cluster estimator of the variance were also utilized in this estimation.

evidence that suggests the existence of a female-male gap in the Chilean wage setting (for instance, Ñopo, H., 2007).

The determinants of income scale were also estimated for the other twelve Chilean regions. The results are not reported in this paper, but they are available upon request. We can say, in general, that all the parameters show the expected sign. There is variation in the significance of the coefficients, but coefficients associated with human capital accumulation are statistically significant in most of the regions.

The constants in these estimations reflect the income scales of an individual that belongs to a household headed by an indigenous woman with spouse. She does not work (she is unemployed, a student or a retired person), and she belongs to a household that does not own a house. The negative value of the constant term in Table 1 indicates that an individual residing in a house with these characteristics acquires a per capita income lower than the poverty line. In each region, the coefficients are interpreted as increments or reductions in income scale with respect to this reference group.

## 4. Ravallion and Wodon's Type Decomposition

Our purpose here is to compare the methodology proposed in this paper with the method suggested by Ravallion and Wodon (1999). We estimate the unconditional, characteristic, and structural profiles proposed by Ravallion and Wodon to get a picture of the importance of the household characteristics and differences in return of these attributes (the structural component) as determinants of living standards and poverty rates among regions. We utilize the estimated coefficients and the mean value of the household characteristics for each region.

### 4.1 Living Standards

We simulate income scales in two different contexts. For the first, we estimate a *characteristics profile of income scales*. As in equation 6, coefficients of a reference group $(\beta_r)$ are utilized to evaluate the mean value of non-geographic household characteristics in each *s* region to observe the influence that differences in mobile household characteristics have on the distribution of income scales throughout the country.

$$E\left(w_s \mid \beta = \beta_r , X = \overline{X_s}\right) = \beta_r \, ' \, \overline{X_s} \qquad (6)$$

For the second, we estimate a *structural profile of income scales*. As in equation 7, the mean characteristics of a reference group $(X_r)$ are evaluated using the coefficient estimated for each region to gain information about the importance of geographical immobile factors on the distribution of income scales throughout the country.

$$E\left(w_s \mid \beta = \beta_s , X = \overline{X_r}\right) = \beta_s \, ' \, \overline{X_r} \qquad (7)$$

Ravallion and Wodon (1999) use national mean characteristics and population-weighted mean parameters as the reference points to simulate welfare ratios. We opt for using one of the regions - its mean characteristics and estimated parameters - as the gauge. Although the profiles do not depend on the chosen reference vector of parameters and characteristics, the choice of a region as a benchmark makes it easier to interpret the results and to consider policy implications. In Chile, the Metropolitan region serves as a natural yardstick device. It is the most populated region. It has the highest rates of investment and its inhabitants enjoy the highest living standards. The country has a highly concentrated administration of public resources and the Metropolitan region is where political and economic power is concentrated. Headquarters of the main state powers and services are located in the region which makes it very difficult to distinguish between issues related to the state administration from the those related to the regional administration. This characteristic makes the Metropolitan region (or State administration) a natural unit for more disadvantaged areas to point its finger at when demanding more resources or policies to improve their economic situations. Moreover, it is also an interesting starting point for studying the structural determinants of well-being, because it is not difficult to hypothesize about several possible economic distortions that could be generated by this centralized administration of the state. Many other developing countries share these characteristics of the Chilean economy, which makes this feature an interesting benchmark for other studies.

The results of this exercise are reported in Table 5. The table exhibits the unconditional and simulated income scales using the characteristics and the coefficients of Metropolitan region (Mr) as a benchmark. The application of the exponential function to this value will provide us with the number of times that income surpasses the poverty line in the region. The unconditional profile represents the mean of the regional attributes evaluated using their respective parameters. Thus, the value of 0.96 associated with the Metropolitan region suggests that the expected income in this region is 2.6 times the value of the poverty line. At the other extreme, in the Araucania the expected income represents only 1.5 times the value of the poverty line. This column illustrates the high dispersion of living standards among the regions. There are areas where income scale does not surpass or surpasses by barely half, the well-being that households obtain in the Metropolitan region. The highest level of income scales are located in the center (Metropolitan), in the extreme North (Tarapaca and Antofagasta), and South (Magallanes) regions.[18] The simulated characteristics profile, the mean regional attributes evaluated using the coefficients estimated for the Metropolitan region, shows that in terms of characteristics regions are more homogenous, although they tend to have less favorable characteristics than the Metropolitan region. In the best of the cases, the average level of the characteristics in Magallanes represents 92 percent of the attributes in the Metropolitan region and in the worse case, Atacama, 75 percent. As an example of another regional comparison, the characteristic profile shows that Los Lagos has an income scale 50 percent higher than the region of Araucanía. However, this difference not only disappears when we control for differences on the return for these characteristics, Araucania reaches an even higher income scale due to Los Lagos being endowed with a lower level of favorable characteristics. In the structural profile, calculated using the regional parameter to evaluate Metropolitan mean attributes, the objective is to measure the importance of the geographical factor and its effect on the return for household characteristics. This simulated profile shows that households get the highest return for their characteristics in the Metropolitan region. Meanwhile, the lowest return for household characteristics is in the Araucanía region. In this case, even if the household were to have the same mean characteristics as the Metropolitan region they would reach only two-thirds of the living standard enjoyed by Metropolitan region inhabitants.

The last two rows of Table 5 report two indicators that highlight the importance of structural differences among regions. The correlation coefficient between unconditional and characteristic profile is 0.69 that shows a positive association between unconditional and characteristic profile. Nevertheless, the correlation is even larger, 0.90, between unconditional

[18] In the tables, regions are in geographic order starting from the north (Tarapaca) and ending in the the south (Magallanes).

and structural profile. In addition, the characteristic profile accounts for only 16 percent of the variance in unconditional income scale, but structural profile accounts for 53% of this variance.

### 4.2 Poverty rates

Following the methodology suggested by the World Bank (2006) we calculate unconditional, characteristic and structural profiles of poverty rates assuming that errors are normally distributed and employing the standard deviation of the error term (σ) obtained from the Maximum Likelihood Estimation.

The probability of being poor in the region *s* (unconditional poverty) is

$$\Pr\left(w_s < 0 \mid \beta = \beta_s, X = X_s\right) = \Pr\left(\varepsilon_s < -\tilde{\alpha}_s - \tilde{\beta}'_s X_s\right) = \Phi\left[-\tilde{\alpha}_s/\sigma_s - (\tilde{\beta}'_s/\sigma_s)\overline{X_s}\right] \quad (8)$$

The characteristic and structural poverty profiles are obtained in the same way, conditioning in the parameters or the mean characteristics of the Metropolitan region, respectively (see equations 9 and 10, respectively).

$$\Pr\left(\varepsilon_s < -\tilde{\alpha}_r - \tilde{\beta}'_r X_s\right) = \Phi\left[-\tilde{\alpha}_r/\sigma_r - \left(\tilde{\beta}'_r/\sigma_r\right)\overline{X_s}\right] \quad (9)$$

$$\Pr\left(\varepsilon_s < -\tilde{\alpha}_s - \tilde{\beta}'_s X_r\right) = \Phi\left[-\tilde{\alpha}_s/\sigma_s - \left(\tilde{\beta}'_s/\sigma_s\right)\overline{X_r}\right] \quad (10)$$

In Table 6 we report estimates of unconditional, characteristic and structural poverty profiles. In the first column, we observe the high heterogeneity in headcount poverty throughout the country. Poverty rates in Araucanía are three times higher than in the Metropolitan region, for example. However, this heterogeneity is reduced when we control for differences in coefficients. Excluding Metropolitan region and Atacama, characteristic poverty profiles show that poverty rate fluctuates between 14 and 17 percent when we only consider differences in the attributes. In the latter example, poverty rate in the Araucanía region is reduced to half when we only consider differences in household characteristics. The structural poverty profile exhibits more variation and still is an important determinant of poverty rates. The correlation between unconditional and characteristic poverty profiles is 0.53, but the correlation coefficient between structural and unconditional poverty is 0.83. Structural poverty accounts as well for a higher percentage of the variation in poverty (49 percent), but differences in characteristics account for only 11 percent of the variance in poverty. This table also suggests different explanations of poverty throughout the country. For instance, while poverty in Atacama is mainly explained by differences in household characteristics, differences in the return for these characteristics provide the underlying factor behind poverty in Araucanía.

## 5. Blinder-Oaxaca Decomposition of Living Standards and Poverty Measure

Although the profiles presented in the previous section are useful for having a notion of the importance of differences in household characteristics and in the return for these attributes, they do not provide the exact contribution of each factor to poverty or an idea about the characteristics or parameters that are more relevant for explaining these differences. In this section, we suggest applying a decomposition method to enhance the analysis. The methodology is illustrated using the Chilean household survey and income scale functions estimated in Section 3. We seek to obtain a more detailed measure of the factors explaining differences of income scale and poverty rates throughout the country. We keep the Metropolitan region as the benchmark region. In addition to the reasons suggested in the previous section, we add the fact that the importance of the structural component in the decomposition depends on the chosen reference group (see Cahuc, P. & A. Zylberberg, 2004, p. 282, for a discussion of this). The utilization of the Metropolitan region as the reference group assures the highest importance to the characteristic component and the more conservative estimation of the structural component. This is because the characteristic component of the decomposition will be larger if the coefficients and the characteristics of the reference group are more favorable among the areas compared, so owing to differences of income scale being fixed and not dependent on the decomposition, the structural component will be smaller (see equation 12).

### 5.1 Blinder-Oaxaca Methodology for Decomposing Mean Differences

This section describes how we employ the Oaxaca decomposition analysis to compare the mean of more than two groups. The starting point is a function that relates the dependent variable to a linear combination of *K* household's attributes in each of the *s* independent groups.

$$Y_s = F\left(X_s \beta_s ,\, \varepsilon_s\right) \quad \text{for each } s \text{ in } S$$

where

$$F(\cdot) = \beta'_s X_s + \varepsilon_s \quad \text{when we decompose "income scale"}$$

or

$$F(\cdot) = \Phi\left[-\left(\beta'_s / \sigma_s\right)\overline{X_s}\right] \quad \text{when we decompose the "headcount index"} \tag{11}$$

$Y_s$ is a $N_s \times 1$ vector where $N_s$ represents the sample size in the group *s*; $X_s$ is a $N_s \times K+1$ matrix of independent variables; $\beta_s$ is a $K+1$ vector of coefficients, and $\varepsilon_s$ is a $N_s \times 1$ vector of error terms.

One of these *s* groups, the group *r*, is chosen as the reference group. The mean difference in the dependent variable between *r* and the other groups is decomposed in terms of differences in characteristics and differences in coefficients using equation 12.

$$\begin{gathered} E(Y_r) - E(Y_s) \\ = \\ \left[E(Y_r \mid X = X_r, \beta = \beta_r) - E(Y_s \mid X = X_s, \beta = \beta_r)\right] \rightarrow \textit{Characteristics} \\ + \\ \left[E(Y_s \mid X = X_s, \beta = \beta_r) - E(Y_s \mid X = X_s, \beta = \beta_s)\right] \rightarrow \textit{Coefficients} \\ \\ \forall \quad s, r \in S \quad \textit{such that} \quad s \neq r \end{gathered} \tag{12}$$

The contribution of each variable is obtained using weights suggested by Yun (2004), as in equation 13.

$$\begin{gathered} E(Y_r) - E(Y_s) \\ = \\ \sum_{k=1}^{K} \left\{ \frac{\left(E(X_r^k) - E(X_s^k)\right)\beta_r^k}{\left(E(X_r) - E(X_s)\right)\beta_r} \right\} \left[E(Y_r \mid X = X_r, \beta = \beta_r) - E(Y_s \mid X = X_s, \beta = \beta_r)\right] \\ + \\ \sum_{k=1}^{K+1} \left\{ \frac{E(X_s^k)(\beta_r^k - \beta_s^k)}{E(X_s)(\beta_r - \beta_s)} \right\} \left[E(Y_s \mid X = X_s, \beta = \beta_r) - E(Y_s \mid X = X_s, \beta = \beta_s)\right] \\ \\ \forall \quad s, r \in S \quad \textit{such that} \quad s \neq r \end{gathered} \tag{13}$$

The differences between the characteristic components of any of these groups, for instance groups $s_1$ and $s_2$, can be directly interpreted as difference in the characteristics between these two groups valuated at the coefficients of the reference group, as in equation 14.[19]

$$\left\{E\left(X_{s_2}\right)-E\left(X_{s_1}\right)\right\}\beta_r \qquad (14)$$

The statistic significance of these differences is calculated following Yun (2005). The asymtotic covariance of the standarized coefficients $(\beta_j/\sigma_j)$ was derived using the delta method by Bhaumik et al. (2006).

**5.2 Decomposing Living Standards**

The purpose of this subsection is to analyze and interpret the source of differences on unconditional income scale (unconditional profile) observed in Table 5. The second column of Table 7 reports these differences. The income scale of region *s* is subtracted from the income scales in the Metropolitan region. The application of the exponential logarithm function to these values provides the relative standard of living in the Metropolitan region in relation to the region *s*. Thus, the value of 0.57 in Araucania suggests that living standards in the Metropolitan region represent 1.8 times the living standards in Araucania. Analogously, differences between any of these values represent differences in standard of living between any other of the regions as well. Then, the difference in income scale of 0.14 between Bio-Bio and Araucania indicates that the standard of living in Bio-Bio is 15 percent higher than in Araucania.

We apply the decomposition methodology discussed previously to determine whether these observed differences are because sorting of affluent households reflects differences in

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[19] The differences in the coefficient components of the decomposition cannot be interpreted in an analogous form. It is easy to show that this difference reflects differences in the coefficients with respect to the parameters of the reference group, but also differences in the characteristics between the two groups.

household attributes, or is the result of differences in the price or the value of the household attributes in the regions. The third and fourth columns in Table 5 report the decomposition of these differences in their *characteristic* and *structural* components.

The *characteristic component* of this decomposition shows the differences in the level of attributes between the Metropolitan region and the region *s* valuated using the parameters of the Metropolitan region. Thus, the coefficient of 0.14 associated with Antofagasta indicates that most of the observed difference (65 percent) in income scale between the Metropolitan region and Antofagasta is because Antofagasta inhabitants are endowed with less favorable characteristics than those of the Metropolitan region. If both regions were to have the same coefficients, the standard of living in the Metropolitan Region would be only 15 percent higher than in Antofagasta (actually, it is 25 percent higher), and this difference could be completely accounted for by the sorting of households with more favorable characteristics in the Metropolitan region. In addition, as suggested by equation 14, the differences in the values between any of these regions represent differences in the level of the household attributes between these regions valuated using the parameters of the Metropolitan region. Thus, the 0.06 difference observed between Bio-Bio and Araucania suggests that the latter region concentrates households with more favorable attributes. Therefore, if the household attributes in both regions were valued at Metropolitan region coefficients then the standard of living in Araucania could be 6 percent higher than in Bio-Bio.

The *structural component* shows the differences in the price of household attributes between Metropolitan region and region *s* valued at characteristics of region *s*. Differences in the parameters count for up to 78 percent of the observed differences in living standards (the case for Araucania). In this region, even if households in the Metropolitan region were to have the same level of attributes as Araucania, inhabitants of the Metropolitan Region would still have living standards 57 percent higher.

All the reported differences are statistically significant at reasonable levels of significance. Moreover, except for the most northern regions of the country, differences in the parameters (i.e. the value/price of the characteristics) account for most of the differences in income scales with respect to the Metropolitan region. This conclusion is consistent with the view we obtained from the simulation of concentration and structural profiles in the previous section. However, in addition to this, the proposed methodology allows us to identify the regions where characteristics or structural components are more relevant.

The concentration of households with similar characteristics could explain from 22 up to 65 percent of the differences in living standards between the Metropolitan region and the other regions. Nevertheless, it is relevant to know which household characteristics explain these differences. For this purpose, Table 8 reports a detailed decomposition of the household characteristics. The decomposition is reported as a percentage over the income scale differences in characteristics (second column). Most of the differences are statistically significant, although not all of them have the same importance in terms of magnitude.

It is clear that formal accumulation of human capital through education is the main variable that explains differences in attributes between the Metropolitan region and most of the other areas in the country. Households with higher levels of education are sorted out in the Metropolitan region. Although, its importance varies from 25 per cent in the North to more than 100 percent in the South for the household head, and from 14 up to 60 percent for the spouse. The other proxy variables for human capital accumulation have an impact in some regions as well.

The impact of the sector of economic activity is in net terms important in Valparaiso, Bío-Bío, Araucania, and Magallanes. They reflect largely the development of the financial, manufacturing, and to a lesser extent, the retail sectors in the Metropolitan region in relation to the rest of the country.[20] These differences are also present in the other regions. However, the impact is not considerable when we aggregate the sector because these Metropolitan advantages are compensated for by higher development and employment in the mining sector in the North (and O'Higgins region), and in agriculture in the Central and South regions.

In the North, the demographic component of the income scale, although difficult to interpret, is a disproportionate source of income differences, even more important than human capital endowments. This variable explains up to 40 percent of the income scale gap in these areas. This large effect is because while the number of adults (age 16 or older) is similar throughout the country, families have a higher number of children (especially babies) in the northern regions. This fact negatively influences income scale through two sources. On the one hand, it increases the number of dependent members of the household, and on the other, from the fact that children have a higher negative impact on income scale than adults.[21]

In Table 7, we see that differences in coefficients can explain from 34 up to 78 percent of the differences in living standards between the Metropolitan region and the other regions. A detailed decomposition of these structural differences could help to clarify the causes or sources of income heterogeneity induced by regional factors influencing the return on mobile household characteristics. We present this detailed decomposition in Table 9.

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[20] The exception is Bio-Bio. There is no difference in the manufacturing sector there compared to the Metropolitan region.

[21] The opposite effect influences well-being in Magallanes. There the number of children is lower than in the Metropolitan region.

The first general impression is that there is large heterogeneity among regions. Moreover, several differences although important in magnitude are not statistically different from zero. The first source of differences is in the constant term. This parameter reveals the influence of regional features that do not interact with household attributes. It represents a lower floor for the income scale in the region. This parameter reflects differences in the income scale obtained by the *reference* individual described in the last paragraph of Section 3 and the influence of non-observed household attributes correlated regionally. As an example, in the case of Magallanes, -0.95 is the difference in constant term associated to the percentage reported in Table 9 (-1258). Applying the exponential logarithm to this value, we found that in the Metropolitan region a household with the reference attributes obtains 40 percent of the income scale obtained in Magallanes. In another example, the implicit difference in the constant parameters in Los Lagos is 0.54, which suggests that the reference household in the Metropolitan region obtains 1.72 times the income scale that the same family could obtain in Los Lagos.

Contrary to what we expected, there are not clear patterns in the value gap associated with household characteristics. The most important sources of differences in the value of a characteristic are linked to human household endowments. Nevertheless, there is no clear direction of its effect. In relation to years of schooling of the household head, it is possible that there is not a statistically significant difference in most of the regions. However, the income scale in the Metropolitan region could be 80 per cent of the income scale in Araucania, Bio-Bio, or Los Lagos, if the number of years of schooling in the Metropolitan region were the same in these regions, ceteris paribus. Along the same lines, age as a proxy of general experience is more valued in Valparaiso, as occurs with specific experience being more valued in Atacama, O'Higgins and Araucania.

## 5.3 Decomposing Poverty

The same methodology is employed to analyze the factors that determine differences in poverty incidence among the different regions of the country. Table 10 reports the decomposition of differences in poverty rates between differences in the characteristics of the households that reside in these areas, differences in the value of these characteristics, and differences between the effective and the estimated poverty rates. The second column shows that poverty rates are significantly lower in the Metropolitan region than in any other Chilean region. However, poverty differences in Tarapacá, Antofagasta and Magallanes are completely determined by differences in the characteristics of the inhabitants in these areas. The situation differs in the other regions. In most other regions, more than half of the observed differences in poverty incidence could be attributed to differences in the coefficients associated with the household attributes. They explain up to 83 percent of the gap. That is the case in Valparaiso. Nevertheless, there are some regions where the estimated income scale function is not a good predictor of poverty rate. That is the case in Magallanes and Aisén. In these regions, the gap between the estimated and the effective poverty rate represents 43 and 30 percent of the difference, respectively.

Tables 11 and 12 show the variables influencing the characteristic and structural component of the difference. On the one hand, in Table 11, we recognize that years of schooling of the head is the main variable. It explains a large part of the difference; a difference of up to four percentage points in the regions of Atacama and Maule. Schooling of the spouse is an important variable as well. In some regions, the household composition or the economic sector where the household head works is also an important variable explaining the poverty gap. On the other hand, the structural component of the differences is statistically significant and large in magnitude in nine regions. However, it is difficult to find particular explanations for this large effect. Table 12 reports the decomposition analysis of the structural effect. It is possible to accept that despite the magnitude of some of these impacts there are just a few differences in coefficient that are statistically significant in some of the regions.

## 6. Conclusions and Discussion

In this paper, we suggest a methodology for studying whether the observed differences in poverty and well-being within a country are due to differences in the attributes of the population living in these zones, or whether they come from other factors, including geographically localized effects, which influence the value of the characteristics in these areas. The methodology is based on the traditional Blinder-Oaxaca decomposition.

This paper uses some recent contributions of Yun (2004; 2005) to extend (in several forms) the method for analyzing the problems proposed by Ravallion and Wodon (1999). We assess the importance of the concentration of households with the same characteristics and structural components to explain differences in well-being and poverty levels. We identify and quantify the importance of a detailed list of household characteristics and return to these factors to explain the gaps. We test the statistical significance of these effects.

To illustrate the methodology, we compare urban areas in 13 Chilean regions in the year 2003. We found large regional heterogeneity. The concentration of households with a low level of favorable attributes explains practically all the poverty gap between Tarapacá, Antofagasta, Magallanes, and the Metropolitan region. The structural component of the decomposition is not statistically significant in these regions. However, in the case of Magallanes the model does not successfully predict the effective differences in poverty rate, as the prediction error represents the largest component in the decomposition.[22] In the other regions, although its importance varies, a large part of the differences can be attributed to variations in the value of the household characteristics.

The detailed decomposition of these effects allows us to surmise how economic policy could help to improve standards of living and reduce poverty in less-advantaged backward regions. Firstly, we confirm the importance of education as determinant of well-being. Improving household human capital endowments of the household head and the spouse has a large impact on living standard and reduces the probability of being poor. Learning by doing through the specific and general experience acquired by having a job reduces poverty incidence as well. The sector of employment of the household head also has an effect. Employment in the financial, manufacturing, and retail sectors contribute to explaining the gaps, although in other regions, employment in the mining and agricultural sector contribute as well. In addition, the demographic household composition has an outsized influence in the North.[23] Secondly, this study pointed out the importance of testing the statistical significance of these differences. The detailed decomposition of the structural component, although considerable in magnitude, is not significant in most of the cases. Differences in the constant term are large which might suggest that there are still mobile household attributes that we are not controlling for and that might be correlated with regional characteristics influencing the probability of being poor.

Therefore, the specification of the income scale function requires further analysis in the future. We should seek to disentangle the factors behind structural differences among regions. Do they obey unobserved household characteristics that are spatially correlated, for instance the

[22] Aisen is another region with a large difference between the predicted and the effective differences in poverty rates.

[23] This is consistent with the importance that the influence of demographic composition have had in the reduction of poverty in China (Gustafsson, B. & W. Zhong, 2000).

self-selection of households with different abilities throughout the different regions? Do they reflect restricted mobility interacting with regional characteristics (Aroca, P. & G.J.D. Hewings, 2002; Soto, R. & A. Torche, 2004)? Do they reflect local externalities and market imperfections with a local scope? Or do they just reflect a slow process of adjustment due to temporal disequilibrium?

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Figure 1: Official Poverty Line and Estimated Poverty Lines

(Chilean Pesos from November 2003)

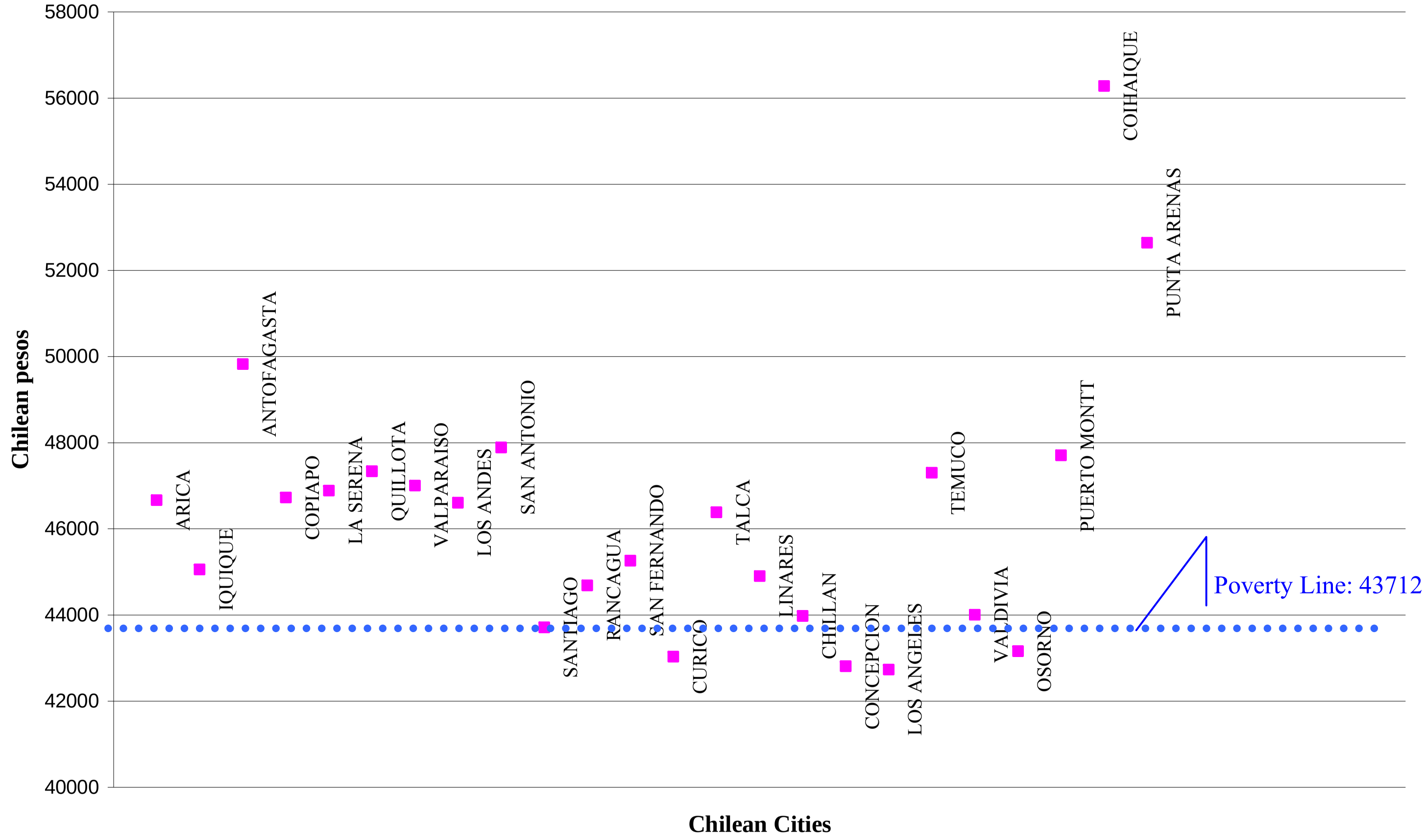

Table 1: Ratio Cluster estimator/Robust estimator of Variance

| Variable | Region | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tarap. | Antof. | Ataca. | Coqui. | Valpa. | Metro. | O'Hig. | Maule | Bío-B. | Arauc. | Lagos | Aisén | Magal. |
| nb | 970 | 1014 | 312 | 700 | 779 | 1231 | 658 | 780 | 661 | 865 | 640 | 173 | 680 |
| … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| hhsex | 737 | 846 | 351 | 596 | 683 | 774 | 565 | 496 | 512 | 385 | 405 | 108 | 560 |
| hhrace | 814 | 567 | 233 | 205 | 230 | 1026 | 238 | 412 | 353 | 634 | 352 | 144 | 540 |
| dec1 | 510 | 708 | 95 | 335 | 767 | 707 | 129 | 203 | 340 | 298 | 175 | 125 | 305 |
| dec2 | 1017 | 783 | 399 | 626 | 606 | 933 | 466 | 405 | 448 | 460 | 425 | 177 | 381 |
| dec3 | 959 | 852 | 539 | 623 | 802 | 986 | 488 | 460 | 428 | 322 | 440 | 135 | 420 |
| cpri | 821 | 1018 | 676 | 718 | 783 | 1027 | 507 | 429 | 510 | 379 | 517 | 162 | 361 |
| csec | 952 | 971 | 430 | 538 | 803 | 1101 | 405 | 490 | 703 | 530 | 512 | 295 | 452 |
| cuni | 936 | 986 | 311 | 793 | 695 | 1207 | 606 | 575 | 942 | 1051 | 996 | 289 | 387 |
| cpost | 851 | 1347 | 258 | 583 | 585 | 1199 | 460 | 754 | 746 | 1729 | 811 | 248 | 679 |
| hpri | 890 | 920 | 514 | 695 | 628 | 1062 | 512 | 471 | 607 | 368 | 507 | 147 | 417 |
| hsec | 1167 | 810 | 440 | 612 | 852 | 1293 | 561 | 472 | 688 | 621 | 555 | 250 | 489 |
| huni | 1329 | 1058 | 335 | 847 | 842 | 922 | 442 | 586 | 761 | 977 | 699 | 190 | 505 |
| hpost | 761 | 829 | 277 | 394 | 894 | 1174 | 622 | 526 | 864 | 1633 | 719 | 326 | 652 |
| ahh | 772 | 914 | 338 | 504 | 670 | 866 | 453 | 360 | 498 | 756 | 394 | 135 | 380 |
| ahh2 | 776 | 897 | 384 | 516 | 603 | 855 | 433 | 374 | 467 | 566 | 394 | 131 | 361 |
| hexp | 952 | 851 | 365 | 538 | 528 | 892 | 476 | 446 | 510 | 945 | 747 | 93 | 469 |
| hexp2 | 828 | 779 | 349 | 467 | 452 | 701 | 381 | 408 | 524 | 669 | 897 | 114 | 549 |
| … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| rama10 | 769 | 840 | 721 | 699 | 687 | 1029 | 534 | 547 | 562 | 519 | 541 | 149 | 465 |
| constant | 971 | 1054 | 376 | 511 | 658 | 987 | 569 | 444 | 529 | 889 | 397 | 135 | 444 |
| σ | 1052 | 461 | 620 | 930 | 687 | 1023 | 492 | 448 | 482 | 977 | 517 | 243 | 389 |

Note: Some variables were not reported to avoid making the table unnecessarily large, but they show the same pattern as the variables in the table. Symbol "…" indicates a group of no reported variables.

Table 2: Wald Tests of Equality of Coefficients among Regions

| | Number of restrictions | Chi-squared value | | |
|---|---|---|---|---|
| All the parameters | 396 | 2911 | Rejected | *** |
| Group of variables: | | | | |
| Constant | 11 | 27 | Rejected | *** |
| Household Composition | 88 | 134 | Rejected | *** |
| Other characteristics | 66 | 92 | Rejected | ** |
| Head Human Capital | 88 | 197 | Rejected | *** |
| Spouse Education | 44 | 45 | Not rejected | |
| Rama | 99 | 447 | Rejected | *** |

Note: *, ** and *** denote the level of confidence: 90%, 95% and 99%, respectively.

Table 3: Wald Tests of Joint Equality of Coefficients within Regions

| | Number of restrictions | Chi-squared value | | |
|---|---|---|---|---|
| Household Composition | 76 | 97 | Rejected | ** |
| Head formal education | 36 | 84 | Rejected | *** |
| Spouse formal education | 36 | 31 | Not Rejected | |
| Rama | 96 | 353 | Rejected | *** |

Note: *, ** and *** denote the level of confidence: 90%, 95% and 99%, respectively.

Table 4: Maximum Likelihood Estimation of Income Scales in the Metropolitan Region

| **Dependent variable:** Log per capita household income normalized by the poverty line | **Coefficient** | **Robust Standard Error** | **Significance** |
|---|---|---|---|
| Standard Deviation of error term (σ) | 0.67 | (0.01) | *** |
| Constant | -0.17 | (0.13) | |
| **Household Composition** | | | |
| Number of babies (aged 4 or below) | -0.32 | (0.04) | *** |
| Number of babies squared | 0.05 | (0.02) | *** |
| Number of children (aged 5-10) | -0.28 | (0.03) | *** |
| Number of children squared | 0.01 | (0.02) | |
| Number of teenagers (aged 11-15) | -0.33 | (0.03) | *** |
| Number of teenagers squared | 0.05 | (0.02) | *** |
| Number of adults (aged 16 or above) | -0.10 | (0.02) | *** |
| Number of adults squared | 0.01 | (0.002) | *** |
| **Other household characteristics** | | | |
| Owned house | 0.12 | (0.02) | *** |
| Male head | 0.04 | (0.03) | |
| Non indigenous head | 0.08 | (0.04) | * |
| *Household structure (excluded category: head with spouse)* | | | |
| No spouse, married | 0.40 | (0.12) | *** |
| No spouse, single | 0.35 | (0.06) | *** |
| No spouse, divorced or widowed | 0.33 | (0.05) | *** |
| **Human capital of the spouse** | | | |
| Years completed primary education | 0.01 | (0.01) | * |
| Years completed secondary education | 0.04 | (0.01) | *** |
| Years completed university education | 0.11 | (0.01) | *** |
| Years completed post-university education | 0.13 | (0.03) | *** |

| | | | |
|---|---|---|---|
| **Human capital of the head** | | | |
| Years completed primary education | 0.01 | (0.01) | |
| Years completed secondary education | 0.07 | (0.01) | *** |
| Years completed university education | 0.15 | (0.01) | *** |
| Years completed post-university education | 0.11 | (0.03) | *** |
| Age of the head | 0.001 | (0.004) | |
| Age of the head squared | 0.0001 | (0.00004) | *** |
| Number of years in the current employment of the head | 0.02 | (0.003) | *** |
| Number of years in the current employment of the head squared | 0.0004 | (0.00008) | *** |
| *Sector of activity (excluded category: non-working head)* | | | |
| Agriculture and Fishing | 0.44 | (0.06) | *** |
| Mining | 0.46 | (0.09) | *** |
| Manufacturing Industries | 0.39 | (0.04) | *** |
| Utilities (electricity, gas and water) | 0.37 | (0.08) | *** |
| Construction | 0.47 | (0.05) | *** |
| Retail | 0.48 | (0.04) | *** |
| Transport and communication | 0.52 | (0.04) | *** |
| Financial services | 0.58 | (0.05) | *** |
| Communal (local) social services | 0.30 | (0.04) | *** |
| Log-pseudolikelihood | -6 198 215 | | |
| Number of observations | 6 085 921 | | |
| Wald Test (36) | 4 023 *** | | |

Note: Standard errors adjusted for 2 350 clusters in "segmento". *, ** and *** denote the level of confidence: 90%, 95% and 99%, respectively.

Table 5: Unconditional and Simulated Living Standards by Region in Urban Areas

| Income Scale: Log on per capita household income normalized by the poverty line | | | |
|---|---|---|---|
| **Region** | **Unconditional Profile**[a] **(U)** $\beta_i'\overline{X_i}$ | **Characteristic Profile (C)** $\beta_{Mr}'\overline{X_i}$ | **Structural Profile (S)** $\beta_i'\overline{X_{Mr}}$ |
| Tarapacá | 0.71 | 0.81 | 0.84 |
| Antofagasta | 0.75 | 0.82 | 0.83 |
| Atacama | 0.48 | 0.72 | 0.74 |
| Coquimbo | 0.57 | 0.86 | 0.66 |
| Valparaiso | 0.59 | 0.86 | 0.66 |
| Metropolitana | 0.96 | 0.96 | 0.96 |
| O'Higgins | 0.65 | 0.81 | 0.81 |
| Maule | 0.50 | 0.77 | 0.71 |
| Bío-Bío | 0.53 | 0.78 | 0.72 |
| Araucanía | 0.39 | 0.84 | 0.56 |
| Los Lagos | 0.58 | 0.78 | 0.77 |
| Aisén | 0.63 | 0.82 | 0.83 |
| Magallanes | 0.81 | 0.89 | 0.91 |
| Correlation (U, · ) | | 0.69 | 0.90 |
| Var (·) / Var (U) | | 0.16 | 0.53 |

Note: "·" denotes "C" or "S". [a]Estimated and effective.

Table 6: Unconditional and Simulated Poverty Rates by Region in Urban Areas

| | Headcount measure of poverty | | | |
|---|---|---|---|---|
| **Region** | **Effective Unconditional Poverty (U)** | **Estimated Unconditional Poverty (E)** $\Phi\left(\sigma_i^{-1}\,\beta_i\,\overline{X_i}\right)$ | **Characteristic Poverty (C)** $\Phi\left(\sigma_{Mr}^{-1}\,\beta_{Mr}\,\overline{X_i}\right)$ | **Structural Poverty (S)** $\Phi\left(\sigma_i^{-1}\,\beta_i\,\overline{X_{Mr}}\right)$ |
| Tarapacá | 19.5 | 17.9 | 16.2 | 13.9 |
| Antofagasta | 17.2 | 16.4 | 15.8 | 13.9 |
| Atacama | 27.9 | 27.1 | 19.0 | 17.4 |
| Coquimbo | 25.2 | 23.7 | 14.6 | 20.5 |
| Valparaiso | 22.9 | 22.8 | 14.6 | 20.2 |
| Metropolitana | 13.0 | 12.0 | 12.0 | 12.0 |
| O'Higgins | 20.8 | 20.9 | 16.2 | 15.6 |
| Maule | 26.6 | 26.4 | 17.4 | 18.6 |
| Bío-Bío | 26.6 | 26.0 | 16.9 | 19.1 |
| Araucanía | 33.7 | 31.8 | 15.2 | 25.1 |
| Los Lagos | 25.3 | 23.5 | 17.1 | 17.0 |
| Aisén | 26.0 | 21.0 | 15.9 | 14.3 |
| Magallanes | 18.6 | 15.1 | 14.0 | 12.2 |
| Correlation (U, · ) | --- | 0.97 | 0.57 | 0.83 |
| Var (·) / Var (U) | --- | 1.02 | 0.11 | 0.49 |

Note: "·" denotes "E", "C", or "S".

Table 7: Decomposing Differences in Income Scales in Urban Areas
(Reported Regions compared to Metropolitan Region)

| Region | Unconditional | Characteristic | | Structural | |
|---|---|---|---|---|---|
| | Differences | Difference | % in total | Difference | % in total |
| Tarapacá | 0.25 | 0.15 | 61 | 0.10 | 38 |
| Antofagasta | 0.22 | 0.14 | 65 | 0.07 | 34 |
| Atacama | 0.48 | 0.25 | 51 | 0.24 | 49 |
| Coquimbo | 0.39 | 0.10 | 26 | 0.29 | 74 |
| Valparaiso | 0.37 | 0.10 | 27 | 0.27 | 73 |
| O'Higgins | 0.31 | 0.16 | 50 | 0.16 | 50 |
| Maule | 0.47 | 0.19 | 42 | 0.27 | 58 |
| Bío-Bío | 0.43 | 0.18 | 41 | 0.25 | 59 |
| Araucanía | 0.57 | 0.12 | 22 | 0.45 | 78 |
| Los Lagos | 0.38 | 0.19 | 49 | 0.20 | 51 |
| Aisén | 0.34 | 0.15 | 43 | 0.19 | 56 |
| Magallanes | 0.15 | 0.08 | 50 | 0.08 | 49 |

Note: Level of confidence of unconditional, characteristics and structural differences are higher than 99%. Antofagasta and Magallanes are the exceptions. In these regions, the level of confidence of the structural difference is higher than 95%.

Table 8: Detailed Income Scale Decomposition of Differences in Characteristics in Urban Areas

(Reported Regions compared to Metropolitan Region)

| Region | Characteristic Difference | Percentage over estimated income scale differences in characteristics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Demographic | Sex | Race | Civil Status | Gen. Exper. | Escolar. Head | Escolar. Spouse | Spec. Exper. | Sector | House owned |
| Tarapacá | 0.15 | 40 *** | 1 * | 4 ** | -6 *** | 3 *** | 27 *** | 14 *** | 10 *** | 6 ** | 0 *** |
| Antofagasta | 0.14 | 42 *** | 0 * | 1 ** | 1 *** | 15 *** | 25 *** | 15 *** | 5 *** | -9 | 5 *** |
| Atacama | 0.25 | 14 *** | 0 * | 0 ** | -2 *** | 0 | 54 *** | 27 *** | 7 *** | 1 | 0 *** |
| Coquimbo | 0.10 | 18 *** | 1 * | -2 ** | -6 *** | -10 *** | 59 *** | 18 *** | 9 *** | 17 *** | -3 *** |
| Valparaiso | 0.10 | -6 *** | 1 * | -2 ** | -3 *** | -22 *** | 52 *** | 38 *** | 10 *** | 30 *** | 2 *** |
| O'Higgins | 0.16 | -12 *** | 0 * | -1 ** | 0 | -2 *** | 72 *** | 32 *** | 7 *** | 5 | 1 *** |
| Maule | 0.19 | 3 *** | 0 * | -1 ** | -2 *** | -10 *** | 69 *** | 28 *** | 3 *** | 11 *** | -3 *** |
| Bío-Bío | 0.18 | -1 ** | 0 * | -1 ** | 1 *** | -3 *** | 48 *** | 23 *** | 8 *** | 26 *** | -1 *** |
| Araucanía | 0.12 | 3 * | 0 * | 6 ** | -7 *** | -3 *** | 44 *** | 20 *** | 14 *** | 23 *** | 1 *** |
| Los Lagos | 0.19 | 11 *** | 0 * | 3 ** | 2 *** | 1 | 54 *** | 19 *** | 3 *** | 8 *** | -1 *** |
| Aisén | 0.15 | -3 * | -1 * | 5 ** | 8 *** | -1 *** | 73 *** | 20 *** | -1 | -2 | 1 *** |
| Magallanes | 0.08 | -68 *** | -1 * | 8 ** | -2 *** | -35 *** | 123 *** | 60 *** | -8 *** | 35 *** | -10 *** |

Note: *, ** and *** denote the level of confidence: 90%, 95% and 99%, respectively.

Table 9: Detailed Income Scale Decomposition of Structural Differences in Urban Areas
(Reported Regions compared to Metropolitan Region)

| Region | Structural Difference | Percentage over estimated structural differences in income scale | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CONSTANT | Demographic | Sex | Race | Civil Status | Gen. Exper. | Escolar. Head | Escolar. Spouse | Spec. Exper. | Sector | House owned |
| Tarapacá | 0.10 | -918 ** | 24 | -152 ** | 24 | 37 | 692 ** | 183 | 8 | -35 | 317 *** | -80 * |
| Antofagasta | 0.07 | -691 | -235 | 13 | 171 * | 43 | 215 | 258 | 110 | 29 | 76 | 111 * |
| Atacama | 0.24 | -230 * | 2 | 13 | -8 | 37 ** | 151 | 17 | 37 | -35 *** | 62 | 54 *** |
| Coquimbo | 0.29 | -12 | 63 * | 33 * | 104 *** | 32 ** | -104 | -10 | 30 | -3 | -19 | -15 |
| Valparaiso | 0.27 | 229 ** | 26 | 24 * | -38 | 26 * | -216 *** | -9 | 33 * | 11 ** | 4 | 10 |
| O'Higgins | 0.16 | -14 | 69 | -15 | 53 | 21 | -73 | -11 | 17 | -34 ** | 82 ** | 5 |
| Maule | 0.27 | -12 | 27 | 0 | 28 | -1 | 122 * | -20 | -32 | 2 | -3 | -11 |
| Bío-Bío | 0.25 | 171 ** | -48 * | 18 | -3 | 9 * | 34 | -87 *** | -4 | 9 * | 12 | -11 |
| Araucanía | 0.45 | 123 * | -11 | 3 | -22 * | -2 | 88 | -49 *** | -1 | -11 * | 6 | -23 ** |
| Los Lagos | 0.20 | 276 ** | -67 | 54 ** | 23 | 20 ** | -99 | -80 ** | -14 | -1 | -3 | -8 |
| Aisén | 0.19 | 228 | 52 | 15 | -33 | 11 | 55 | 32 | -61 | -9 | -164 *** | -26 |
| Magallanes | 0.08 | -1258 * | 277 | 73 | 190 | 158 ** | 123 | -145 | 497 ** | -74 | 188 | 71 |

Note: *, ** and *** denote the level of confidence: 90%, 95% and 99%, respectively.

Table 10: Decomposing Differences in Poverty Ratios in Urban Areas

(Reported Regions compared to Metropolitan Region)

| Region | Poverty[a] | Characteristic | | Structural | | Error[b] | |
|---|---|---|---|---|---|---|---|
| | Differences | Difference | % in total | Difference | % in total | Difference | % in total |
| Tarapacá | 6.5 | 4.2 *** | 65 | 1.8 | 27 | 0.5 | 8 |
| Antofagasta | 4.1 | 3.8 *** | 92 | 0.7 | 17 | -0.4 | -9 |
| Atacama | 14.9 | 7.1 *** | 48 | 8.0 *** | 54 | -0.2 | -2 |
| Coquimbo | 12.2 | 2.6 *** | 22 | 9.1 *** | 75 | 0.5 | 4 |
| Valparaiso | 9.9 | 2.6 *** | 27 | 8.2 *** | 83 | -1.0 | -10 |
| O'Higgins | 7.8 | 4.3 *** | 54 | 4.7 ** | 60 | -1.2 | -15 |
| Maule | 13.6 | 5.4 *** | 40 | 9.0 *** | 67 | -0.9 | -7 |
| Bío-Bío | 13.6 | 4.9 *** | 36 | 9.1 *** | 67 | -0.4 | -3 |
| Araucanía | 20.7 | 3.3 *** | 16 | 16.5 *** | 80 | 0.9 | 4 |
| Los Lagos | 12.3 | 5.2 *** | 42 | 6.3 *** | 52 | 0.7 | 6 |
| Aisén | 12.9 | 3.9 *** | 30 | 5.1 *** | 39 | 3.9 | 30 |
| Magallanes | 5.6 | 2.0 *** | 36 | 1.2 | 21 | 2.4 | 43 |

Note: *, ** and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a] shows differences in poverty rates. [b] shows the difference between the effective and the estimated poverty rate.

Table 11: Detailed Poverty Decomposition of Differences in Characteristics in Urban Areas

(Reported Regions compared to Metropolitan Region)

| Region | Characteristic Difference [a] | Percentage points | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Demographic | Sex | Race | Civil Status | Gen. Exper. | Escolar. Head | Escolar. Spouse | Spec. Exper. | Sector | House owned |
| Tarapacá | 4.2 | 1.7 *** | 0.0 | 0.2 | -0.2 *** | 0.1 *** | 1.1 *** | 0.6 *** | 0.4 *** | 0.3 | 0.0 *** |
| Antofagasta | 3.8 | 1.6 *** | 0.0 | 0.0 | 0.1 | 0.6 *** | 0.9 *** | 0.6 *** | 0.2 *** | -0.3 | 0.2 *** |
| Atacama | 7.1 | 1.0 *** | 0.0 | 0.0 | -0.2 *** | 0.0 | 3.8 *** | 1.9 *** | 0.5 *** | 0.1 | 0.0 *** |
| Coquimbo | 2.6 | 0.5 *** | 0.0 | 0.0 | -0.2 *** | -0.3 *** | 1.5 *** | 0.5 *** | 0.2 *** | 0.5 | -0.1 *** |
| Valparaiso | 2.6 | -0.2 ** | 0.0 | 0.0 | -0.1 ** | -0.6 *** | 1.4 *** | 1.0 *** | 0.3 *** | 0.8 *** | 0.1 *** |
| O'Higgins | 4.3 | -0.5 *** | 0.0 | 0.0 | 0.0 | -0.1 ** | 3.1 *** | 1.3 *** | 0.3 *** | 0.2 | 0.0 *** |
| Maule | 5.4 | 0.2 *** | 0.0 | 0.0 | -0.1 *** | -0.6 *** | 3.8 *** | 1.5 *** | 0.2 *** | 0.6 ** | -0.1 *** |
| Bío-Bío | 4.9 | -0.1 | 0.0 | 0.0 | 0.1 ** | -0.1 *** | 2.4 *** | 1.1 *** | 0.4 *** | 1.3 *** | -0.1 *** |
| Araucanía | 3.3 | 0.1 | 0.0 | 0.2 | -0.2 *** | -0.1 | 1.4 *** | 0.7 *** | 0.4 *** | 0.8 *** | 0.0 *** |
| Los Lagos | 5.2 | 0.6 *** | 0.0 | 0.1 | 0.1 *** | 0.0 | 2.8 *** | 1.0 *** | 0.1 *** | 0.4 * | -0.1 *** |
| Aisén | 3.9 | -0.1 | -0.1 | 0.2 | 0.3 *** | 0.0 ** | 2.9 *** | 0.8 *** | 0.0 | -0.1 | 0.0 *** |
| Magallanes | 2.0 | -1.4 *** | 0.0 | 0.2 | 0.0 * | -0.7 *** | 2.4 *** | 1.2 *** | -0.2 * | 0.7 *** | -0.2 *** |

Note: *, ** and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a] corresponds to differences in estimated poverty rates due to the concentration of households with the same characteristics.

Table 12: Detailed Poverty Decomposition of Structural Differences in Urban Areas

(Reported Regions compared to Metropolitan Region)

| Region | Structural Difference[a] | Percentage points | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CONSTANT | Demographic | Sex | Race | Civil Status | Gen. Exper. | Escolar. Head | Escolar. Spouse | Spec. Exper. | Sector | House owned |
| Tarapacá | 1.8 | -16.2 | 0.4 | -2.7 | 0.4 | 0.7 | 12.2 | 3.2 | 0.1 | -0.6 | 5.6 | -1.4 |
| Antofagasta | 0.7 | -4.8 | -1.6 | 0.1 | 1.2 | 0.3 | 1.5 | 1.8 | 0.8 | 0.2 | 0.5 | 0.8 |
| Atacama | 8.0 | -18.5 | 0.2 | 1.1 | -0.7 | 3.0 | 12.2 | 1.4 | 2.9 | -2.8 ** | 5.0 | 4.4 * |
| Coquimbo | 9.1 | -1.1 | 5.8 | 3.0 | 9.5 * | 2.9 | -9.5 | -0.9 | 2.8 | -0.3 | -1.7 | -1.3 |
| Valparaiso | 8.2 | 18.9 * | 2.2 | 1.9 | -3.1 | 2.1 * | -17.8 ** | -0.7 | 2.7 | 0.9 | 0.3 | 0.8 |
| O'Higgins | 4.7 | -0.7 | 3.3 | -0.7 | 2.5 | 1.0 | -3.4 | -0.5 | 0.8 | -1.6 | 3.9 | 0.2 |
| Maule | 9.0 | -1.1 | 2.5 | 0.0 | 2.5 | -0.1 | 11.1 | -1.8 | -2.9 | 0.2 | -0.3 | -1.0 |
| Bío-Bío | 9.1 | 15.6 * | -4.3 | 1.6 | -0.3 | 0.8 | 3.1 | -7.9 *** | -0.4 | 0.8 | 1.1 | -1.0 |
| Araucanía | 16.5 | 20.3 | -1.8 | 0.5 | -3.7 | -0.3 | 14.5 | -8.1 ** | -0.2 | -1.9 | 1.0 | -3.8 |
| Los Lagos | 6.3 | 17.5 * | -4.3 | 3.4 | 1.5 | 1.3 | -6.2 | -5.1 | -0.9 | -0.1 | -0.2 | -0.5 |
| Aisén | 5.1 | 11.6 | 2.7 | 0.8 | -1.6 | 0.5 | 2.8 | 1.6 | -3.1 | -0.5 | -8.3 * | -1.3 |
| Magallanes | 1.2 | -14.7 | 3.2 | 0.8 | 2.2 | 1.8 | 1.4 | -1.7 | 5.8 | -0.9 | 2.2 | 0.8 |

Note: *, ** and *** denote the level of confidence: 90%, 95% and 99%, respectively. [a] corresponds to differences in estimated poverty rates due to coefficient differences.

# Paper III

# Absenteeism and Time-Inconsistent Behavior. Should we make lecture attendance compulsory?

Miguel Quiroga

**Abstract**

We investigate the problem of absenteeism in an educational program with time-consistent and naïve time-inconsistent students and the effect that mandatory attendance has on the behavior and well-being of the students. We observe that time-inconsistent students tend to postpone lecture attendance such that they are more likely to be absent from lectures located in the first part of the term while they later show up in the second part of the course. Absenteeism rates are not necessarily lower for naïve time-inconsistent students vis-à-vis time-consistent; nevertheless, the performance of time-inconsistent students is worse in any case. We showed that the well-being of myopic time-inconsistent students could be dramatically reduced because of the shortcoming in their intertemporal preferences. Therefore, it seems as mandatory attendance could benefit these students in the classroom, although there is some possibility of harming the time-consistent. The outcome depends on the distribution of the benefits and costs of lecture attendance along the term, which requires empirical evaluation.

**Key Words:** absenteeism; education; mandatory attendance; teaching; time-inconsistent preferences; present-biased preferences; hyperbolic discounting.

**JEL Classification**: A2; D11; D18; D91; I21

## 1. Introduction

The lessons or lectures held by a teacher or instructor are usually an important component of a course. However, Romer (1993) showed empirical evidence that the presence of students at lectures is far from perfect in undergraduate courses in economics.[1] He also found evidence that absenteeism has a substantial effect on the learning process.[2] In spite of both ideas being interesting enough by themselves, his speculative third proposal was the most controversial. He suggested urging students to attend class to combat absenteeism and to improve learning in a course. Economists and teachers reacted one year later to Romer's proposal, the Journal of Economic Perspective, in its correspondence section, published six letters commenting on the normative Romer suggestion (Brauer et al. 1994). Most of the letters disagreed with Romer's recommendations. The most popular argument was the sovereignty of the consumer. Rational and informed students can make a better decision of whether or not to attend a lesson based on the costs and benefits associated with their choice. In the words of Powell and Shughart (1994): "Mandatory attendance artificially distorts the opportunity cost of absenteeism and imposes a welfare loss on the student." In his response, Romer (1994) observed that some individuals have problems making consistent intertemporal choices and that several examples of self-limiting possibilities of choice are evidence of this shortcoming.[3] Thus, compulsory attendance could be a

[1] Other papers provide similar evidence, for instance, Kirby and McElroy (2003), Rodgers (2002), and Marburger (2001).

[2] Nowadays, there are more empirical evidence of this relationship, e.g., Cohn and Johnson (2006), Lin and Chen (2006), Rich (2006), and Kirby and McEkroy (2003).

[3] Bettinger and Slonim (2007) provide evidence of these shortcomings on children. Recently, Wong (2008) shows that most of the student from an introductory macroeconomics class at the National University of Singapur exhibited some time-incosistent behavior and that this conduct is related to inferior class otucomes.

a mechanism that might mitigate the effect that the self-control problem has on student performance.

The purpose of this paper is investigate the consequences that self-control problems have on the level of absenteeism in an educational program and to analyze the effect that mandatory attendance has on well-being and performance of the students. In line with O'Donoghue and Rabin (1999), we use a quasi-hyperbolic discount function to represent intertemporal preferences of individuals who lack self-control. The model considers lecture attendance as an activity that entails immediate costs and delayed reward.

The results show that lecture absence could be a severe problem for students with time-inconsistent intertemporal preferences. Time-inconsistency reduces the well-being of these students and affects their performance in the course, but how does it influence absenteeism? The answer is ambiguous. The presence of time-inconsistency could even reduce student absenteeism under certain circumstances. Mandatory attendance could increases the well-being of the time-inconsistent students, but it could reduce the well-being of time-consistent students. The convenience of this policy depends on how mandatory attendance modifies absenteeism profile of time-inconsistent students. This is associated to the severity of time-inconsistency, the distribution of benefits and the costs of lecture attendance along the term, and the number of lectures in a course. The negative effect that compulsory attendance produces on time-consistent students is associated to the magnitude of the benefits and costs that make them to deviate optimally from a perfect attendance register. Therefore, the suitability of imposing compulsory attendance is still an open empirical question.

The paper has the following structure. In Section 2, we develop a model that links grades in formal education to future benefits in the labor market. In the next section, we describe the temporal distribution of benefits and costs coming from lecture attendance. In Section 4, we analyze absenteeism, performance and student well-being employing the proposed model. We introduce mandatory attendance in Section 5. Finally, in the last section, we discuss the implication of these results and the conclusions.

## 2. Model

Our approach combines a human capital model and a signaling model. The main features of this model came from Costrell (1994) and Betts (1998). They study the impact of educational standards on wages and inequality. Wages in their models are endogenously determined by the level of productivity. An educational signal provides information about workers' productivity.[4] The signal is binary in Costrell (1994) and Betts (1998) – to receive the certificate or to fail - while we assume that a full information system providing grades of graduated students is available.[5] School transcripts are accessible for employers. We think that this structure of incentives reflects the aim of the compulsory attendance policy suggested by Romer (1993) because the purpose is to improve the results ("learning") in a class; not only to reduce the rate of failure.

We assume that attendance to lessons increases productivity. Attendance is important for passing the exam and achieving a higher academic qualification. Firms observe whether workers were successful in their studies; they know whether they graduate or not. This information is a

[4] Albrecht and van Ours (2006) found empirical evidence of the use of education as a signal in the Dutch labor market.

[5] Betts (1997) proposes a similar model to show that school grading standards influence student effort and achievement. Nonetheless, in her model students have different abilities.

signal to firms about the expected productivity of each worker.[6] Furthermore, firms have access to the grades obtained by graduated students. Based on this information, firms remunerate workers based on the results that they achieved in the courses.[7]

Let us assume that $W$ denotes individual lifetime earnings. Firms remunerate workers according to the marginal value of their work (see equation (1) below). There are two components of the salary: a fixed component $\varpi$ (that stands for the student's marginal value before the course) and a variable component $\sum_{\mathrm{t}=1}^{\mathrm{T}} v_{\mathrm{t}} a_t^i$, an educational production function, which is a non-decreasing function of lecture attendance over the whole study spell (denoted T). The variable $v_t$ represents the value of the marginal product of attending a lecture, i.e. the value of one unit of educational achievement.

$$W^i = \begin{cases} \varpi + \sum_{\mathrm{t}=1}^{\mathrm{T}} v_{\mathrm{t}}\, a_t^i = \xi^i & \text{if } \xi^i \geq \underline{\xi} \quad \text{and} \quad t > T \\ \varpi & \text{otherwise} \end{cases} \tag{1}$$

where: $a_t^i = \begin{cases} 1 & \text{if the student attends the class} \\ 0 & \text{in the student does not attend the class} \end{cases}$

$v_t > 0$

Attendance is a measure of the effort placed by students during the course.[8] Educational production function and wages are bounded with bounds $[0, \bar{\xi}]$ and $[\varpi, \overline{W}]$, respectively. The minimum level of educational production function necessary to pass, set by the school, is

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[6] See Grogger and Eide (1995) and Rose and Betts (2004).

[7] The evidence is inconclusive. Wise (1975) shows evidence that college grade point average substantially influences estimates rates of salary. However, Miller and Rosenbaum (1997) in an interview of 51 employers found that employers do not use all the information available to infer skill and work abilities. More recently, Grant (2007) suggest that grades in a microeconomic principles course provides scarse evidence about student productivity. Nevertheless, Chia and Miller (2008) show that university-weighted average marks form the main determinant of graduates' starting salaries.

[8] Moreover, we might consider other measures of the effort put forth by a student such as the time he/she spends studying out of class, attitude, etc. We assume that these levels of effort are exogenous and independent of lecture attendance.

represented by $\underline{\xi}$. The standard set by the school is contrasted with an individual educational production function that determines his/her education and wage.

There are numerous other factors that influence the outcome in an educational production function, e.g. supply factors (innovative teaching-learning environment, teaching methods, classroom equipment, instructor quality, class notes, size of the group, etc.), individual factors (abilities, aptitude, attitude, etc. ) and institutional (financial support, schedule, course features, nature of the course, etc.). These factors influence the marginal contribution of attending a lecture, nevertheless we will assume that they do not change in this model and they are independent of attendance.

Therefore, lesson attendance in period $t$ increases individual income in period $\tau > T$. We assume that students also reap the benefit of their effort in the present; their current utilities reflect future earnings. This assumption could be interpreted as a level of consumption determined by permanent-income rather than transitory income. Nevertheless, in economies with a developed credit market, it could reflect current loans available for students based on their future rents.

Thus, $\nu_t$ in equation (1) reveals the effect that attending the lesson in period $t$ would have on the individual utility. In other words, $\nu_t$ shows the marginal benefit from attending a lecture. The increase in welfare comes from the effect that an educational unit has on the marginal educational product, the wage and the lifetime income. We assume that attendance to the lesson affects not only individual salary in time $T + \tau$, but also earnings through the individual's lifetime. Hence, marginal utility from attending classes considers not only the effect over the utility in period T, but over the individual's lifetime.

Furthermore, let $c_t$ reflect the opportunity cost of attending a lesson. Our view of the opportunity cost is very broad. It could reflect non-educational activities such as leisure and illness, but could also reflect time spent in other courses, higher productivity coming from an alternative learning strategy, course dislike, etc.

As a result, the reward schedule associated with class attendance is $v \equiv (v_1, v_2, \ldots, v_T)$ and the cost schedule is $c \equiv (c_1, c_2, \ldots, c_T)$.

### 2.1 Intertemporal Decision Problem

The student, given his/her rewards and costs and his/her preferences over temporal well-being, determines the attendance strategy $a^i \equiv (a_1^i, a_2^i, \ldots, a_T^i)$ that maximizes his/her welfare. In this framework, the student decides which lessons to attend and, as a result, the level of absenteeism, which is $\chi_i = T - \sum_{t=1}^{T} a_t^i$.

The student solves this problem by adding up the utility obtained in different periods. We distinguish between two types of students according to the intertemporal stability of their preferences. One of them has *time-inconsistent preferences*. He/she represents the evidence that some individuals tend to avoid costs and overweight benefits when future periods get closer. We interpret a lesson as an activity that provides future benefits in exchange for immediate costs. The student chooses today between two substitute lessons. It is efficient for students to attend the lesson when their opportunity cost is lower in relation to the benefits. A student has an optimal plan ab ovo. However, a student with *time-inconsistent preferences* has difficulties sticking to the original plan at every time *t* when he/she has to decide whether to attend a lecture because of future benefits looks smaller in relation to the salient present opportunity costs. On the contrary, the student preferences for well-being at an earlier time over a later time are the same no matter when the individual is asked when the student has *time-consistent preferences*.

We assume a particular expression for capturing these preferences (equation (2)). It is called "quasi-hyperbolic" function and it was introduced in the literature by Laibson (1994).

$$U_t\left(u_t, u_{t+1}, \ldots, u_{T-1}\right) \equiv \delta^t u_t + \beta \sum_{\tau=t+1}^{T-1} \delta^\tau u_\tau \quad \textit{for all } t, \textit{ with } \quad \delta, \beta \in \left(0, 1\right] \tag{2}$$

In this function $U_t$ represents student preferences over intertemporal well-being from the perspective of period *t*. This function is continuous and increasing in all components. The parameter $\delta$ is the discount factor. It captures people's preference for immediate satisfaction in most of the intertemporal economic model. The parameter $\beta$ allows us to distinguish time-consistent from time-inconsistent preferences. The standard exponential discounting model assumes $\beta = 1$ and, therefore, *time-consistent preferences* (*tc*). However, with *time-inconsistent preferences* (*ti*) the hyperbolic discounting function assumes $\beta < 1$. In the latter case, the individual gives more importance to the utility in the present than in any other future period, but discounts all the future periods in the same way.[9]

Models that use a hyperbolic function to discount the future are extensively utilized to explain intransitive behavior, preference reversals and the use of commitment in decision-making (see Ainslie and Haslam 1992). In particular, they have been employed to clarify addictive behavior (O'Donoghue and Rabin 1999, 2002; Gruber and Köszegi 2001; Carrillo 2005), household saving conduct (Laibson 1997; Bernheim, Skinner, and Weinberg 2001; Harris and Laibson 2003), and a person's decision to acquire information (Carrillo and Mariotti 2000;

[9] For this particular characteristic, it is called "present-biased preferences" by O'Donoghue and Rabin (1999).

Bénabou and Tirole 2002), among other applications. Besides these, they have been used to analyze procrastination (Fischer 2001; O'Donoghue and Rabin 1999, 2001; Akerlof 1991; O'Donoghue and Rabin 1999) and preproperation (O'Donoghue and Rabin 1999) in the materialization of one or several tasks.[10]

Ted O'Donoghue and Matthew Rabin have studied the last topic in different contexts. For instance, they examined procrastination and preproperation when individuals must perform an activity exactly once and the activity involves immediate cost or immediate reward (O'Donoghue and Rabin 1999). In another piece of research, they explored procrastination when a person must not only choose when to complete a task, but also which task to complete. They show that a person might never carry out a very easy and very good option because they continually plan to achieve an even better but more onerous alternative (O'Donoghue and Rabin 2001). More recently, they investigated procrastination in long-term projects to illustrate how people might expend costly effort to begin a project but then never finish it (O'Donoghue and Rabin 2005). Finally, they examined how the Principal should design a scheme of incentives to help *time-inconsistent* Agents to combat procrastination (O'Donoghue and Rabin 1999).

A subsidiary contribution of our research is in line with this literature. We interpret a lecture to mean a task involving immediate cost and delayed reward. In this sense, the problem is very similar to the multi-task model that O'Donoghue and Rabin (1999) discussed as a generalization of the one task setting. However, an important distinction in this study is that the student endogenously, not fixed and exogenous as in O'Donoghue and Rabin's paper, determines the number of tasks. We interpret this result as the level of effort chosen by the student. To the

[10] "Preproperation" is a term coined by O'Donoghue and Rabin (1999, footnote 16) to represent a situation where an individual chooses to do a task when his/her long-run self would choose to wait.

best of our knowledge, this literature has not discussed the effect that time-inconsistent preferences have on the intensity of effort, at least not in this form.[11]

In this framework, the student decides the number of lesson that he/she will attend and its temporal distribution.

## 3. Temporal distribution of benefits and costs of lecture attendance

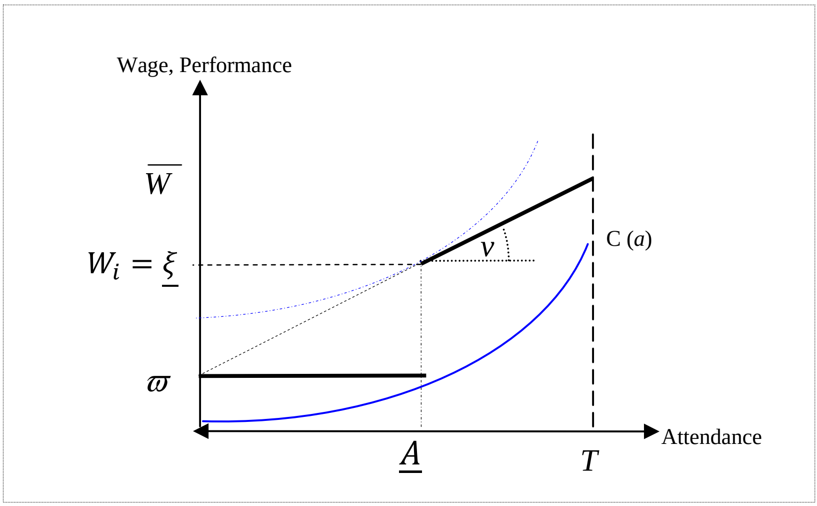
The temporal distribution of the decisions in the model is the following. Based on the educational production from equation (1), the student decides whether to take the course at time zero. In order to illustrate this issue, we assume that educational production function is a linear combination of lecture attendance such that the marginal contribution of an additional lecture attended is constant and equal to $v_t = v$ for all $t$. Marginal cost of lecture attendance is increasing through the time. Figure 1 illustrates this problem in the presence of the standard $\left(\underline{\xi}\right)$. The horizontal axis shows the lecture timetable and the registered lecture attendance, the variable $\underline{A}$ represents the minimum number of lectures that the student needs to attend for achieving the standard. The vertical axis shows the wages and the standard. The student chooses the number of lectures that maximize their utility. The utility come from the difference between the increases in income that he/she will receive by showing up in lectures and fulfilling the standards, minus the cost of attending a lecture. A student who faces a situation as represented in Figure 1 (a) and (b), decides to take the course and to achieve the standard. In the first case, the student just complies with the minimum level of attendance, or effort, to pass the course. In the second case, the

[11] O'Donoghue and Rabin (2001) investigate how much effort to apply to a chosen task, but they concentrate on the effect that the possibility to improve the task in the future has over the level of effort today.

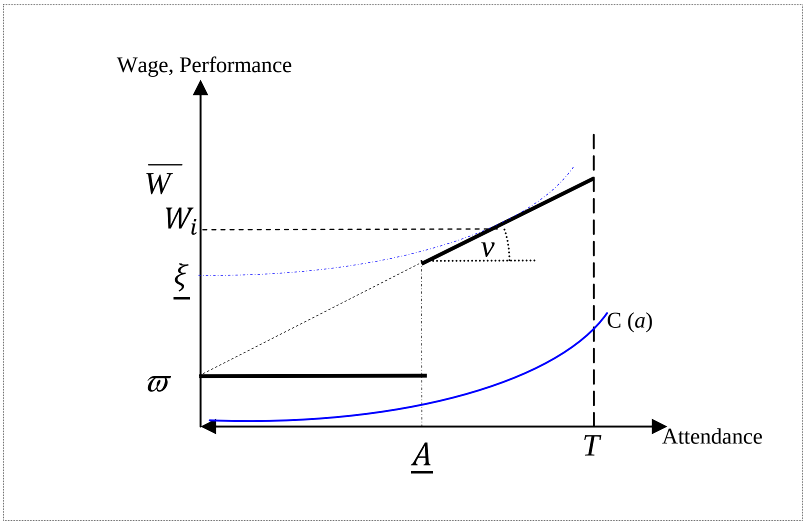
student has a level of lecture attendance over the standard and higher grades in the evaluation of the course. Figure 1(c) illustrates the situation of a student with a high marginal opportunity cost of lecture attendance. He/she prefers not to take the course because the cost of achieving the standard is lower than the increase in income that he/she will get.

Figure 1: Comparison of attendance lectures' equilibria

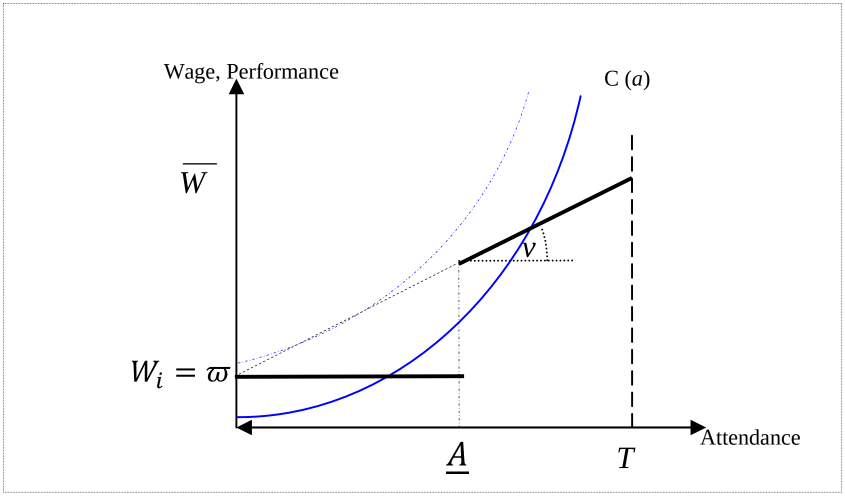
(a) Attendance: fulfilled standard




(b) Attendance: low absenteeism



(c) Not enrolled




Source: Author's elaboration.

A student enrolled in a course must decide at any $t$ whether to attend the lecture or not.[12] After the last lecture, educational institutions compare student performance with the minimum required standard: if $\xi^i < \underline{\xi}$ then the student fails; nevertheless, if $\xi^i \geq \underline{\xi}$ then the student passes the course and the institution awards a degree. Firms, considering whether the student has passed or not and noting the grade obtained by a graduate, instantaneously calculates wages.

We consider lesson attendance as an activity that has immediate costs and delayed rewards. Equation (3) illustrates the net contribution to the student's well-being coming from lecture attendance in any period $\tau \geq t$.

$$U_i'(a_\tau = 1, \tau) = \begin{cases} \beta v_\tau - c_\tau & \text{if } \tau = t \\ \beta v_\tau - \beta c_\tau & \text{if } \tau > t \end{cases} \qquad (3)$$

[12] Therefore, this analysis is only relevant for students who decided to take the course, i.e. students with preferences such as (a) and (b) in Figure 1.

The student's well-being at time $t$ over the temporal well-being distribution from lesson attendance in the period is obtained adding all the net contribution to the student's well-being coming from lecture attendance in the periods $\tau \geq t$, equation (4) below.[13]

$$U_t^i(a_\tau, \tau) = -(1-\beta)c_t a_t + \beta\left(\sum_{\tau=t}^{T} v_t a_t - \sum_{\tau=t}^{T} c_t a_t\right) \quad \text{if} \quad \xi^i \geq \underline{\xi} \quad \text{where } i = \{tc, ti\} \tag{4}$$

We follow Pollak's strategy (1968) to analyze the behavior of the students. We model the lecture attendance decision as an intra-personal extensive game where different temporal selves of the student maximize present well-being, sequentially choosing whether to attend a lecture regarding their future selves' conduct. Consequently, we represent the attendance decision as an extensive finite game with perfect information between T players.[14] The players are temporally different selves of the same student. Let us define $h_t$ as the *history* of the game of length *t*. It contains all the information about the choices made by the student before *t*.

We utilize the concept of *perception-perfect strategy* (O'Donoghue and Rabin 1999) to characterize the student solution to this problem. If the student follows a perception-perfect strategy then in all periods he/she chooses the optimal action given his/her current preferences and perception about future behavior. Time-consistent and time-inconsistent individuals apply the same solution concept, but they differ in their perception about future behavior. Time-consistent students have a correct perception about their future behavior, but time-inconsistent students believe that they will behave as time-consistent students in the future.

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[13] For simplicity we assume $\delta = 1$, i.e. there is no long-run discounting. This assumption is not unrealistic because we have concentrated on the effect of the present-biased preferences and on relatively short horizons. Moreover, this simplification will not affect the most important conclusions. Also, we could modify equation (4) slightly to accommodate an alternative interpretation of the the time-inconsistent behavior. In this case, it surges of salient costs when we have to incur on them (Akerlof 1991).

[14] This is a game with *singleton* information sets, i.e. each information set contains a single decision node. There are a finite number of such nodes.

## 4. Absenteeism

We now turn to analyze lecture absence through the lens of the model presented in sections 2 and 3.

### 4.1 Student's Attendance Behavior

Equation (5) represents the problem solved by the student *i* every time *t* when he/she has to decide whether or not to attend a lecture. It illustrates the implementation of the perception-perfect attendance strategy by the student.

$$Max_{a_\tau}\left\{U_t^i(a_\tau,\tau) = -(1-\beta)c_t a_t + \beta\left(\sum_{\tau=t}^{T} v_\tau a_\tau - \sum_{\tau=t}^{T} c_\tau a_\tau\right)\right\}$$

subject to (5)

$$(i)\;\; \varpi + \sum_{\mathrm{t}=1}^{\mathrm{T}} v_{\mathrm{t}}\, a^t = \xi^i \geq \underline{\xi}$$

$$(ii)\;\; t \in \{1,\dots,T\} = \mathcal{T}$$

We consider only students enrolled in the course. Therefore, we know before the course starts that there is an optimal attendance plan $a^* = a(\mathcal{T}) = \{a_1^*,\dots,a_t^*,\dots,a_T^*\}$ for every student which is similar for time-consistent and time-inconsistent students, such that: present value of the student well-being is non-decreasing and maximum, $U_0^i(a^*) \geq \varpi$; minimum standards are fulfilled, $\xi^i(a^*) \geq \underline{\xi}$, and lecture attendance equalizes or surpasses the minimum level to fulfill the standard, $A^i(h_{T+1}) = A^{i^*} = \sum_{\tau=1}^{T} a_\tau^*$ such that $\xi^i \geq \underline{\xi}$. Let us define $A^i(h_t) = A_{-t}^i = \sum_{\tau=1}^{t-1} a_\tau^*$ as the number of lessons attended before *t* and $A^i(f_t) = A_{+t}^i = \sum_{\tau=t}^{T} a_\tau^*$ as the number of lessons to attend from *t* forward.

A time-consistent student who utilizes a *perception-perfect attendance strategy* observes the following procedure every time *t* when he/she has to decide whether to attend the lesson or not. First, it is easy to see from equation (4) that the student will attend any lesson at *t* whenever $(v_t - c_t) \geq 0$. Before continuing, let us define a subset $\mathcal{T}_{t+} \subset \mathcal{T}$ that includes all the periods after the *history* $(t+1)$ where the before criteria are satisfied and a subset $\mathcal{T}_{t-} \subset \mathcal{T}$ that includes all the periods where these criteria are not fulfilled. What will the student decide if $(v_t - c_t) < 0$? The student compares $\underline{\xi}$ to $\xi\left(a^{tc}(h_t) + a(\mathcal{T}_{t+})\right)$, if $\left(\underline{\xi} - \xi\left(a^{tc}(h_t) + a(\mathcal{T}_{t+})\right)\right) \leq 0$ then $\xi_{t-}^{tc} = 0$, so $a_t^* = 0$ and the student will be absent from the class. Nevertheless, if $\left(\underline{\xi} - \xi\left(a^{tc}(h_t) + a(\mathcal{T}_{t+})\right)\right) = \xi_{t-}^{tc} > 0$ then the student solves a last stage; he/she would consider attending $a^{tc}(\mathcal{T}_{t-})$ lectures that solve the problem formulated in equation (6) below. In general, $a^i(\mathcal{T}_{t-})$ defines the optimal attendance strategy that the student is considering to follow in the future. Let us include the lessons that the student will attend in $a^{tc}(\mathcal{T}_{t-})$ in the subset $\mathcal{T}_{t-}^{tc} \subset \mathcal{T}_{t-}$. The student will attend the lecture only if the reduction in well-being from showing up at the lecture at *t* is smaller than or equal to the disutility from attending any of the lectures in the subset $\mathcal{T}_{t-}^{tc}$.

$$Min_{a_\tau}\left\{U_{t-}^{tc}(a_\tau, \tau) = -\left(\sum_{\tau\in\mathcal{T}_{t-}} v_\tau a_\tau - \sum_{\tau\in\mathcal{T}_{t-}} c_\tau a_\tau\right)\right\}$$

$$\text{subject to} \qquad (6)$$

$$(i) \quad \sum\nolimits_{t\in\mathcal{T}_{t-}} v_t\, a_t = \xi_{t-}^{tc}$$

$$(ii) \quad t \in \mathcal{T}_{t-}$$

In comparison, the *perception-perfect attendance strategy* for a time-inconsistent student is to attend every lesson at *t* whenever $(\beta v_t - c_t) \geq 0$. However, if $(\beta v_t - c_t) < 0$ then the student compares $\underline{\xi}$ to $\xi\left(a^{ti}(h_t) + a(\mathcal{T}_{t+})\right)$, if $\left(\underline{\xi} - \xi\left(a^{ti}(h_t) + a(\mathcal{T}_{t+})\right)\right) \leq 0$ then $\xi_{t-}^{ti}$=0, so $a_t^* = 0$ and the student will be absent from class. Nevertheless, if $\left(\underline{\xi} - \xi\left(a^{ti}(h_t) + a(\mathcal{T}_{t+})\right)\right) = \xi_{t-}^{ti} > 0$ then the student solves a last stage; he/she would consider attending $a^{ti}(\mathcal{T}_{t-})$ lectures that solve the problem formulated in equation (7) below. Let us include the lessons that the student will attend in $a^{ti}(\mathcal{T}_{t-})$ in the subset $\mathcal{T}_{t-}^{ti} \subset \mathcal{T}_{t-}$. Therefore, the student will attend this lecture only if the reduction in the well-being from showing up at the lecture at *t* is smaller than or equal to the disutility from attending any of the lectures in the subset $\mathcal{T}_{t-}^{ti}$, i.e. if $(\beta v_t - c_t) \geq (\beta v_\tau - \beta c_\tau)$ for some $\tau \in \mathcal{T}_{t-}^{ti}$ then $a_t^* = 1$ otherwise $a_t^* = 0$.

$$Min_{a_\tau}\left\{U_{t-}^{ti}(a_\tau, \tau) = -\left(\sum_{\tau \in \mathcal{T}_{t-}} v_\tau a_\tau - \sum_{\tau \in \mathcal{T}_{t-}} c_\tau a_\tau\right)\right\}$$

$$\text{subject to} \qquad (7)$$

$$(i)\ \sum\nolimits_{t \in \mathcal{T}_{t-}} v_t\, a_t = \xi_{t-}^{ti}$$

$$(ii)\ \ t \in \mathcal{T}_{t-}$$

### 4.2 Lecture Absenteeism

In this section, we compare how the different conduct of time-consistent and time-inconsistent students influences class absenteeism. We present two propositions that characterize in more general terms lecture attendance between these two types of students. Then, we analyze three cases that illustrate the interaction between time-consistent preferences, costs and benefit from attending lectures, and absenteeism.

We observe that time-inconsistent students tend to procrastinate regarding lecture attendance, so they will be prone to be absent from the first part of the course and attend later lectures. Furthermore, in contrast to what we expected, a time-inconsistent student could even attend more lectures and increase effort vis-à-vis a time-consistent student.

Proposition 1 tells us that a time-inconsistent student in relation to a time-consistent student will tend to show up at the later lectures of the course rather than the earlier lectures.

**PROPOSITION 1:** For any $v$ and $c$, time-inconsistent students procrastinate in the fulfillment of lecture attendance.

*PROOF 1: At every* $t$ $(v_t - c_t) > (\beta v_t - c_t)$ *then* $A_{-t}^{ti} \leq A_{-t}^{tc}$ *and* $\xi_{t-}^{ti} \geq \xi_{t-}^{tc} \geq 0$, *so* $A_{+t}^{ti} \geq A_{+t}^{tc}$ ■

Because at every period *t*, the current benefit from attending a lecture for a time-inconsistent student is lower than for a time-consistent student, then it is more probable that a time-inconsistent student will be absent from a lecture that a time-consistent student will attend. Therefore, owing to the fact that lecture attendance is important to achieve the standard, time-inconsistent students will need to attend these lectures later on in the course.

Proposition 2 illustrates the consequence of time-inconsistent preferences in lecture absenteeism. In general, we expect that time-inconsistent preference and the self-control problems affecting the behavior of myopic or naïve students could reduce effort and increase absenteeism in these students. This was what Romer (1994) suggested in his answer to the letters commenting his proposal. Nevertheless, on the contrary, we show in Proposition 2 that a time-inconsistent student could even increase effort and end up attending more lecture that a time time-inconsistent student.

**PROPOSITION 2 :** (a) It is possible that $\chi_{ti} \geq \chi_{tc}$ for some $v$ and $c$.

(b) A necessary condition for (a) is $\dot{v} = dv_t/dt < 0$.

*PROOF 2: Let us assume that the time-consistent student just fulfills the standard,* $\xi^{tc} = \underline{\xi}$, *and the marginal benefit of attending a lecture decreases overtime,* $\dot{v} < 0$. *(a) If the statement is true then there is some* $v$ and $c$ *such that* $\chi_{ti} < \chi_{tc}$. *(i) For definition,* $A^{ti^*} > A^{tc^*}$ *and* $\sum_{t=1}^{T} a_t^{ti} > \sum_{t=1}^{T} a_t^{tc}$. *(ii) From the assumptions we consider that* $\underline{\xi} = \xi^{tc}$ *and from equation (3) up we know that at every t* $(v_t - c_t) > (\beta v_t - c_t)$ *then* $\xi^{tc} \geq \xi^{ti}$. *(iii) From the standard we know that* $\underline{\xi} \leq \xi^{ti}$. *Therefore, from conditions (ii) and (iii) we know that* $\underline{\xi} = \sum_{t=1}^{T} v_t a_t^{tc} = \sum_{t=1}^{T} v_t a_t^{ti}$, *so* $\dot{v} < 0$ *is a necessary condition for this been true. (b) If* $\dot{v} < 0$ *is not true then* $\xi^{tc} < \xi^{ti}$ *and the condition (ii) is not fulfilled.* ■

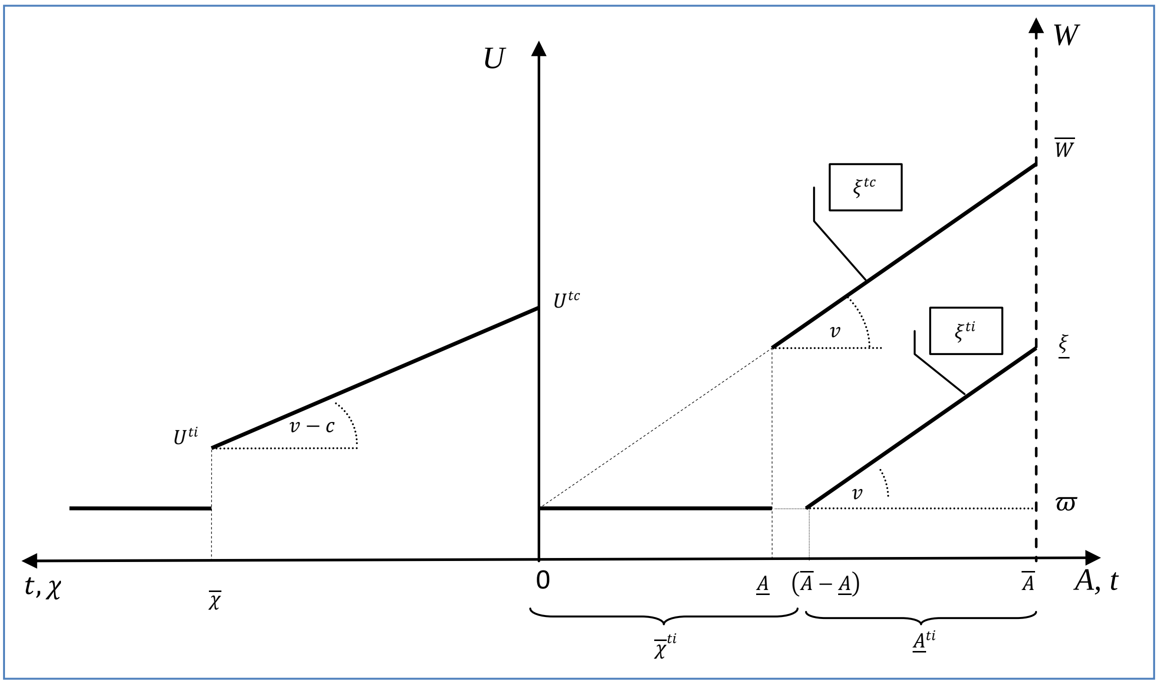
We already showed from Proposition 1 that a time-inconsistent student has a tendency to postpone lecture attendance to the last part of the term. However, if these are the less productive lectures, such as we assume in the Proposition 2, then the student will need to do an extra effort to achieve the standard, increasing lecture attendance and reducing absenteeism. Therefore, we actually showed that contrary to what we expected time-inconsistent student could even have a lower rate of absenteeism than time-consistent students have.

Differences in perception of the benefits of attending lectures or in the opportunity cost of this attendance could help to explain differences in absenteeism among students in the same class. However, Propositions 1 and 2 tell us that even when students perceives similar benefits and faces similar opportunity costs, their lecture attendance profile could differ from the others' due to the inconsistency of their intertemporal preferences. Nevertheless, how important is time-inconsistency in terms of absenteeism? It is clear that even with time-inconsistent students, if the marginal benefits from lecture attendance largely surpass the opportunity cost of showing up in class, then time-inconsistent preferences will not affect the student at all. However, what will happen if this is not the case? For instance, if $\beta < c_t/v_t < 1$ for all $t$ such that the student systematically could be absent from class, losing the opportunity to increase his/her welfare from a long-run perspective. If the costs and benefits coming from attending lectures are large, even a small systematic time-inconsistency could generate large reductions of well-being. Even when the size of the present bias is small and the losses owing to time-inconsistent preferences are small, Akerlof (1991) suggested that the cumulative effect of small repeated errors could be large. Kim (2006) proposes that psychology's self-fulfilling prophecy could help to explain the prevalence of these repeated errors committed by people with time-inconsistent preferences. He suggests that people not well aware of their self-control problems could produce a signal of low-ability of willpower if they fail to resist the temptation in the first round, which could reduce their self-confidence and increase the possibility of weak self-control in the next stages of the game.

Let us analyze the consequences of time-inconsistent preferences utilizing three examples. In the first case, marginal benefits of lecture attendance are constant, while in the second and third cases, they are decreasing. Let us start with the first case using the right side of

Figure 2. This figure is similar to Figure 1 except for the opportunity cost of lecture attendance being constant and lower than the marginal benefit of class attendance such that $\beta < c/v < 1$.[15] In this case, the time-consistent student will attend all the lectures $(\overline{A})$, but the time-inconsistent student will procrastinate regarding lecture attendance and will only show up at the last $\underline{A}^{th}$ lessons to allow him/her to achieve the standard $\underline{A}$.

Figure 2: Absenteeism with a linear benefit and cost function



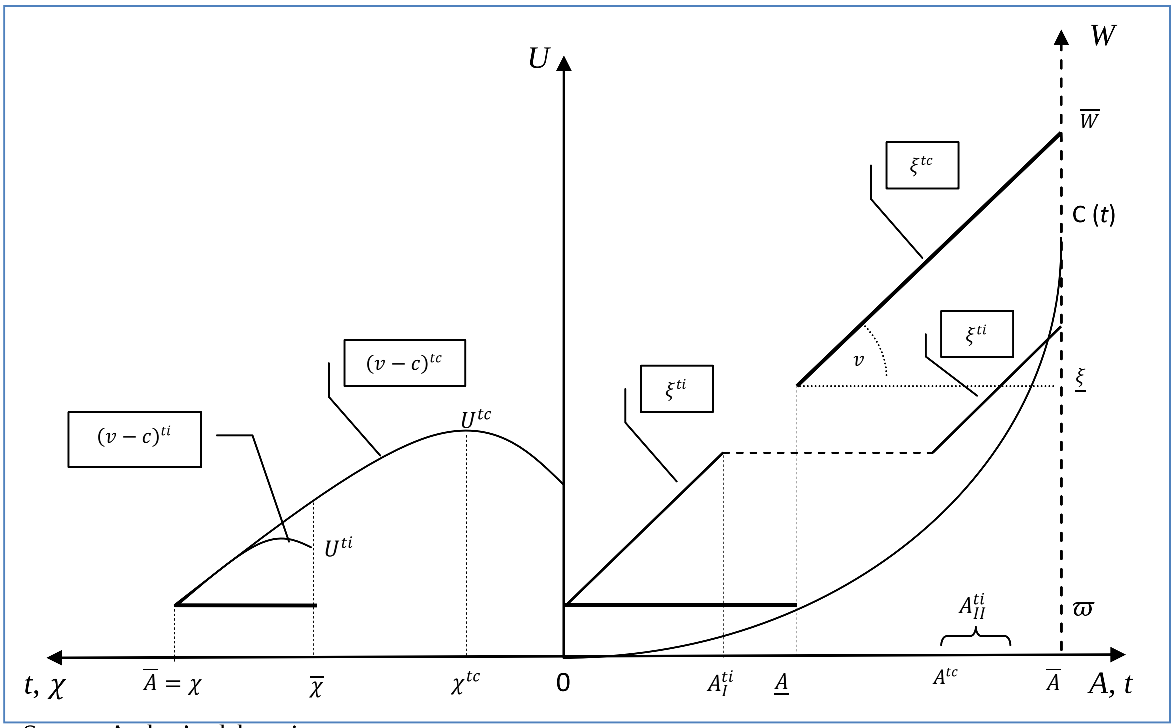

Source: Author's elaboration.

[15] We did not draw the marginal cost in the graph to avoid making it less comprehensible.

Figure 3 represents the same problem but marginal costs are increasing as the lectures proceed such that the marginal cost of attending the last lectures is higher than at the beginning of the term, i.e. $\frac{dc}{dt} > 0$ and $\frac{d^2c}{dt^2} > 0$. We are not sure about the particular intuition for this assumption, but we seek to represent a more general situation where the marginal contribution to the well-being from lecture attendance is decreasing through time such that not only absenteeism will be important, but also the distribution of absenteeism will be relevant throughout the term.

We observe on the right side of Figure 3 the same problem illustrated in Figure 2, but marginal costs increase over time. On the one hand, it could be optimal for time-consistent students not to attend the lesson in the last part of the course, the part of the course where opportunity costs are high enough to discourage them from attending the lecture. Therefore, lecture attendance for a time-consistent student will not be perfect: $A^{tc} < \overline{A}$. On the other hand, time-inconsistent students will still want to achieve the standard, so they will show up at $\underline{A}$ lectures. However, the distribution of lecture attendance over time will be uneven. For instance, it is possible that at the beginning of the term when the opportunity cost is low, the student will attend the lectures while $\beta > c'(t)/v$, then he/she will be absent from the lectures when $\beta < c'(t)/v$ and $c'(t+1)/v < 1$, but will show up at the lectures again when $c'(t)/\beta v > c'(t+\tau)/v > 1$ for any $\tau \in [1, N^{ti}]$. To illustrate this idea in the graph, the student will attend $A_I^{ti}$ lectures at the beginning of the course, and $A_{II}^{ti}$ lectures later on, such that $A_I^{ti} + A_{II}^{ti} = \underline{A}$.

Figure 3: Absenteeism: costs are an increasing function on time



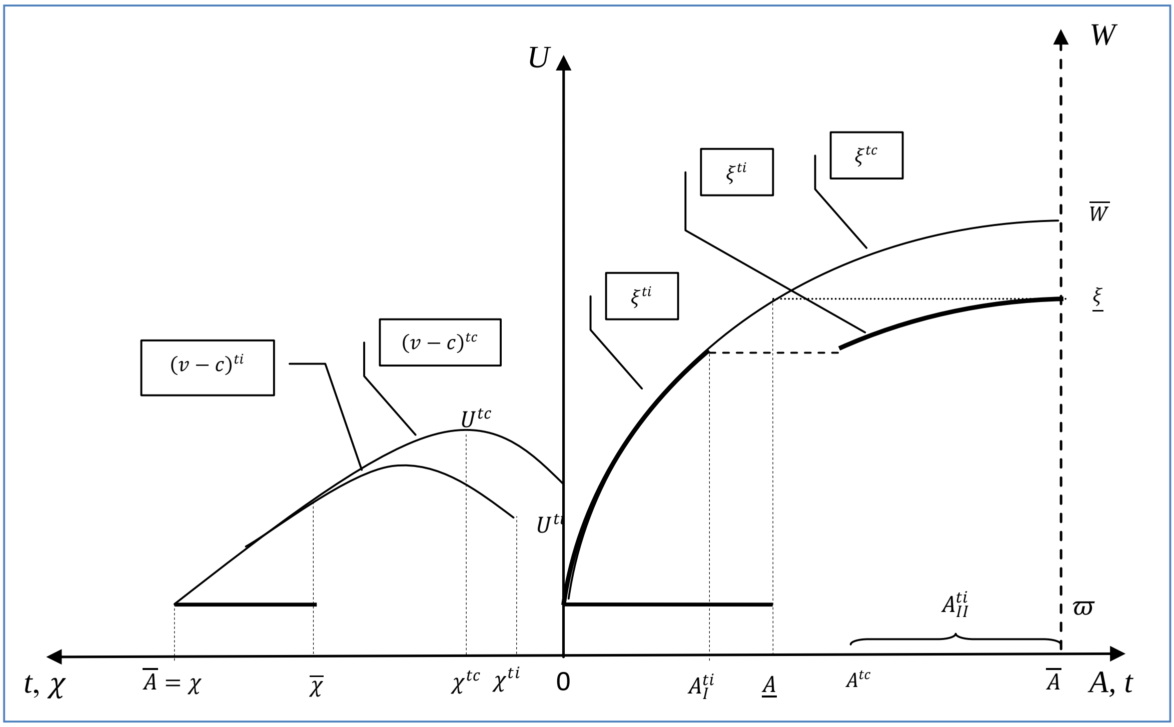

Source: Author's elaboration.

In Figure 4, we represent a situation where lectures later on in the term have a smaller learning impact than the lessons held at the beginning of the term. Marginal benefit from lecture attendance will be decreasing. In this case, the attendance component of the educational production function could be time dependent $\Phi(a,t)$ such that $\Phi'(a,t) > \Phi'(a,t+\tau)$ for any $\tau$.[16] The situation is very similar to the one discussed previously, but this case is due to the time-

[16] Another source of time dependence assumed by Krohn and O'Connor (2005) in their theoretical framework considers that student attendance in the first part of the course could positively influence the performance of the student in the second part of the course.

inconsistent student's procrastination regarding lecture attendance and the lectures later in the term having lower productivity. It could be possible that at the end of the term, the student needs to attend a larger number of lectures to achieve the standard than a time-consistent student does. Therefore, absenteeism could be even less for time-inconsistent students, but they will attend the less productive lectures.

Figure 4: Absenteeism: marginal contribution of attending lectures is decreasing in time.




Source: Author's elaboration.

### 4.3 Performance

From the previous analysis, it is clear that under certain conditions time-inconsistent preferences could raise class absenteeism considerably in students who are naïve to this shortcoming in their behavior, but that in some cases lesson attendance could even rise. In the worst-case scenario, the students could just attend the minimum number of lectures needed to fulfill the requirements and receive the credentials. In Figures 2, 3 and 4, we observe the performance of the students on the right side. The performance of time-consistent students is the upper line $\xi^{tc}$, while the performance of time-inconsistent students is the lower line $\xi^{ti}$. In Figure 2 it is clear that time-inconsistent student performance is worse than that of time-consistent students. This result is similar in Figures 3 and 4, where the performance of time-inconsistent students is shown as a broken line $\xi^{ti}$. Therefore, we observe that in all cases, a time-inconsistent student's performance is worse than a time-consistent student's is. This is true even in the case of a time-inconsistent student having lower absenteeism than a time-consistent student. This result stems from the lesser learning impact of lectures later on in the term. In this case, even when the student is absent from a fewer number of lectures, the student will perform more poorly; he/she will miss the more productive lectures in the middle of the term and they will be substituted by the less productive lectures at the end of the term.

### 4.4 Student Well-being

How do time-inconsistent preferences affect the welfare of the student? It is not an easy question to answer. Welfare comparisons on individuals with time-inconsistent preferences involve normative challenges (see Schelling 1984). Within a time-inconsistent student dwells simultaneously more than one self and the preferences of these different selves at different times can be conflicting. Which preferences should we consider in the analysis? Like O'Donoghue and Rabin (1999), we consider the long-run perspective as the benchmark. Hence, we see the absenteeism problem in a student with time-inconsistent preferences as a self-control problem, represented as preferences for "immediate gratification" (O'Donoghue and Rabin 1999) or "salient costs" (Akerlof 1991), that generate reduction in the welfare of the student from a long-run perspective. At time 0, time-consistent and time-inconsistent students have the same optimal plan, however while time-consistent students follow this plan, time-inconsistent students could deviate systematically from this optimal long-run strategy.

To illustrate the possible consequences for well-being we will come back to Figures 2, 3, and 4, but this time we will look at the left side of the figures. These figures illustrate the evolution of student well-being under different absenteeism profiles. We observe in all cases that time-inconsistent preferences could have a large impact on the well-being of the students.

In Figure 2, a time-inconsistent student attends the bare minimum of lectures necessary for achieving the standard, so absenteeism will be high and the student utility will be low $\left(U^{ti}\right)$ vis-à-vis a time-consistent student who attends all the lectures reaching a higher utility level $(U^{tc})$. We observe the same impact of intertemporal preferences in Figure 3. Nevertheless, in this case the well-being lost that affects the time-inconsistent student is even larger vis-à-vis the time-consistent student. This is because the well-being lost is not only originated by the forgotten lectures that would increase his/her well-being from a long-run perspective, but also for the fact that he/she will need to attend lectures with an opportunity cost higher than its marginal benefits to fulfill the standard at the end of the term. A more surprising result is the fact that even in the third case, when the time-inconsistent student achieves the standard and has a low level of absenteeism, the student could suffer considerable long-run pain because of attending only the less productive lectures at the end of the term.

### 4.5 Incentives for combating absenteeism

One of the starting points in this research was the observation that absenteeism was prevalent in undergraduate economics courses, so (Romer 1993) suggested experimenting with mandatory attendance to improve the student results in a course. Nevertheless, we can also look at other incentive schemes or policies to reduce absenteeism. One natural possibility to explore is to increase the benefit of attending lectures or to reduce the cost. It would seem that both strategies are symmetric; however, it is easy to see in Equation (3) that in a time-inconsistent student, incentives oriented to the reduction in cost of attending a lecture are more cost-effective than an increase in the benefit of showing up in class. This is because at time $t$ when the student has to decide whether or not to attend the lecture, the extra benefit that comes from the incentives will be reduced by $\beta$.

## 5. Mandatory attendance

We have noticed that absenteeism might be higher for students with time-inconsistent preferences. Moreover, absenteeism could have a large impact on the long-run utility of these students. Therefore, in the spirit of Romer (1993), let us experiment with compulsory attendance. How will mandatory attendances perform with myopic time-inconsistent students? How will it affect time-consistent students? These are the key questions that we seek to answer in this section.

In our model, compulsory attendance imposes an additional constraint $(iii)$ $A^i \geq \overline{A}$ in the problem solved by the student every time he/she has to decide whether to attend class (Equation 5 up). For the constraint to be relevant, it has to be binding. This condition will be fulfilled if $\overline{A} \geq \underline{A}$ and $N^i$ is larger for at least some $i$ where $i = \{tc, ti\}$ such that lecture absenteeism after compulsory attendance policy will be lower than before the policy, i.e. $\overline{A} \geq A^i$ for at least some $i$.

Then, given the fact that the compulsory attendance condition is binding, how would it affect the student in a class? In Figure 2 we observe the case where compulsory attendance is only binding for time-inconsistent students. On the one hand, the time-consistent students will not be affected by this measure; on the other hand, the performance of time-inconsistent students in the course will be better and their well-being will improve along with their long-run perspective. They will reach the same performance and well-being that they would have had without their myopic views regarding future behavior.

The situation illustrated in Figure 3 and 4 is different. Compulsory attendance is binding for both kinds of students. In the case of time-consistent students, the obligation to attend lectures with high opportunity costs or with a low impact in educational production function will reduce their well-being. From the point of view of performance in the course, even the time consistent-student could experiment an improvement, although this improvement could be low, or negligible, in the case of time dependent and decreasing educational production function (see Figure 4). On the other hand, time-inconsistent students will increase their performance and well-being, since mandatory attendance constitutes an edge against their myopic behavior. In this case, it will also avoid the procrastination of the students being absent from the less costly or more productive classes. However, in the third case, Figure 4, well-being improvement originates from the obligation to attend the most productive lectures.

## 6. Discussion and Conclusions

In this paper, we analyze a student's lecture attendance decision and its impact over his/her performance in the course and long-run well-being. We distinguish between two students who despite having similar intertemporal preferences, one of the two tends to postpone costs when they become closer in time. We study the effect that mandatory attendance has on these two types of students as well.

We use a human capital/signaling model to investigate the effect that self-control problems have on the level of absenteeism and to analyze the effect that mandatory attendance has on performance in a course.

We observe two distinctive characteristics of a time-inconsistent student vis-à-vis a time-consistent. Time-inconsistent students have a tendency to be absent from lectures that have a positive impact on their long-run well-being. They tend to postpone lecture attendance such that they are more likely to be absent from lectures located in the first part of the term while they later show up in the second part of the course.

In terms of absenteeism, the implications of time-inconsistency are not so clear. A time-inconsistent student could even need to attend more lessons than a time-consistent student does. That could be the case if marginal benefits from attending lectures are decreasing over time. However, what is more clear is the fact that a time-inconsistent student tends to procrastinate in attending lectures vis-à-vis a time-consistent student. This is consistent with the results reported by Cohn and Johnson (2006) who suggest that attendance during the last weeks of the course is not representative of the average attendance throughout the term and contrary to what Romer (1993) affirms: "…attendance a few week at the end of the semester was likely to be representative of average attendance " (p. 168). Therefore, we can imagine that if time-inconsistent preferences really influence absenteeism, then time-consistent students will be underrepresented and time-inconsistent students will be over-represented in his sample, thus absenteeism and its consequences are likely to be overestimated in his study.

We showed that the well-being of myopic time-inconsistent students could be dramatically reduced because of the shortcoming in their intertemporal preferences. It seems as though mandatory attendance could benefit these students in the classroom, without disregarding the possibility of harming the time-consistent. Therefore, we face an empirical question: how extended and how severe is time inconsistency in college or university education? Wong (2008) suggests that most students have at least some degree of time-inconsistency. However, most of them are at least partially self-aware of this shortcoming. Therefore, it is difficult to imagine that these students have not been able to generate strategies for coping with this issue. Sophistication is a possibility. But, do they really have tools for avoiding procrastination? We should expect that student are able to learn from past experience, so it is possible that more advanced students in an undergraduate career are more able to cope with this issue than first-year students are. What are these mechanisms? Are they effective? How learning about their time-inconsistent could help is an interesting issue to explore in the future. This is also a hypothesis to test empirically.

There are several additional issues to explore as extensions of this work. The first is to consider the possibility of utilizing this model for designing empirical tests that could help to test these hypotheses in the classroom. It is also a challenge to consider sophistication for solving this model. Another, interesting possibility is to introduce uncertainty, in the standard or in the marginal productivity of the lectures, and see how it affects absenteeism and mandatory attendance policy.

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