

# Human Capital, Institutions, and Incentives: Micro and Macro Perspectives

by

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Submitted to the Department of Economics  
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy in Economics

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2006

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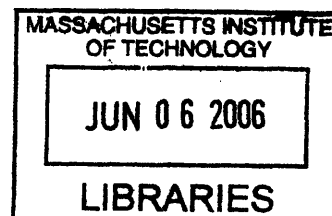
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## Abstract

This dissertation consists of four essays on human capital, institutions, and incentives.

In the first essay, I investigate the effects of voucher-school competition on educational outcomes in Chile. I present a theoretical model that produces three empirical predictions: voucher-school competition 1) improves student outcomes; 2) may put stronger pressure on public schools to increase quality; and 3) has weaker effects when public school budget constraints are softer. I exploit the interaction of the number of Catholic priests and the institution of the voucher system as a potentially exogenous determinant of voucher school entry. Using this instrument, I confirm the main predictions of my theoretical model.

In the second essay, I show that cross-country differences in schooling persist to the present because colonial factors influence the extent of institutional variables, such as democracy and political decentralization. By using the number of native cultures before colonization as an instrument for political decentralization, I show that the degree of democratization positively affects the development of primary education, whereas political decentralization is the more important explanation for differences in higher levels of schooling.

In the third essay, coauthored with Robert Woodberry, we show that competition between Protestant and Catholic missionaries increased schooling in former colonies. Our evidence implies that Protestant missionaries increased schooling in Catholic countries, and that the impact of Protestant and Catholic missionaries on educational outcomes was similar when missionaries of both denominations faced the same legal and institutional treatment. We interpret these results in the context of an economic rationale in which different institutions created differences in competitive pressures faced by Catholic and Protestant missionaries.

Finally, in the fourth essay, I investigate the evolution of the skill premium in Chile over the last decades. I present evidence that patterns of skill upgrading in Chile have followed the evolution of the same variable in the US, consistent with a model of endogenous technological choice where new technologies are produced in developed countries and adopted in developing economies.

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# Contents

<b>1</b>	<b>Introduction</b>	<b>11</b>
1.1	Outline of Thesis . . . . .	11
<b>2</b>	<b>Voucher-School Competition, Incentives, and Outcomes: Evidence from Chile</b>	<b>19</b>
2.1	Introduction . . . . .	19
2.2	Institutional Setting: Primary and Secondary Education in Chile . . . . .	23
2.3	Motivating Theory . . . . .	26
2.3.1	Agents . . . . .	26
2.3.2	Equilibrium . . . . .	28
2.4	Data . . . . .	35
2.5	Identification Strategy . . . . .	37
2.6	Reduced Form Estimates: Difference-in-Difference Analysis and Robustness Checks	41
2.7	Estimating Level Effects . . . . .	43
2.7.1	Test Score Regressions . . . . .	45
2.7.2	Expenditures, Productivity, and Student Composition . . . . .	51
2.8	Estimating Interaction Effects . . . . .	53
2.9	Concluding Comments . . . . .	55
2.10	Appendix: Proofs . . . . .	56
2.10.1	Result 1 . . . . .	56
2.10.2	Result 2 . . . . .	57
2.10.3	Result 3 . . . . .	58
2.10.4	Result 5 . . . . .	59

2.11	Tables and Figures . . . . .	65
<b>3</b>	<b>Historical Origins of Schooling: The Role of Political Decentralization</b>	<b>79</b>
3.1	Introduction . . . . .	79
3.2	Theoretical Background . . . . .	81
3.2.1	Political and Social Institutions and Schooling . . . . .	81
3.2.2	Historical Origins of Schooling . . . . .	83
3.3	Historical Background . . . . .	85
3.4	Empirical Framework . . . . .	88
3.5	Data . . . . .	90
3.6	The Effects of Historical Factors on Schooling . . . . .	92
3.7	Institutions and Schooling: Democracy or Political Decentralization? . . . . .	95
3.8	Conclusions . . . . .	99
3.9	Appendix: Benavot and Riddle (1988) . . . . .	100
3.10	Tables and Figures . . . . .	108
<b>4</b>	<b>Christian Missionaries and Education in Former Colonies: An Early Example of the Economics of School Choice?</b>	<b>119</b>
4.1	Introduction . . . . .	119
4.2	Non-Economic Literature and Historical Background . . . . .	121
4.3	An Economic Interpretation . . . . .	125
4.4	Empirical Framework . . . . .	128
4.5	Cross-Country Evidence . . . . .	131
4.6	African Cross-Region Evidence . . . . .	134
4.7	Concluding Comments . . . . .	137
4.8	Tables and Figures . . . . .	143
<b>5</b>	<b>Skill Premium in Chile: Studying the Skill Bias Technical Change Hypothesis in the South</b>	<b>153</b>
5.1	Introduction . . . . .	153
5.2	Stylized Facts . . . . .	157

5.2.1	Time-Series Evidence: A CES Framework (Katz and Murphy, 1992 and Krusell et al., 2000)	157
5.2.2	Sectoral Evidence: Between and Within Sector Decomposition	165
5.3	Motivating Theory: A Simple Model of Skill Upgrading	166
5.3.1	Environment	168
5.3.2	Skill premium	170
5.3.3	Equilibrium Skill Bias	171
5.3.4	Trade Openness in the US	172
5.4	Time Series Evidence	173
5.5	Sectoral Evidence	176
5.6	Technology Imports to Chile	179
5.7	Conclusions	180
5.8	Appendix: Construction of Economic Sectors using the University of Chile Employment Survey	181
5.9	Tables and Figures	188





# Acknowledgments

I would like to start this thesis by thanking many people who have contributed in significant ways to my research and my graduate studies. I thank first my family: my wife Leo, and our children Malú, Juancho, and the newborn Josecho. They are a continuous source of support, joy and inspiration and to them I dedicate this dissertation.

Next I thank my advisors Daron Acemoglu and Dora Costa. I have been fortunate to have the opportunity to interact with both of them since my first year as a student at MIT. In particular, I am grateful for the amount of time they have taken to teach me how to do good economic research. In the last two years, I have benefited from their support, encouragement, and very detailed suggestions that enormously improved my research. Previous research by Daron has greatly influenced the last three papers of this thesis. I recognize the central influence of his work, both in terms of style and contents, on my own research.

Also at MIT, I have had the opportunity to interact with other faculty members from whom I have learned a lot. I thank Ricardo Caballero for his support at different stages of my graduate studies and for the opportunity to work with him as a research and teaching assistant. I thank David Autor for detailed comments on three of the papers included in this dissertation. Peter Temin also gave me valuable advice at different stages of my graduate studies. I have learnt a lot by being a teaching assistant for Olivier Blanchard and a research assistant for Daron Acemoglu and Josh Angrist. I have also received comments from Josh Angrist, Amy Finkelstein, Jerry Hausman, and participants in the Labor Lunch and Labor-Public Economics Workshop. Finally, I would like to thank Gary King for all his help during my graduate studies.

I have also had the opportunity to interact with many fellow graduate students and friends from whom I have learnt much. This especially includes Herman Bennett, Miriam Bruhn, Pa-

tricia Cortés, Alex Debs, Andrés Hernando, Geraint Jones, Oscar Landerretche, Borja Larraín, Arturo Ramírez-Verdugo, and José Tessada.

My road to graduate school started well before coming to MIT, I thank my professors at the Catholic University of Chile, in particular Vittorio Corbo. I also thank my former colleagues at the Central Bank of Chile, in particular Andrea Butelman, Leonardo Hernández, Norman Loayza, Klaus Schmidt-Hebbel, and Matías Tapia.

I gratefully acknowledge the financial support of the MIT Department of Economics, the Fulbright Program, and the MIT-World Economy Laboratory.

Finally, I would like to thank my extended family. My parents Antonio and Pilar, my sister Pili, and my in-laws, the Chaigneaus, have helped us in many ways during these four years at MIT. My parents deserve a very special mention. Without their tireless efforts to give me a good education I would never have had the luck of being at MIT.

# Chapter 1

## Introduction

While there is a growing consensus that human capital is an important determinant of the welfare of individuals and countries, there are still many open questions about how to produce human capital and about what the determinants of the returns of human capital are. In this dissertation, I contribute to answering some of these questions using a combination of analytical and empirical models. In the first three essays, I focus on the production of human capital in formal education systems. In particular, I study how different institutional settings (both at the macro and the micro levels) affect incentives provided to producers of education (i.e., teachers, school principals, local government officials, or even missionaries). The general answer offered by these three essays is that institutions do affect educational outcomes through the incentives they provide to human capital producers. In the fourth essay I move to study the determinants of the demand for human capital in an emerging economy (Chile) that uses technologies produced abroad. The results suggest that the patterns of skill upgrading in Chile have followed the evolution of the same variable in the US, thus suggesting that the demand for human capital is affected by the skill-bias of technologies developed in the “North”.

### 1.1 Outline of Thesis

The first essay analyzes the effects of inter-school competition on educational outcomes in the context of the Chilean voucher system. Creating competition between schools is a cornerstone of voucher school proposals. Proponents have argued that by creating competition, vouchers

create stronger incentives for public schools to increase quality. However, critics counter that school competition may increase student segregation and harm poor students. In parallel, a line of research on the effects of inter-school competition on student outcomes has not reached a consensus on the causal effects on academic outcomes. The first essay contributes to the literature by studying the effects of inter-school competition on the academic outcomes of Chilean students who attend publicly subsidized schools. Chile is the only developing country that has operated the complete K-12 sector under a “quasi-voucher” system for a long period of time (since 1981). Voucher schools (that is, private schools that receive a voucher for each enrolled student) currently serve above 40% of all students. However, voucher school enrollment varies widely across areas. While in 10% of the educational markets the voucher enrollment is more than 50%, about 20% of Chilean municipalities have no voucher schools in operation.

The essay presents a Hotelling-type model, in which parents have heterogeneous preferences for different schools, to analyze the effects on student outcomes of having two types of schools in a market: public schools with no direct incentives to produce quality beyond meeting a minimum enrollment level; and voucher schools that face explicit competitive incentives. In this context, the model predicts positive effects of voucher school entry on the quality offered by both voucher and public schools (*level effects*). The model also predicts that the size of the response of public schools to voucher school entry depends on the minimum enrollment level needed by a public school to operate and on the size of the school age population (*interaction effects*). Finally, the model suggests that voucher-school competition may put stronger pressure to improve quality on public schools than on voucher schools.

As a potentially exogenous determinant of voucher school competition in different markets, I exploit the interaction of the number of Catholic priests per person in 1950 in different areas of Chile with the establishment of the voucher system in 1981. I show that the number of priests per person is historically determined; and, Catholic priests are correlated with the entry of both Catholic and non-Catholic voucher schools after 1981. I also document that the number of priests per person had little effect on educational outcomes prior to 1981 and has a positive effect on outcomes after the voucher system was established.

I estimate the *level effects* of the ratio of voucher-to-public schools on test scores in an educational market for a cross-section of students in 2002. Because my reduced-form results

imply that priests had little effect on educational outcomes before 1981, I use the number of priests in different areas in 1950 as a potentially valid source of exogenous variation in the supply of voucher schools during the *post*-reform period. I find that once I instrument for the ratio of voucher-to-public schools in different educational markets, the entry of one voucher school per public school in a market increases tests scores by about 0.14 standard deviations. The results are similar for students attending both public and voucher schools, using different measures of voucher school competition, and controlling for educational outcomes before the voucher reform. In contrast, the OLS estimates do not show a strong effect of voucher-school competition on test scores.

The data also support the existence of *interaction effects* of voucher school competition, as predicted by my theoretical model. Public schools located in municipalities that have relatively low minimum enrollment levels and big education deficits do not react strongly to voucher-school competition. These results constitute a more demanding test of the predictions of my model and are hard to be explained by alternative theoretical models that may explain the level effects of inter-school competition.

Overall, the evidence presented in the first essay is consistent with a theoretical rationale that emphasizes the role of incentives provided by voucher-school competition.

In the second essay I move to a cross-country setup and provide some new evidence of why educational attainment varies widely across countries. I study the connection between historical variables, political institutions, and educational outcomes in former colonies. Theoretically, I argue that historical variables determine the distribution of political power among different agents and affect the political institutions established in the past. These institutions present a high degree of inertia and affect educational institutions and outcomes. I argue that two important political institutions that affect schooling are democracy and *local* democracy (decentralization of political power). My main hypothesis is that these political institutions explain the effect of historical factors on past and current levels of schooling.

This hypothesis is also related with the literature on the determinants of the quality and quantity of education. The literature suggests that the link between resources spent on education and *quantity* of education is stronger than the link between resources and *quality* of education. While a salient feature of democracies is the ability to increase public expenditure

in areas such as education, political decentralization tends to raise local pressures to increase the efficiency of educational systems. This argument implies that democratic countries may have better access to education and that decentralized democracies may have a stronger effect on the efficiency of the educational system.

To test these hypotheses empirically, I use settler mortality, population density in 1500, and pre-existing factor endowments as proxies for the historical factors that affect political institutions. In addition, I use the number of native cultures before colonization as a source of exogenous variation for political decentralization. The number of native cultures before colonization affected the colonization strategy in each former colony. Colonizers tended to establish (or take up) centralized states in colonies with one (or no) strong ethnic group(s) and relatively decentralized governments in colonies with several ethnic groups. Current political structures resemble at least partially these initial structures. Thus, I expect areas where colonizers established more centralized states to have more centralized states in the present. By using the number of native cultures before colonization as an additional instrument for political decentralization, I am able to disentangle the effects of these two political institutions on schooling.

My results suggest that conditions faced by colonizers and pre-existing factor endowments affected the characteristics of educational systems established in the past. Cross-country differences in schooling levels persist to the present because colonial factors influence the extent of democracy and decentralization of political power. I show that the degree of democratization positively affects the development of primary education, whereas the decentralization of political power is the most important explanation for differences in higher levels of schooling, such as secondary and higher education. Results suggest that the decentralization of school management at the local level explains the effect of political decentralization on current levels of schooling. These results confirm my hypothesis that while democratization should be more relevant for variables related to the quantity of education (such as primary enrollment), decentralization of political power should be more related with variables capturing differences in the quality of education (such as years of schooling or secondary and higher enrollment).

In the third essay, jointly with Robert Woodberry, we continue studying the institutional determinants of schooling in the context of these colonies. In particular, this essay analyzes

how national identity, religion, and institutions explain educational outcomes in the former colonies by seeing how differences in market structure affected the provision of education by Christian missionaries in former colonies. Christian missionaries were central agents in the development of the educational systems in former colonies. In most former colonies, the first schools were founded by missionaries (as in British colonies) or were managed by priests as agents of the colonial power (as in most Belgian, Portuguese, and Spanish colonies). Interestingly, different colonial powers had very different regulations affecting missionaries. While in British and German colonies there was a relatively neutral policy allowing both Catholic and Protestant missionaries to operate under similar conditions, in Spanish, Belgian, and Portuguese colonies there were implicit or explicit policies favoring the Catholic Church. The policies ranged from those directly granting the monopoly of production of education to Catholic groups (including harsh barriers of entry to non-Catholic groups) to those providing subsidies to Catholic schools.

Economic theory predicts that these differences in the institutional environment should affect missionaries' productivity. Parents choose schools consider differences in school quality, missionaries want to maximize the number of children that attend their schools, and production of school quality is costly for missionaries. Thus while the productivity of Protestant and Catholic missionaries should be similar in colonies where both groups have to compete for students, Protestant missionaries should be especially productive in areas where Catholic missionaries are protected.

This paper uses data on educational outcomes combined with detailed information on the activities of Protestant and Catholic missionaries to examine their productivity in both Catholic and Protestant countries. Our results support our theoretical predictions: while Protestant missionaries were particularly productive in comparison to Catholic missionaries in places with a Catholic state (i.e. with explicit protections to Catholic missionaries), Protestant and Catholic missionaries were equally productive in areas where both groups were treated equally.

Finally, in the fourth essay, I study the determinants of the skill premium (i.e., the wage differential between skilled and unskilled workers) in an emerging economy (Chile). Studying the evolution of the wage premium has interest from at least two perspectives. First, the skill premium is a rough measure of inequality among workers of different qualifications. Second, the

evolution of the skill premium provides information on the characteristics of the development process of the economy. A large body of the literature has analyzed the evolution of the skill premium in developed and developing economies. In the case of developed economies, the literature tends to emphasize the role of skill-biased technical (SBTC) change as a driving force of the evolution of the skill premium. In the case of developing economies, the emphasis is more related to the effect of reforms such as trade openness on wage differentials, albeit the results are not uncontroversial. Some papers have tried to relate both literatures. Theoretically, in a context where only developed countries produce new technologies, the skill premium in developing economies –which adopt new technologies created in developed countries–should be correlated with the skill premium in developed economies, controlling for the relative supply of skilled and unskilled workers in developing countries. Empirically, some papers report positive correlations between measures of skill upgrading in high and middle income countries for the manufacturing sector in the 1970s and 1980s.

In this essay, I extend this line of research in three dimensions: (i) I explicitly study the correlation between the wage premium and skill upgrading in a developed country (the US) and a developing country (Chile) using macro time series, (ii) I extend the analysis to include sectors outside manufacturing and data from 1960 to 2000, and to use a unique panel data set which allows me to control for time and sector specific effects, and (iii) I study empirically the theoretical implication that trade openness in the US should affect skill upgrading both in the US and in Chile.

Chile is a particularly interesting case of study because it corresponds to a small open economy that has undergone a significant change in its economic structure over the last 40 years. Starting in the mid 1970s, a process of economic liberalization has been implemented. At the same time, I estimate in this paper that the skill premium has increased significantly from the 1960s to the 1990s. In turn, the relative supply of skilled workers has increased significantly over the last forty years. This suggests that the relative demand for skilled workers has increased significantly in the latter period.

The finding that changes in the relative demand for skilled labor are important leaves open the question of what factors explain the recent evolution of the skill premium in the Chilean economy. In this essay, I provide macro and sectoral evidence of a close relationship



between patterns of skill upgrading in the US and Chile. As predicted by a simple model of skill upgrading, macro time-series regressions imply that a proxy for the relative demand for skilled labor in Chile is significantly correlated with skill premium and trade openness in the US, after controlling for the traditional determinants presented in the literature. In turn, the sectoral evidence presents the same conclusion: skill upgrading in Chile is correlated with skill upgrading in the US, after controlling for sector and time effects. The sectoral evidence also suggests that this effect is relatively stronger in the tradable sectors especially in the period of economic liberalization (post 1975).



## Chapter 2

# Voucher-School Competition, Incentives, and Outcomes: Evidence from Chile<sup>1</sup>

### 2.1 Introduction

Creating competition between schools is a cornerstone of voucher school proposals. Proponents have argued that by creating competition, vouchers create stronger incentives for public schools to increase quality. However, critics counter that school competition may increase student segregation and harm poor students. In parallel, a line of research on the effects of inter-school competition on student outcomes has not reached a consensus on the causal effects on academic outcomes. While some papers find positive and significant effects of school competition and school choice (e.g., Bayer and McMillan, 2005; Hoxby, 1994, 2000, 2005; Lavy, 2005; and

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<sup>1</sup>I would like to thank Daron Acemoglu and Dora Costa for their continuous advice and comments; Josh Angrist, David Autor, Miriam Bruhn, Ricardo Caballero, Dante Contreras, Alexandre Debs, Amy Finkelstein, Julio Guzmán, Jerry Hausman, Andrés Hernando, Daniel Hojman, Caroline M. Hoxby, Chang-Tai Hsieh, Borja Larrain, Jin Li, Norman Loayza, John Londregan, Bruce Meyer, Arturo Ramírez-Verdugo, Casey Rothschild, José Tessada, Andrea Tokman, Sergio Urzua, Bernardita Vial, and seminar participants at the Central Bank of Chile, Dartmouth College, the U. of Chicago, MIT, Northwestern U., Princeton U., U.C.-Irvine, and Washington U.-St. Louis for comments; the Ministry of Education of Chile for access to data, especially Mauricio Jélvez and Claudia Matus; Sr. M. Jimena Alliende, Fr. Juan Díaz s.j., and Br. Aldo Pasalacqua for information on Catholic schools; Gregory Elacqua for sharing information; and Pamela Siska and Donna Zerwitz for editing help. The usual disclaimer applies.

Sandstrom and Bergstrom, 2005), other papers do not find significant effects (e.g., Hsieh and Urquiola, 2004; Rothstein, 2004, 2005).

This paper contributes to the literature by studying the effects of inter-school competition on the academic outcomes of Chilean students who attend publicly subsidized schools. Chile is the only developing country that has operated the complete K-12 sector under a “quasi-voucher” system for a long period of time (since 1981). Voucher schools (that is, private schools that receive a voucher for each enrolled student) currently serve above 40% of all students. However, voucher school enrollment varies widely across areas. While in 10% of the educational markets the voucher enrollment is more than 50%, about 20% of Chilean municipalities have no voucher schools in operation.

This paper first presents a Hotelling-type model (Hotelling, 1929), in which parents have heterogeneous preferences for different schools, to analyze the effects on student outcomes of having two types of schools in a market: public schools with no direct incentives to produce quality beyond meeting a minimum enrollment level; and voucher schools that face explicit competitive incentives. In this context, the model predicts positive effects of voucher school entry on the quality offered by both voucher and public schools (level effects). The model also predicts that the size of the response of public schools to voucher school entry depends on the minimum enrollment level needed by a public school to operate and on the size of the school age population (interaction effects). Finally, the model suggests that voucher-school competition may put stronger pressure to improve quality on public schools than on voucher schools.

As a potentially exogenous determinant of voucher school competition in different markets, I exploit the interaction of the number of Catholic priests per person in 1950 in different areas of Chile with the establishment of the voucher system in 1981. I show that the number of priests per person is historically determined; and, Catholic priests are correlated with the entry of both Catholic and non-Catholic voucher schools after 1981. Enrollment in *formally* Catholic voucher schools increases from at most 5% of the school-age population before the voucher reform to about 14% in 2002.<sup>2</sup> In addition, I present evidence that the entry of non-Catholic

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<sup>2</sup>Notice that by the Canon Law of the Catholic Church, a school is formally recognized as Catholic when either (i) the Church directly appoints the school principal or (ii) the Church approves the appointment of the school principal. Therefore, many schools that are related to the Catholic Church are not considered *formally* Catholic.

voucher schools is also related to priests and present some hypotheses to explain this correlation. Moreover, before the 1981 reform, private school competition had no financial effects on public schools because revenues of public schools *did not depend* in any way on enrollment in private schools. Consistent with this, I also document that the number of priests per person had little effect on educational outcomes prior to 1981 and has a positive effect on outcomes after the voucher system was established. In other words, the potential validity of my identification strategy relies on the assumption that Catholic priests were present in the pre-voucher period, but that their effects on educational outcomes only became evident during the period when the voucher system was established. The evidence supports this view.

I estimate the *level effects* of the ratio of voucher-to-public schools on test scores in an educational market for a cross-section of students in 2002. This sample of students allows me to test the predictions of my theoretical model using data for the *post*-reform period. Because my reduced-form results imply that priests had little effect on educational outcomes before 1981, I use the number of priests in different areas in 1950 as a potentially valid source of exogenous variation in the supply of voucher schools during the *post*-reform period. I find that once I instrument for the ratio of voucher-to-public schools in different educational markets, the entry of one voucher school per public school in a market increases tests scores by about 0.14 standard deviations. The results are similar for students attending both public and voucher schools, using different measures of voucher school competition, and controlling for educational outcomes before the voucher reform. In contrast, the OLS estimates do not show a strong effect of voucher-school competition on test scores.

The data also support the existence of *interaction effects* of voucher school competition, as predicted by my theoretical model. Public schools located in municipalities that have relatively low proxies for minimum enrollment levels and high education deficits do not react strongly to voucher-school competition. These results constitute a more demanding test of the predictions of my model and are hard to be explained by alternative theoretical models that may explain the level effects of inter-school competition. Some of these alternative theories are as follows: (1) There may be direct effects of competition on parents' or other schools' information; i.e., parents or schools use the information provided by competitors to improve quality (Hoxby, 1994). (2) There may be reputation effects: yardstick competition among teachers who care

about their performance in comparison to other teachers (Juerges et al. 2004); this effect may be more relevant in markets with more comparison points.<sup>(3)</sup> There may be poaching: good teachers signal their unknown characteristics and good (voucher) schools learn and hire these good teachers. My results on the existence of the interaction effects of voucher-school competition are hard to reconcile with these alternative explanations and support the work of my model stressing the role of incentives on the behavior of public school agents.

This paper contributes to the previous literature on the effects of voucher school entry on school quality in Chile (Auguste and Valenzuela, 2002; Carnoy and McEwan, 1998; Contreras and Macias, 2002; Gallego, 2002; and Hsieh and Urquiola, 2004) by providing new IV estimates using a potentially valid source of exogenous variation for voucher school entry (and providing a number of indirect tests to support its potential validity) and presenting a theoretical model that allows me to study the mechanism through which competition may affect the behavior of public schools. The contribution in terms of having potentially valid instruments is relevant because previously used instruments include variables like population size, urbanization rates, or socioeconomic characteristics that likely do not meet the exclusion restrictions.

The remainder of the paper is organized as follows. Section 2.2 briefly describes the Chilean education sector. Section 2.3 presents a theoretical model for framing the empirical analyses of the paper. Section 2.4 presents the data used in this paper. Section 2.5 describes the identification strategy. Section 2.6 presents the results of difference-in-difference regressions using data on educational outcomes before and after 1981. Section 2.7 presents estimates of the level effects of voucher-school competition on student outcomes using a cross-section of primary students in 2002. Section 2.8 presents estimates of interaction effects and section 2.9 briefly concludes. An appendix presents the proofs of some results of the theoretical model.

## 2.2 Institutional Setting: Primary and Secondary Education in Chile

Before 1981, the government in Chile was involved in the funding and provision of education, the supervision and regulation of curricula, the handling of human resources, and investment.<sup>3</sup> The 1981 educational reform: transferred public education from the central to the local governments (municipalities); established a per-student subsidy (voucher) to be received by voucher and public schools depending on enrollment; allowed parents to choose among any publicly-financed school; and allowed would-be schools to enter the market.<sup>4</sup>

Three types of schools emerged: publicly owned schools (managed by local governments), voucher schools (owned by private agents), and non-voucher schools.<sup>5</sup> The first two types of schools receive vouchers; the non-voucher private schools do not receive public funds, charge high tuitions, and serve upper- income students. In 2004, voucher schools enrolled about 42% of students in 2002 up from an enrollment rate of 15% in 1981. Public school enrollment dropped from 78% in 1981 to 49% in 2002. The remaining enrollment corresponds to non-voucher private schools, which I do not include in my sample.

Public and voucher schools present important differences in terms of their incentive structures and the amount of non-voucher resources they receive. Voucher schools tend to behave like competitive firms, receiving revenues proportional to enrollment. While some voucher schools are operated by for-profit firms, other voucher schools are operated by non-profit organizations that raise additional funds in a relatively competitive market for donations to be spent in schools (Aedo, 1998).<sup>6</sup> In contrast, public schools work under “softer” budget constraints: when needed, public schools that are losing students receive transfers, above and beyond the vouchers to pay their expenses (Sapelli, 2003). In addition, while vouchers were the only public

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<sup>3</sup>While the reform was formally enacted in 1981, Aedo-Richmond (2000) suggests that the reform began to be implemented *de facto* around 1978.

<sup>4</sup>Larrañaga (2004) and Sapelli (2003) present a more detailed description of the Chilean voucher system.

<sup>5</sup>A small group of subsidized private schools did operate before the 1981 reform. These schools enrolled about 7% of the school-age population (estimates using data from the 2002 Social Protection Survey) and were financed with small public subsidies and private donations (Aedo-Richmond, 2000). Gregory Elacqua estimates that subsidized private schools enrolled about 12% of the students enrolled in schools in 1979 (personal communication). Considering that enrollment rate was about 75% in the same period, subsidized private schools enrolled about 9% of the school-age population.

<sup>6</sup>Gregory Elacqua estimates that about 63% (58%) of voucher school students were enrolled in for-profit schools in 1998 (1992). Notice that some for-profit schools are formally Catholic.

intervention in the K-12 sector during the 1980s, governments during the 1990s channeled additional resources to “vulnerable” schools and increased non-voucher spending. My estimates are that about 30% of public expenditure in education for the average student is not related to the voucher (data for 2002). In terms of teacher regulations, the public school teachers face flat wage schedules and cannot be removed easily from their positions—only since the mid-1990s could public school teachers be moved to other schools in the same municipality (Mizala and Romaguera, 2004). The number of teachers per student is 25% higher in public schools than in voucher schools (CENDA, 2002). And, public schools are highly unionized.<sup>7</sup> I use these differences in the institutional environment that voucher and public schools face in the model in Section 2.3.

The closing of public schools is a second institutional feature of the Chilean system that I study in the model. The data suggest that about 8% of public schools stopped reporting test scores during the 1990s. The most likely reason for this is that these schools were closed or merged with other public schools. The closed schools tended to have fewer students than other public schools and to under-perform relative to other public schools. Interestingly, the teachers’ union is now actively lobbying against the closing and merging of public schools. Moreover, the opinions of teachers reported in Bellei et al. (2003) suggest that teachers do not want to be moved from one public school to another. This evidence, in conjunction with the evidence on fixed wages, suggests that public school teachers earn significant rents from working in public schools.

Previous papers analyzing the effect of voucher school entry on academic achievement in Chile include Carnoy and McEwan (1998) who use a panel of schools from the early 1980s to the mid 1990s and find no effect of the share of voucher school enrollment on average test scores at the school level. Given that the entry of voucher schools may be endogenous, all the other papers in the literature present some instrumental variable approach to deal with the endogeneity problem. These papers could be classified according to the time period studied. Hsieh and Urquiola (2004) use the change in educational outcomes at the municipality level between 1982 and the early and mid 1990s and find no effect of the change in voucher school enrollment on

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<sup>7</sup>The teachers’ union has strong political power and actively lobbies for additional benefits and against policies aimed at providing performance incentives.



outcomes. Even though the focus of that paper is on OLS estimates, Hsieh and Urquiola (2004) also present some IV estimates using the size of the population, urbanization rate, and the inter-quartile range of education in 1982 as instruments for voucher school enrollment.

These results contrast with other papers analyzing the effect of school competition on test scores using data for the 1990s: Gallego (2002) using school level data for 1994-1997 and IV estimates (the instruments are urbanization rates and population size) finds a positive effect of voucher school enrollment on test scores; Contreras and Macias (2002) find a positive effect of competition (measured using a Herfindahl index) on pre-college tests for 1998 using instrumental variables (population size, area, lagged Herfindahl index, and availability of private schools, among others). Auguste and Valenzuela (2003) is the paper most directly comparable to Hsieh and Urquiola (2004). They present both student and market level regressions for the effect of voucher school enrollment on test scores using data for the late 1990s and find a positive and significant effect of voucher school entry on test scores.

Differences in the time period studied are important to understand the differences in the results between the paper by Auguste and Valenzuela (2003) and Hsieh and Urquiola (2004). It is hard to argue that the system operating in the 1980s was a real voucher system from the point of view of several agents: (i) public school budgets were not affected by the voucher reform (in part because the decentralization of public schools was not completed until the late 1980s), (ii) employment of public school agents was quite rigid until the mid-1990s, (iii) test scores were not public until the mid/late 1990s, (iv) local governments were not elected democratically until 1992, and (v) the real value of the voucher decreased steadily during the 1980s and only recovered in the early 1990s. All these factors may explain why the effects are positive in the 1990s (when the educational system was operating under rules that are closer to the textbook version of a voucher system) and insignificant in the 1980s.<sup>8</sup> My paper presents additional evidence of the positive effects of voucher school competition in the early 2000s.

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<sup>8</sup> Another important difference between the 1990s and the 1980s is that test scores for the complete population are only available for the 1990s. The test scores available for the 1980s possibly cover a highly selected sub-sample of schools in some areas (personal communication with Erika Himmel who was in charge of the early tests). In addition, there are no pre-reform test scores available—notice that Aedo-Richmond (2000) argues that the reform started to be implemented about 1978.

## 2.3 Motivating Theory

I present a simple theoretical model for studying the potential effects of voucher-school competition on school quality. The model incorporates three groups of agents: parents deciding among different schools, voucher school owners, and public school agents.

### 2.3.1 Agents

$\bar{L}$  parents are uniformly distributed over a linear neighborhood of length 1. The location of parents along the linear neighborhood refers to their preferences for public and voucher schools, which are located at the extremes of the city. In particular, let  $x$  denote location along the linear neighborhood, public schools are located at  $x = 0$  and voucher schools at  $x = 1$ . This modelling approach formalizes the notion that public and voucher schools not only offer formal instruction (i.e., measured in test scores), but also instruction in other areas, such as religious education and civic values. I assume that parents have heterogeneous preferences about these school characteristics and that schools cannot choose their location along the linear city (i.e., public and voucher schools have intrinsic differences in the non-formal instruction they provide).<sup>9</sup>

The utility of a parent located at  $x$  is given by:

$$U_{jx} = q_j - td_{jx}, \quad (2.1)$$

where  $q_j$  is quality offered by the school  $j$  and  $d_{jx}$  is the distance from parents located at  $x$  to school  $j$ .  $d$  captures the discrepancy between parents' preferred instruction and the instruction provided by school  $j$ . Therefore,  $t$  is a "transportation cost" that measures the disutility per unit of distance of sending children to a school that is not located at  $x$ . Parents choose the school that maximizes (2.1). If two voucher schools offer the same quality, then parents randomize among them.

There is only one public school in each neighborhood, but the number of voucher schools ( $N$ ) is endogenously determined in the model, given some number of would-be voucher schools in an area ( $N^P$ ). The number of would-be voucher schools may be limited, because school

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<sup>9</sup>I could generate spatial differentiation in equilibrium by adding more structure into the cost functions (Tirole, 1988).

quality is a good whose reputation is important. School quality is provided after students are enrolled; therefore, voucher schools may “hold up” parents and not fulfill their initial offers of quality. In a context of incomplete contracts, only voucher schools with good reputation or that can signal that they are not opportunistic agents are able to enter the market and generate a positive demand. In addition, cultural and social factors may constrain the number of acceptable voucher schools.<sup>10</sup>

Owners of voucher schools decide simultaneously whether they enter the market and what quality they provide ( $q_V$ ). Profits of voucher school  $i$  are given by:

$$\Pi_i = [(v - c^V(q_{V_i}))n_{V_i} - F], \quad (2.2)$$

where  $v$  is the per-student voucher,  $c^V(\cdot)$  is the unitary cost of providing quality  $q_V$ ,  $n_V$  is the number of voucher school students, and  $F$  is a fixed cost. I assume  $c^{V'}(\cdot) > 0$  and that quality offered by voucher schools has to be above a minimum level  $q_V^M$ .

In terms of public schools, mayors (who manage public schools in a municipality) face an agency problem; in contrast to voucher schools, public schools cannot use variable wages and other forms of explicit incentives to implement their optimal choices. Thus, public school agents (teachers) decide the quality that public schools provide ( $q_P$ ) by maximizing:

$$\{y - c^P(q_P) + R \mathbf{1}[n_P \geq \bar{n}]\}, \quad (2.3)$$

where  $y$  is income of teachers, which is fixed,  $c^P(\cdot)$  is the effort cost of providing quality  $q_P$  ( $c^{P'}(\cdot) > 0$ ),  $\mathbf{1}[n_P \geq \bar{n}]$  is an indicator function that takes a value of one if  $n_P \geq \bar{n}$  and a value of zero otherwise,  $n_P$  is the number of public school students,  $\bar{n}$  is the minimum enrollment level, and  $R$  is a positive constant that captures rents of public school agents that are lost if the public school closes. The public school closes when its enrollment is below the minimum enrollment level or its quality is below  $q_P^M$ .

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<sup>10</sup>Survey data from Chile suggest that, indeed, there are limitations in the supply of voucher schools. Lehmann and Hinzpeter (1997) report that in 1996 about half of the parents with children in public schools wanted to have their children in voucher schools. In 2001, while 39% of middle-income parents had their children in voucher schools, 66% preferred a voucher to a public school. Results for low-income parents are similar: while 21% of these parents had their children in voucher schools, about 50% preferred a voucher school.

The public school budget is:

$$[(v - o)n_P - F + NV],$$

where  $NV$  is a non-voucher transfer and  $o$  is a per student cost. I assume that only non-voucher transfers vary across public schools. The minimum enrollment level of each public school is the enrollment level associated with a balanced public school budget, which is given by:

$$\bar{n} = \frac{F - NV}{v - o}.$$

Since, in the model, only  $NV$  varies across public schools,  $\bar{n}$  is determined by changes in  $NV$ .<sup>11</sup>

### 2.3.2 Equilibrium

The timing of events is as follows:

1. First, a finite number  $N^P$  of voucher schools simultaneously decide whether they enter the market and the quality they provide ( $q_V$ ).
2. Next, public school agents decide the quality they provide ( $q_P$ ).
3. Finally, parents decide to which school to send their only child.

The symmetric subgame perfect equilibrium of this model is characterized by values for  $q_P, q_{V_i}, N, n_P, n_V$ , and  $n_{V_i}$ , such that:

- Quality offered by all voucher schools is the same, i.e.,  $q_{V_i} = q_V \forall V_i$ .
- Parents maximize (2.1) by selecting among available schools.
- Public school agents maximize (2.3) by selecting public school quality.
- $N \leq N^P$ .

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<sup>11</sup>Non-voucher transfers could be understood as soft budget constraints. In this case, the model in Robinson and Torvik (2005) could be used to explain why in a political economy equilibrium, the central government can be willing to transfer public money to public school agents.

- $\Pi_i \geq 0$ , and the  $N$  voucher schools that have entered the market maximize (2.2) by selecting voucher school quality.

To solve the symmetric subgame perfect equilibrium of the model, I use backwards induction, starting from parents' choices. Parents choose a school to maximize (2.1). Aggregating their decisions, I derive the demand for public and voucher schools, as stated in Result 1 (proofs of the theoretical results are presented in the Appendix):

**Result 1** *Enrollment in the public school and voucher schools is, respectively:*

$$n_P = \begin{cases} \bar{L} & \text{if } N = 0 \\ \bar{L} \left( \frac{q_P - q_V}{2t} + \frac{1}{2} \right) & \text{if } N > 0 \end{cases},$$

$$n_{V_i} = \begin{cases} 0 & \text{if } N = 0 \\ \frac{\bar{L}}{N} \left( \frac{q_V - q_P}{2t} + \frac{1}{2} \right) & \text{if } N > 0 \end{cases} \quad \forall V_i.$$

School quality is determined by maximizing utility of public school agents, given Result 1. Note that maximization of Equation (2.3) implies that either the minimum quality or the minimum enrollment constraint is binding in equilibrium. Condition 1 states the case in which the minimum enrollment constraint binds.

**Condition 1 (Minimum Enrollment Constraint Binding)**

$$\left( \frac{\bar{n}}{\bar{L}} - \frac{1}{2} \right) \geq \frac{q_P^M - q_V}{2t}.$$

Condition 1 is quite intuitive and states that the minimum enrollment level is more likely to be binding when the minimum enrollment is high relative to the population and the difference between minimum public school quality and voucher school quality is large.

Result 2 presents the optimal public school quality.

**Result 2** 1. *If Condition 1 holds, optimal public school quality is given by:*

$$q_P = \begin{cases} q_P^M & \text{if } N = 0 \\ 2t \left( \frac{\bar{n}}{\bar{L}} - \frac{1}{2} \right) + q_V & \text{otherwise} \end{cases}.$$

and, enrollment in public schools is given by:

$$n_P = \begin{cases} \bar{L} & \text{if } N = 0 \\ \bar{n} & \text{otherwise} \end{cases} .$$

2. If Condition 1 does not hold, optimal public school quality is given by:

$$q_P = q_P^M,$$

and, enrollment in public schools is given by:

$$n_P = \begin{cases} \bar{L} & \text{if } N = 0 \\ \bar{L} \left( \frac{q_P^M - q_V}{2t} + \frac{1}{2} \right) & \text{if } N > 0 \end{cases} .$$

The intuition of this result is that only one of the two constraints is binding in equilibrium. Thus, if there is no voucher school in the market, then public school agents offer the minimum quality,  $q_M^P$ . The same result emerges if the minimum enrollment level is not binding. In contrast, if the minimum enrollment constraint binds, then public school agents have to produce a (higher) quality level, such that the public school has exactly the number of students needed to satisfy the minimum enrollment level.

Finally, regarding the behavior of voucher schools, I first determine the number of voucher schools that have non-negative profits if they produce the minimum quality level ( $q_V^M$ ), assuming no restriction on the number of would-be voucher schools. I denote this number of schools as  $N^*$ . I analyze below the case in which there are a limited number of would-be voucher schools.

**Result 3** 1.  $N^* = 0$  if  $n_V(v - c^V(q_V^M)) < F$ .

2.  $N^* > 0$  if  $n_V(v - c^V(q_V^M)) \geq F$ .  $N^*$  is given by:

$$N^* : \frac{n_V}{(N^* + 1)}(v - c^V(q_V^M)) < F \leq \frac{n_V}{N^*}(v - c^V(q_V^M)).$$

This result highlights an important property of the model. Namely, that  $N^*$  depends positively on the total enrollment in voucher schools which, in turn, depends negatively on

public school quality (See Result 1). Therefore, this model predicts that the better the public schools in an area are, the lower is the number of voucher schools operating in that area. Even though the model is deterministic, when I move to the empirical analyses, I could extend the model to have some randomness (e.g., in enrollments) and get the result that there may be reverse causality from public school quality to the number of voucher schools in an area. Therefore, OLS estimates of the effect of voucher-school competition are downward biased. This bias suggests using instrumental variables to identify the causal effect of the number of voucher schools on public school quality.

Next, the actual number of voucher schools depends on the availability of would-be voucher schools in a market.

**Result 4** *The number of voucher schools operating in a market is:*

$$N = \min (N^*, N^P).$$

Finally, the next result determines the optimal quality level offered by each voucher school.

**Result 5** *If Condition 1 holds, quality offered by voucher schools is:*

$$q_V = \begin{cases} q_V^M & \text{if } N = 1 \text{ and } N^P = 1 \\ c^{V-1} \left( v - \frac{NF}{L-n} \right) & \text{if } N \geq 1 \text{ and } N^P \geq 2 \end{cases}.$$

*If Condition 1 does not hold, quality offered by voucher schools is:*

$$q_V : \begin{cases} \frac{c^V(q_V)}{c^{V'}(q_V)} = 2t \frac{n_V}{L} & \text{if } N = 1 \text{ and } N^P = 1 \\ q_V = c^{V-1} \left( v - \frac{NF}{n_V} \right) & \text{if } N \geq 1 \text{ and } N^P \geq 2 \end{cases}.$$

This result highlights the role of competition in creating incentives for voucher schools to increase quality. In the case when  $N = 1$  and  $N^P = 1$ , the single public school does not face potential competitors, chooses the minimum quality level ( $q_V^M$ ) and earns rents in equilibrium. In contrast, when  $N^P \geq 2$  and  $N = 1$ , the existence of potential entrants creates incentives for the incumbent voucher school to increase quality until profits are equal to 0. Similarly,

when  $N \geq 2$ , the existence of potential competitors creates incentives for incumbents to offer a quality level such that profits are equal to 0 in equilibrium.

Results 1 through 5 allow me to characterize the equilibrium quality given different parameter values. This is presented in Proposition 1.

**Proposition 1 (Equilibrium Public and Voucher School Quality)** *If Condition 1 holds in equilibrium, public and voucher school quality are given by:*

$$q_P = \begin{cases} q_P^M & \text{if } N = 0 \\ 2t(\frac{\bar{n}}{L} - \frac{1}{2}) + q_V^M & \text{if } N = 1 \text{ and } N^P = 1, \\ 2t(\frac{\bar{n}}{L} - \frac{1}{2}) + c^{V-1} \left( v - \frac{NF}{L-\bar{n}} \right) & \text{if } N \geq 1 \text{ and } N^P \geq 2 \end{cases}$$

$$q_V = \begin{cases} q_V^M & \text{if } N = 1 \text{ and } N^P = 1 \\ c^{V-1} \left( v - \frac{NF}{L-\bar{n}} \right) & \text{if } N \geq 1 \text{ and } N^P \geq 2 \end{cases}.$$

*If Condition 1 does not hold in equilibrium, public and voucher school quality are given by:*

$$q_P = q_P^M \forall N,$$

$$q_V : \begin{cases} \frac{c^V(q_V)}{c^{V^t}(q_V)} = 2tn_V & \text{if } N = 1 \text{ and } N^P = 1 \\ q_V = c^{V-1} \left( v - \frac{NF}{n_V} \right) & \text{if } N \geq 1 \text{ and } N^P \geq 2 \end{cases}.$$

To focus on the most interesting cases for the purposes of this paper and to reduce the number of possible cases, I discuss mainly the case in which the minimum enrollment constraint binds in equilibrium (Condition 1). This seems the most plausible case for Chile.<sup>12</sup> When Condition 1 is violated, public school quality does not depend on the number of voucher schools. In turn, voucher school quality is an increasing function of the number of voucher schools in the market. When Condition 1 holds, the minimum enrollment level is binding; therefore, public school quality also depends on the number of voucher schools in the market, because public schools respond to voucher school quality in order to achieve the minimum enrollment level.

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<sup>12</sup>Condition 1 is supported by the data. The Chilean data suggests that:  $-0.06 \approx (\frac{\bar{n}}{L} - \frac{1}{2}) > \frac{q_P^M - q_V}{2t} \approx \frac{-0.16 - 0.03}{1.61} \approx -0.12$ . I estimate  $t$  from a regression of  $\frac{n^P}{L}$  on  $q_P - q_V$ . I approximate  $q_P^M$  using the average test scores of public schools when  $N = 0$ , and  $q_V$  using the average test scores for voucher schools in markets with  $N = 1$ .



Proposition 1 allows me to study the effects of increases in  $N^P$  on public and voucher school quality. These comparative static exercises are closely related to my empirical analysis in this paper, which uses a potentially valid source of exogenous variation of  $N$ . In the remainder of the model, I only consider the case in which  $N \leq 2$ , which is the relevant interval for Chile, because the ratio of voucher-to-public schools is less than 2 in 95% of the educational markets.

**Corollary 1 (Level Effects)** *If Condition 1 holds in equilibrium and  $N \leq 2$ , an increase in  $N^P$  that increases  $N$  has a positive effect on equilibrium voucher and public school quality .*

*If Condition 1 holds in equilibrium and  $N = 1$ , an increase in  $N^P$  from 1 to 2 has a positive effect on equilibrium voucher and public school quality.*

Intuitively, when  $N$  increases from 0 to 1, the public school increases the quality offered because the minimum enrollment constraint becomes binding. When  $N$  increases from 1 to 2, the incumbent voucher school has to increase its quality until rents are dissipated, because the entering voucher school offers a higher level of quality. In this case, the public school has to respond to the increase in voucher school quality in order to meet the minimum enrollment constraint. The second case stated in Corollary 1 highlights the effects of increasing potential competition when the market is such that only one voucher school operates. In this case, potential competition creates incentives for the incumbent voucher school to increase quality until profits are dissipated.

Corollary 2 presents another interesting theoretical implication of an increase in  $N$  that is caused by an increase in  $N^P$ . This corollary resembles an empirically relevant case for Chile because public schools in about 85% of the educational markets face competition from at most one voucher school and, as previously mentioned, the ratio of voucher to public schools is less than 2 in 95% of the educational markets. Thus, this corollary produces theoretical predictions related to the variation I observe in the data.

**Corollary 2 (Public vs. Voucher School Response to Competition)** *Let  $q_j^N$  denote equilibrium quality of school  $j$  when the number of voucher schools in a market is  $N$ . Define  $z_P$*

and  $z_V$ :

$$z_P \equiv q_P^1 - q_P^0, \text{ and}$$
$$z_V \equiv q_V^2 - q_V^1$$

If Condition 1 holds in equilibrium and  $N$  increases initially from 0 to 1 and next from 1 to 2 as a consequence of an increase in  $N^P$ :

1. If  $z_P > z_V$ , public school quality responds more strongly than voucher school quality to an increase in voucher school competition.
2. If  $z_P = z_V$ , public school quality and voucher school quality respond the same to an increase in voucher school competition.
3. If  $z_P < z_V$ , public school quality respond less strongly than voucher school quality to an increase in voucher school competition.

The comparative static exercise in Corollary 2 implies that voucher school competition could put stronger pressures to increase quality on public schools than on voucher schools. Theoretically, there is no restriction to the relative response of both voucher schools to the comparative static exercise presented in Corollary 2. For instance, public school quality may be more responsive when the difference between minimum voucher school quality ( $q_V^M$ ) and minimum public school quality ( $q_P^M$ ) is sufficiently large, which produces a tremendous increase in public school quality in order to meet the minimum enrollment level. On the contrary, if  $q_V^M - q_P^M$  is small or the minimum enrollment level is sufficiently small, then voucher schools' response to competition may be greater. The empirical results in this paper suggest that both types of schools respond similarly to voucher school competition.

Finally, Proposition 1 implicitly states that the response of the public school to an increase in the number of voucher schools produced by an increase in  $N^P$  depends on how binding the minimum enrollment constraint is. The minimum enrollment constraint is more binding when the school age population is large or when non-voucher transfers are large. Corollary 3 states this result.

**Corollary 3 (Interaction Effects)** *If Condition 1 holds in equilibrium and  $N$  increases from 0 to 1 as a consequence of an increase in  $N^P$ , then the lower the minimum enrollment level (the more the non-voucher transfers there are), the lower is the response of the public school to the entry of a voucher school in the market.*

The predictions of Corollary 3 are quite intuitive. Public schools with more stringent incentives in the form of harder enrollment levels have to increase quality more when a voucher school enters the market. This corollary clearly illustrates the working of the model in terms of the mechanism that makes voucher schools increase quality when facing voucher school competition.

In summary, the most important empirical prediction of the theoretical framework presented in this section is that public and voucher school quality should increase as the number of voucher schools in a market increases exogenously. In addition, there should be interaction effects: the public school response to exogenous changes in voucher school competition depends on how binding the minimum enrollment is. This result illustrates the theoretical mechanism at work in the model, which is basically related to the implicit incentives that the minimum enrollment constraint gives to public school agents. In addition, the theory predicts that the response of public schools to an increase in the number of voucher schools in a market may be greater than the response of voucher schools if the minimum public school quality is sufficiently low. Finally, the theory also suggests that the number of vouchers in a market is endogenous to public school quality. This suggests the use of instrumental variables in the empirical analyses of this paper.

## 2.4 Data

I use several datasets in this paper. Table 1 presents the variables used, the level at which each variable is collected, and the descriptive statistics of each variable. I use data on students' educational outcomes, their backgrounds, parent preferences, school characteristics, and the characteristics of the area where they attend school from the dataset of the 2002 SIMCE (*Sistema de Medición de la Calidad de la Educación*) test, which was administered to 4th graders. This test has been given nationwide since 1988 to more than 90% of students in a different grade each year (4th, 8th, or 10th graders). I use the average of the Math and Spanish portions of the test (standardized to have an average of 0 and a standard deviation of 1) as my measure

of academic outcomes. I use income per household member and mother's education to measure the socioeconomic background of students.<sup>13</sup>

Second, I use the CASEN (*Encuesta de Caracterización Socioeconómica*) 2000 survey, which collects information on socioeconomic variables for a representative cross-section of the population. I use a high school graduation dummy as a measure of educational attainment for members of different cohorts that attended school in different places. Third, I use the 2002 Social Protection Survey (called "Labor History and Social Security"), which collects life-time information for a sample of individuals. I use information on high school graduation rates at the market level for individuals attending school before the 1981 reform, the migration decisions of parents with school-age children in 2002, and information on the type of school attended (public, subsidized private, and paid private).

I measure the degree of voucher school competition as the ratio of voucher schools to public schools in each educational market. I use 297 municipalities and the Metropolitan Area of Santiago as proxies for local educational markets. Municipalities are separate educational markets because, with the exception of municipalities in the Metropolitan Area of Santiago, most students attend schools in the town where they live (Hsieh and Urquiola, 2004; and Sapelli and Vial, 2002). Data on the availability of schools in each market come from the Ministry of Education files.

Data on religious variables at the diocese level related to my identification strategy come from the yearly publication by the Vatican called *Anuario Pontificio* (the number of priests, the share of Catholics, and the ratio of order to total priests in each Chilean diocese).<sup>14</sup>

I also use other sources of data in some empirical exercises. Data on Catholic schools come from the school directory of the Chile Catholic Church (<http://www.feducech.cl/> and

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<sup>13</sup>I use five categories to measure mother's education (having attained at most primary education, secondary general education, secondary technical education, post-secondary technical education, and college or postgraduate education).

<sup>14</sup>In particular, I use data on priests per-capita for 1950 from *Anuario Pontificio*. I estimate the number of priests in the different dioceses in 1950 by considering the territorial division existing in the 1990s (which includes 26 dioceses) and the number of priests in 1950. I make this adjustment because some dioceses (namely Santiago) included disproportionately big areas of population in 1950. Between the 1960s and the 1990s, new dioceses appeared when some dioceses were split up—so the number of dioceses increased from 19 to 26. I assume that the distribution of priests *within* the split dioceses is given by the distribution when the new dioceses were created (the distribution of priests within dioceses in the following periods is quite stable). In all the empirical applications, I cluster standard errors at the 1950 dioceses level.

<http://www.iglesia.cl/>). Data on municipal variables such as expenditures per student and the size of public schools come from the Chilean Municipal Dataset (available at <http://www.sinim.cl/>). Finally, I use information on electoral outcomes at the municipality level from the Chilean Electoral Office, when analyzing the interaction effects of inter-school competition.

## 2.5 Identification Strategy

One major challenge for an empirical analysis of the relationship between voucher school competition and educational outcomes is the potential endogeneity of the number of voucher schools. In this section, I argue that the interaction of the number of Catholic priests per person in 1950 and the school reform of 1981 allows me to identify the exogenous variation in the number of voucher schools in different educational markets.

The potential endogeneity between the number of voucher schools and public school quality can be illustrated using the model in Section 2.3, in a context with randomness. Increases in minimum quality ( $q_P^M$ ) or minimum enrollment ( $\bar{n}$ ) decrease the number of voucher schools operating in an area and have a positive effect on quality offered by public schools. Thus, entry into the market is endogenous to public school quality; therefore, simple correlations or OLS estimates will produce *downward* biased estimates of the causal effect of voucher-school competition on educational outcomes. Alternatively, OLS estimates could be biased upward if voucher school entry responds to some unobserved (to the econometrician) characteristic of the market that has a positive effect on school quality.

My identification strategy exploits the interaction of the (log of the) number of Catholic priests per person in 1950 and the 1981 reform to identify the exogenous variation in the number of voucher schools in an area, after controlling for the share of Catholic population.<sup>15</sup> The basic motivation for this identification strategy is two-fold. On the one hand, there are direct effects of priests on Catholic schools. The involvement of priests in educational activities is understood as a key element of their religious mission (Garrone, 1977). However, although Catholic priests were involved in schools before the reform (my estimates are that at most 5% of the school-age

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<sup>15</sup>By controlling for the share of the Catholic population, I take into account potential direct effects of this variable on educational results (as suggested by recent research on the effects of religious affiliation on income, education, and other social and economic variables, e.g., Barro and McCleary, 2003 and Gruber, 2005).

population attended Catholic schools that were publicly subsidized),<sup>16</sup> there is a big increase in the enrollment in Catholic voucher schools after the reform, increasing to a level close to 14% of the school-age population in 2002. This increase takes place along three margins: (i) new Catholic schools were installed, (ii) existing Catholic schools increased in enrollment,<sup>17</sup> and (iii) former paid Catholic schools became voucher schools after the reform.<sup>18</sup> <sup>19</sup> The main reason for this big increase in enrollment in Catholic voucher schools is that only after the reform did Catholic schools start to receive vouchers (the voucher represented an increase of about 160% in the value of the subsidy received by Catholic schools from the government),<sup>20</sup> allowing priests to establish new schools or to expand enrollment among middle- and lower-class students.

Priests are important actors in Catholic schools. These schools can be owned directly by the Church, by religious orders, or by people supported by the Church, but they always have at least one priest acting as a chaplain. Currently, priests tend to focus on pastoral ministries (e.g., being chaplains and teaching religious education classes) and on the management of schools. In terms of time requirements of being a priest in a school, priests have to spend a significant amount of time working with students, teachers, and parents. Priests working in schools receive wages that are comparable to those of other teachers. Pasalacqua (2004) reports that about 5% of the teaching staff and 10% of the non-teaching staff in Catholic voucher schools are religious personnel (including not only priests, but also brothers and nuns).

In addition, there may be effects of priests on the establishment of non-Catholic schools.

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<sup>16</sup>These estimates are computed as follows: the Social Protection Survey implies that 7% of the members of pre-voucher cohorts attended subsidized private schools. Numbers in Brahm et al. (1971) imply that 68% of pre-reform enrollment in subsidized private schools was in Catholic schools. Then, I estimate that 4.8% of the school-age population attended Catholic subsidized schools before the reform.

<sup>17</sup>Brahm et al. (1971) report that the average size of a Catholic subsidized school was 269 students in 1971, in comparison to an average of 652 students in 2002 (data from Pasalacqua, 2004)

<sup>18</sup>Unfortunately, there are no systematic data on enrollment in Catholic schools before and after the reform. My estimates, using data from Pasalacqua (2004), are that 25% of enrollment in Catholic voucher schools in 2002 corresponds to brand new Catholic schools and between 15 and 25% of the enrollment corresponds to schools that became voucher schools after the reform.

<sup>19</sup>Anecdotal evidence from one of the most important Catholic groups in Chile (the Marist brothers) may help to understand the increase in enrollment in Catholic voucher schools after the reform. Enrollment in Marist schools was 5,000 students in 1980, with about 10% of these students in subsidized schools. In contrast, enrollment was 14,800 in 2002, with 40% corresponding to voucher schools. About two thirds of enrollment in voucher schools corresponds to schools established after the reform (Personal communication with Br. Aldo Pasalacqua).

<sup>20</sup>This value is computed as follows. The initial value of the voucher was 30% higher than expenditure per student in public schools before the reform. Before 1981, private schools received on average 50% of public schools expenditure per-student (Hsieh and Urquiola, 2004). Therefore, the nominal value of the voucher increased by 160%.

First, as previously discussed, the formal definition of a Catholic school is restrictive; therefore, there may be some schools that are somewhat informally related to the Church.<sup>21</sup> Second, some non-Catholic voucher schools may have been established by former teachers of Catholic schools (or even priests/nuns that retired from their religious orders). A slight variation of this mechanism is non-Catholic voucher schools that establish religious practices, names and curricula in their schools to try to mimic Catholic schools in the same area. And, third, the propensity of parents to send their children to private schools may be affected by the presence of old Catholic schools (and, therefore, priests) in the same area. I do not have systematic evidence of these three channels, but I present evidence in the next two sections that (i) priests are correlated with the entry of non-Catholic schools, and (ii) priests do not affect the propensity to attend Catholic vis-à-vis non-Catholic voucher schools at the individual level.

In addition, there is a fundamental change in the incentive scheme related to the 1981 reform. Even if enrollment in Catholic schools were constant after the reform, the effect of priests on the behavior of public schools changes dramatically: from a system where public school funds did not depend at all on enrollment in private schools to a system where total funds are fixed and are allocated proportionally to enrollment. The actual degree of school choice should have changed dramatically during the reform period even if the enrollment in private schools were the same. This further motivates using the interaction of priests in 1950 and the establishment of the voucher system as an instrument for voucher school competition and expecting the effects of priests to be significantly bigger over the voucher period.<sup>22</sup>

Finally, the number of priests per person is historically determined and varies widely across Chilean dioceses, despite the majority of the population being Catholic.<sup>23</sup> While the average diocese has a ratio of about 0.15 priests per 1,000 people, the diocese with the highest ratio

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<sup>21</sup> Again, I have no systematic data to quantify this hypothesis, but two examples may help understanding the magnitude of this phenomenon. About 40% of enrollment in voucher schools related to the Jesuits (through *Red Educacional Ignaciana* and *Fe y Alegria Chile*) is not counted as enrollment in Catholic schools. Most of these schools were established after the reform. Similarly, enrollment in the (two big) Opus Dei voucher schools in Santiago is not counted as in Catholic schools because Opus Dei schools are not related to the local bishop.

<sup>22</sup> Bayer and McMillan (2005) present a theoretical discussion on why choice and competition are not synonyms and provide examples of situations in which the same degree of choice is associated with different degrees of competition under different institutional and technological regimes.

<sup>23</sup> In the Catholic Church, a diocese is an administrative territorial unit, composed of many parishes and governed by a bishop. Technically, each diocese is independent of the others and the bishop only responds to the Pope.

(0.23 priests per 1,000 people) has more priests per person than most Latin American countries; and, the diocese with the lowest ratio (0.06 priests per 1,000 people) is comparable to what is observed in a poor (and non-Catholic) country such as Kenya. The variation in the number of priests across Chilean dioceses has to do mainly with the fact that religious orders are more numerous in some areas than others.

Religious orders established themselves in a non-uniform way in different dioceses in the past. The allocation of orders to different dioceses was related mainly to the desire to bring priests to some Chilean areas beginning in the mid nineteenth to the mid twentieth centuries (Aliaga, 1989; Araneda, 1986; Barrios, 1992). Some areas ended up with more order priests because the bishops of some dioceses either belonged to orders themselves or were more open to receiving order priests. While 71% of the order priests in Chile in 2002 belonged to orders that entered the country between 1810 (the year of independence) and the 1950s, only 5% of these priests belonged to orders that entered the country after the 1950s.<sup>24</sup> In general, there are more order priests than non-order priests, conditional on the establishment of order in a place. Therefore, dioceses where religious orders work tend to have more priests. The historical roots of the presence of orders in different areas creates a positive correlation between the number of priests today and in the past: the correlation between the number of priests per capita during the 1990s and the 1950s is 0.78.

Table 2 illustrates the importance of orders in explaining the cross-diocese variation in (the log of) priests per capita in 1950. I use the ratio of order priests to the total number of priests as a proxy for the presence of orders in different dioceses. Results in columns 3 and 4 support the claim that the variation of priests per capita is related to the presence of orders in different dioceses.

I use priests per capita in 1950 as the main instrument for voucher school entry in different areas during the voucher period, and the ratio of order-to-total priests as an alternative instrument in some regressions. The next section empirically studies the validity of this identification strategy.

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<sup>24</sup>These numbers were computed using information from the 2002 directory of the Catholic Church in Chile.



## 2.6 Reduced Form Estimates: Difference-in-Difference Analysis and Robustness Checks

To validate the identification strategy discussed in the previous section, I need to show that priests are not related to educational outcomes before the voucher reform and are related to educational outcomes after the reform. Table 3 presents the basic evidence supporting this identification strategy. In particular, I focus on three different cohorts. People older than 37 in 2000 (the year the CASEN survey was collected) attended school before the reform was implemented; people between 26 and 37 years attended school between 11 years and one year after the reform was implemented; and those less than 26 received their complete K-12 education after the reform was implemented. Because I do not have data on test scores before the reform, I use high school graduation as a proxy for school quality.

The results in Table 3 suggest that the number of priests has no relationship to high school graduation rates for people attending school before 1981 (column 1). For the second group (i.e. those receiving only a share of their primary and secondary education after 1981), the effect of priests is slightly bigger but still not significant. Finally, for those receiving their entire education after 1981, priests have a positive and marginally significant effect on educational outcomes. Overall, this evidence supports the idea that priests are correlated with educational outcomes only for the cohorts that attended school after the 1981 reform.

Figure 1 presents a more detailed exercise to evaluate the differentiated effects of priests on educational outcomes for cohorts that have different degrees of exposure to the 1981 reform. This figure plots the relation between high school graduation and priests in the decade closer to school attendance for individuals of different ages in 2000. This exercise also allows me to study whether the effect of the reform varies for individuals of different ages. The results suggest that priests are only correlated with the level of education for cohorts that attended school after the reform was implemented. As importantly, the effect of priests on high school attainment is increasing in the number of years that people attended school after the reform.

Overall, these results demonstrate the claim that priests only are correlated with educational outcomes after the 1981 reform, and they confirm the rationale presented in Section 2.5. Having established this central result, I present a number of additional exercises to validate

my identification strategy. Columns (1) and (2) in Table 4 presents estimates of the relationship between priests per capita and the ratio of order-to-total priests in 1950 and the ratio of voucher-to-public schools in each market in the voucher period. Priests and the ratio of order-to-total priests both have a positive and significant effect on the number of voucher schools per public school. The effect of Catholic affiliation is also positive and significant, as expected.<sup>25</sup> Column (3) presents the same regression but using voucher school enrollment as the measure of voucher school entry (as in all the other papers in the literature). Again, priests have a positive and significant effect on voucher school enrollment.

Column (4) presents estimates of the effect of priests on the *change* in public school enrollment from the pre-reform period. I was able to compute public enrollment rate for 52 geographical areas for 1975 from MINEDUC (1975)—the geographical classification corresponds to the split between urban and rural of 26 provinces covering the complete Chilean territory. I define the change in enrollment in public schools as enrollment today minus enrollment in 1975 in the area where the school is located. Results imply that public school enrollment decreased more in areas with more priests, confirming my argument in Section 2.5. The last three columns study the correlation between priests and Catholic and non-Catholic voucher schools. The results imply that priests are correlated with both the entry of Catholic and non-Catholic voucher schools. Moreover, the ratio of Catholic to non-Catholic schools does not seem to be affected by priests. Thus, these results confirm my argument of the potential effects of priests on the entry of non-Catholic voucher schools.

I present additional evidence of the differential effect of priests after and before the voucher reform in Table 5. This table studies the effect of priests on the attendance to voucher schools for members of cohorts that attended school after and before the voucher reform. Data come from the 2002 Social Protection Survey. I study whether priests have a different effect on the likelihood of attending a voucher school before and after the reform, controlling for a dummy for urban areas, and region and age dummies. Results both coming from linear probability and probit models suggest that priests are more related with the decision to attend a voucher school after the reform, as expected. Results for the effect of priests on private school attendance before

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<sup>25</sup>Results for other variables included in these regressions are similar to other papers in the literature: mean (standard deviation of) education and income have positive (negative) effects on the availability of voucher schools, and more populated areas have more voucher schools.

1981 are inconclusive: the linear probability model suggests a positive and significant effect, but the probit model suggests an insignificant effect. Overall, evidence in this table confirms the hypothesis that priests are more important to explain voucher school attendance over the voucher period.

One potential concern for my identification strategy is that priests may have affected education outcomes after the reform through other channels than voucher-school competition. In this context, I study whether immigration decisions of families with school-age children are correlated with the presence of priests in different areas. If in-migration rates of families with children are higher in areas with more priests, then an alternative explanation may be sorting of families based on taste/motivation for education. I do not expect this channel to be important, given the available evidence showing that migration in Chile is low because of public housing policies (Soto and Torche, 2004; Tironi, 2003). The results in Table 6 confirm this presumption and show that both micro estimates of in-migration decisions of families with children and macro estimates of immigration rates at the region level do not support the view that in-migration rates are higher in areas with more priests.

Overall, I document that the number of priests per person is historically determined; prior to 1981, it has little effect on educational outcomes. I also show that Catholic priests affected educational outcomes after the voucher system was established and are correlated with several proxies of the levels of and changes in voucher school entry. These results suggest that I have a potentially valid source of exogenous variation in the supply of voucher schools in different areas during the voucher period. Using these results, the next section estimates the level effects of voucher-school competition on student test scores in a cross-section of students in 2002.

## **2.7 Estimating Level Effects**

In this section, I present the results of regressions using information on test scores from a cross-section of students in the voucher period. This approach has several advantages over the reduced form estimates I presented before. First, I have detailed information on the degree of voucher-school competition in the educational market where the student attends school. Second, I have a more direct measure of school outcomes (test scores) than in the previous

exercises (high school graduation), which allows me to estimate more precisely the effect of voucher-school competition on test scores. Third, I am able to study whether the interaction effects predicted by the model are supported by the data. Since the results in Section 2.6 suggest that priests only affect educational outcomes after the reform, the number of priests per capita prior to 1981 is a valid instrument for voucher-school competition during the reform (as well as for the interaction of priests with the reform). Thus, I estimate the impact of voucher-school competition on student test scores by running a regression of the form:

$$q_{im} = \pi R_m + X'_{im}\alpha + M'_m\beta + Y'_m\rho + \varepsilon_{im}. \quad (2.4)$$

Subscript  $i$  refers to students and  $m$  to educational markets.  $q$  is test scores,  $R$  is the ratio of voucher to public schools in market  $m$ ,  $X$  is a vector including pre-school characteristics of students (mother's education and log of income per household member),  $M$  is a vector including the mean and standard deviation of mother's education and income at the market level,  $Y$  is a vector including exogenous variables (Catholic population, total school age population, urbanization rate, and region dummies), and  $\varepsilon$  is a student-specific error term.<sup>26</sup>

Following the model presented in Section 2.3, I use the ratio of voucher-to-public schools as my measure of voucher-school competition— $R_m$  in equation (2.4)—at the market level. When I compute the number of voucher schools per public school at the market level, I obtain the average availability of voucher schools per public school in each neighborhood (assuming that one public school exists in each neighborhood, which is reasonable in the case of Chile).

I estimate equation (2.4) using the log of Catholic priests per person in 1950, or the ratio of order-to-total priests (only in some regressions to save space), as my instrument for  $R_m$ . In addition, as discussed in Section 2.5, the ratio of order-to-total priests corresponds to a more basic source of variation in the number of priests in different areas in Chile. Thus, I also present IV estimates using the ratio of order-to-total priests as an alternative instrument (in one specification I use both variables as instruments for voucher-school competition). I use variables measured in 1950, which corresponds to the end of the period of entry of Catholic

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<sup>26</sup>Since I include multiple observations of variables in the same area, I use the White/Huber estimator of the variance-covariance matrix to compute corrected standard errors that are robust to arbitrary heteroskedasticity and clustered standard errors.

orders into Chile.

### 2.7.1 Test Score Regressions

I first estimate equation (2.4) using the complete sample of students attending public and voucher schools in the 2002 SIMCE dataset. Table 7 presents OLS estimates (columns 1-2) and IV estimates of equation (2.4) using log of priests in 1950 (columns 3-4) and the ratio of order-to-total priests (columns 5-6) as my instruments for  $R_m$ . In each case, I present first a parsimonious representation of the regression without including controls and only including my measure of voucher-school competition. Next, I include market- and student-level controls. The IV estimates are larger than the OLS estimates as suggested by my model, because school entry may be endogenous to quality. While the OLS estimates are -0.02 and 0.04, the IV estimates are in the interval between 0.13 and 0.17.<sup>27</sup> The IV point estimates are always positive and significant. These results imply that the effects of voucher-school competition on test scores are also economically relevant. An increase of one voucher school per public school in a market is associated with an increase in test scores of between 0.13 and 0.17 standard deviations. This is equivalent to about half of the effect of increasing mother's attainment from primary to secondary general education.

Estimates for other variables included in the regression have the expected signs. All socioeconomic controls are significant and have the expected sign: students with more educated mothers tend to perform significantly better, and students from households with higher incomes have higher test scores. The only two market-level variables with a statistically significant effect are mean per capita income (a positive effect) and the school-age population of the market (negative effect). The effect of the share of Catholics is negative, but it is not precisely estimated.

Next, column (7) in Table 7 presents estimates using *both* priests and the ratio of order-to-total priests as instruments. As expected, the estimated effect falls between the estimates in columns (4) and (6). More importantly, an over-identification test of this specification does not reject the null hypothesis that the instruments are valid. Formally, the result of the over-identification test implies that IV estimates using each of the two instruments separately are

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<sup>27</sup>Measurement error in voucher-school competition may also explain why my OLS estimates are smaller than my IV estimates.

not statistically different among them.

These estimates of the effect of voucher school competition on test scores are in the range of the estimated results of previous studies for Chile. My estimates imply that a one-standard deviation increase in voucher school competition increases test scores by about 0.10 standard deviations. Auguste and Valenzuela (2003) find an effect of the same size at the student level, Contreras and Macias (2002) report an effect of a one-standard deviation increase in the Herfindahl index in the interval of 0.08 and 0.17 standard deviations of test scores, and Gallego (2002) presents estimates that imply an increase of between 0.03 and 0.18 standard deviations of the test scores when his measure of competition increases by one-standard deviation. In contrast, my estimates are slightly smaller than the effects of inter-school competition reported in papers for the US. Bayer and McMillan (2005) and Hoxby (2000) report that a one-standard deviation increase in their proxies for the degree of inter-school competition increases test scores by about 0.15 standard deviations.

The estimates on the effect of voucher-school competition on test scores also are consistent with my reduced-form estimates of the effects of priests on high school graduation rates reported in Section 2.6. My reduced-form estimates in the previous section imply that a one-standard deviation increase in the (log of the) number of priests (roughly equivalent to 43 log points) increases high school graduation by about 11 percentage points for people attending school after the reform (computed using results from Figure 1). In turn, a similar increase in the number of priests increases the ratio of voucher-to-public schools by about 0.22 (Table 4), which increases test scores by between 0.031 and 0.037 standard deviations. To relate both results, I use the estimates of Hanushek and Kimko (2000), who find that a one-year increase in schooling is associated with an increase in about 0.042 standard deviations in test scores. In my sample, a person who graduated from high school has about six years more of education than the rest of the population. Putting everything together, I expect the impact of the increase in high school graduation to be consistent with an increase in test scores of 0.03 standard deviations ( $0.11 \times 0.042 \times 6 \approx 0.028$ ). Therefore, reduced-formed estimates of the impact of priests on high school graduation and cross-section estimates of the effects of voucher school competition on test scores are consistent.

Table 7 presents additional specifications in which I replace my measure of voucher-school

competition by three alternative measures: the share of enrollment in voucher schools (Auguste and Valenzuela, 2003; Gallego, 2002; Hsieh and Urquiola, 2004), the Herfindahl index (Contreras and Macias, 2002), and the change in enrollment in public schools between the pre-reform (1975) and post-reform periods (2002). Results in the last three columns of Table 7 imply a positive effect of the three alternative measures of voucher school competition on test scores. The size of the effects of a one-standard deviation increase of competition on test scores varies across specifications: while the implicit estimates in columns (7) and (9) imply an increase of test scores of about 0.15 standard deviations, estimates in column (8) imply a probably unreasonable increase of test scores of 0.48 standard deviations.

I study several specifications checks in Table 8. First, I study one potential concern with the results in Table 7: some variables, such as income and mother's education, may be affected by my instruments if parents attended school after the reform. If mother's education and income do not involve measurement error, then my earlier estimates can be interpreted as the direct effects of voucher-competition on student outcomes. However, if mother's education and income are subject to measurement error, then the estimates of voucher-school competition may be biased upward.<sup>28</sup> To deal with this potential problem, Column (1) presents the results excluding students with parents who attended school after the reform (i.e. parents older than 39 years). The results are very similar to those shown in Table 7, suggesting that my previous estimates do capture the direct effect of voucher-school competition on test scores, controlling for mother's education and income.

Next, column (2) presents the results of excluding schools located in rural areas. The implicit assumption in the model in Section 2.3 applies for students that have low physical transportation costs of moving from one school to another. I expect the effects of competition to be significantly smaller if students cannot move easily from one school to another, as expected in rural areas. Results in Column (2) confirm this idea: the point estimate of inter-school competition increases when excluding rural schools. The next two columns deal with the potential effect on the results of the Santiago Metropolitan Area. Santiago is at the same time the biggest market (includes about 28% of the students in my sample) and one of the markets with the highest ratio of

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<sup>28</sup> More precisely, mother's education and income may not capture all the effects of mother's human capital on children's educational outcomes.

voucher to public schools (2.41 voucher schools per public school). To deal with the size effect without losing information on a market that has a high degree of choice, I report in columns (2) and (3) the results of running 50 regressions excluding randomly 90% and 50% of the Santiago students. The point estimates are smaller but positive, statistically significant, and within the confidence interval of the estimates for the complete sample.

Next, Columns (5) to (7) present the results of an additional exercise: I include controls for systematic differences in pre-reform educational outcomes in equation (2.4). I use three proxies for pre-reform outcomes: (i) high school graduation rate in public schools for cohorts that attended school before 1980 from the Social Protection Survey (column 5), (ii) high school graduation rate at the municipality level for cohorts that attended school before 1980 from the CASEN survey (column 6), and (iii) average 1991 SIMCE test scores at the municipality level (column 7), (indeed, this test score was applied 10 years after the reform was implemented, but at the same time (i) 1991 corresponds to the first year for which I have complete information for all the schools after the decentralization of the management of public schools was completed and (ii) as previously discussed, it is hard to argue that a real voucher system was in operation until at least the mid 1990s). Even though my results in Section 3.1 suggest that my instruments are not correlated with pre-reform differences in academic outcomes, these results provide an additional check. The results show that my main estimates of the effect of the ratio of voucher-to-public schools change slightly in value, but remain statistically significant. The point estimates for the effect of voucher school competition decrease slightly in columns (6) and (7), and increase slightly in column (5).

Next, column (8) of Table 8 introduces controls for the composition of students at the school level: mean and standard deviation of mother's education and per-capita income. I follow Hoxby (2000) in including these variables without giving a formal interpretation to the estimates I find, and, therefore, I only focus on the effect of including these variables on the estimate of voucher-school competition on test scores. Results imply that the point estimate of the effect of voucher school competition is basically unchanged with respect to most other estimates I present in Tables 7 and 8. Unfortunately, I do not have additional valid instruments to study the causal effects of peer-effects on test scores, but results in this column are at least suggestive that peer-effects are not driving my main results.



I take an alternative way of analyzing whether peer-effects are driving my results in the last two columns of Table 8, where I present estimates for sub-samples of students in public and voucher schools. These sub-samples allow me to analyze whether the estimated effect of voucher-school competition on student outcomes in public schools is different than for voucher schools. These exercises have interest from two perspectives: (i) I am able to study empirically the predictions of Corollary 2 and (ii) I am able to test the conjecture of some papers that voucher-school competition may increase average test scores but students attending public schools may be harmed if voucher schools are able to cream-skim. Indeed, I cannot disentangle the contributions of both perspectives without an additional source of exogenous variation.

Since I estimate (2.4) for sub-samples of students, I implement a Heckman selection model with endogenous variables (Wooldridge, 2002). This procedure allows me to control for potential selection bias if the students included in these regressions are not randomly selected from the population. To implement this procedure, I need to find a variable that affects the selection of students in different schools and has no direct effect on test scores. My instrument in the selection equation is a dummy that takes a value of one if the teaching of values was among the top three criteria used by parents for choosing schools. Since the mention of "teaching of values" (i.e., *la enseñanza de valores* in Spanish) has a religious connotation in Chile, this variable may capture relative preferences for voucher vis-a-vis public schools, or Catholic vis-a-vis non-Catholic voucher schools.<sup>29</sup> In terms of my model, the values variable is a proxy for the location of parents in the linear city.

In the initial stage of the estimation, I run a selection equation of the following form, using probit:

$$p_{im} = \mathbf{1} \left( \varphi S_{im} + \zeta Z_m + X'_{im} \xi + M'_m \varkappa + Y'_m \tau + \mu_{im} > 0 \right), \quad (2.5)$$

where  $p_{im}$  takes a value of 1 if an observation is included in the regression of interest,  $S_{im}$  is some variable that affects  $p_{im}$  and is not included in equation (2.4),  $Z_m$  is an instrument for  $R_m$  (i.e., priests per capita), and  $\mu_{im} \sim N(0, 1)$ . Notice that in this equation I include all the right-hand side variables included in the first stage of (2.4). Next, for the selected subsample

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<sup>29</sup>Other papers have found that parents' preferences for the teaching of values affect the choice of private versus public schools in the US (Sander, 2001). In a related result, Howell (2004) finds that religious identity affect the participation in a voucher program in New York.

(i.e., for observations with  $p_{im} = 1$ ), I estimate the equation:

$$q_{im} = \pi R_m + X'_{im}\alpha + M'_m\beta + Y'_m\rho + \psi\hat{\lambda}_{im} + \varepsilon_{im}$$

by 2SLS, excluding  $S_{im}$  from the second stage regression.  $\hat{\lambda}_{im}$  is the estimated inverse Mill's ratio for each observation.

Table 9 presents probit estimates of the marginal effects of the variables included in equation (2.5) on the choice between attending a public versus a voucher school and the choice between a non-Catholic versus a Catholic voucher school. The results indicate that the values variable is significantly correlated with the decision to send the student to a non-Catholic school. Marginal effects imply that if parents care about the teaching of values, they are 36% less likely to send their children to a public school versus a voucher school, and are 28% less likely to send their children to a non-Catholic voucher school vis-a-vis a Catholic voucher school.

Estimates for other variables included in equation (2.5) confirm previous results in the literature on the socioeconomic determinants of attending a public school (e.g. Sapelli and Vial, 2002 and 2003 for Chile; Checchi and Jappelli, 2004 for Italy): mother's education and family income have a negative and significant impact on the probability of attending a public school. Other estimates in column (1) suggest that market characteristics are also important: the probability of attending a public school drops in urban and more populated areas, in poorer areas, and in areas where Catholic affiliation increases. Results for the probability of attending a non-Catholic versus a Catholic voucher school indicate that education and income play a similar role to the choice between a public and a voucher school, although the estimated effects are smaller and less significant. Similarly, the probability of attending a non-Catholic voucher school decreases in areas with a larger Catholic population and increases in more populated markets. Interestingly, as previously discussed, priests do not have a significant effect on the probability of attending a non-Catholic vis-a-vis a Catholic school.

Using these probit models, I include the inverse of the Mills ratio in the second stage regression (columns (9) and (10) in Table 8). From these regressions, I obtain estimates that allow me to evaluate whether the effect of an additional voucher school is greater on public schools or existing voucher schools. The results show that the effect of an additional voucher

school is quantitatively similar for public and voucher schools.

The results in the last two columns of Table 8 confirm the prediction of Corollary 2 in my model: public schools may react similarly to the entry of an additional voucher school if most public schools face competition from at most one voucher school as the data for Chile confirm and the difference between the minimum quality offered by public schools and the minimum quality offered by voucher schools is sufficiently high. As previously discussed, an alternative interpretation of these results is that either voucher schools do not tend to cream-skim, peer-effects do not have a causal impact on test scores, *or* the incentive effects created by the voucher system on public school students dominate any cream-skimming effect.

Finally, I present quantile regression estimates of voucher-school competition for students in different positions of the distribution (Figure 2). Results suggest that the estimated effects do not vary a lot across quantiles, but are slightly smaller for the students in the 1st and 10th quantile than for the other students. Therefore, these results also suggest that the effect of voucher-school competition on test scores does not vary significantly accordingly to the students characteristics.

Overall, the evidence presented in this section presents a consistent pattern of positive effects of voucher-school competition on test scores for the average student and for students attending public and voucher schools, as predicted by the model. In the next subsection, I study the effects of voucher-school competition on expenditures, productivity, and student composition at the school level.

### **2.7.2 Expenditures, Productivity, and Student Composition**

This subsection studies the role that expenditures in education play in my previous results. I present results for the effects of voucher school competition on private, public, municipal (i.e. not related to the voucher or other central government programs), and total expenditure per capita in columns (1) to (4) of Table 10. The main motivation for these exercises is to study whether competition increases test scores by increasing expenditure in education. Results imply positive and significant effects on municipal, total public, and total expenditures per student. Only the implicit elasticity of the increase in municipal transfers is economically relevant (1.04); in all the other cases the implicit elasticities are smaller than 0.20. This result is interesting

because it suggests that local governments are able to increase expenditure in education, as competitive pressures increase. This has the positive effect that the increase in expenditure may reflect a greater effort to increase quality as a response to political pressures, but, at the same time, as suggested in my theoretical discussion, non-voucher transfers may dampen the incentive effect on test scores created by competition. I study the latter in the next section using a potentially valid source of exogenous variation of non-voucher transfers to local governments.

Next, column (5) in Table 10 studies how competition affects the copayment level in voucher schools. In the model I assume that there are no prices because copayments represent on average less than one third of public expenditure in education. In this sense, the model can be interpreted in terms of the effort that agents exert. However, in a more general model, voucher schools subject to competition may decrease prices. This is exactly what results in column (5) show: an increase in competition decreases copayment charged. Interestingly, the implicit elasticity is also economically significant: a one-percent increase in competition decreases copayments by 0.3%.

Overall, results in column (3) imply that an increase in competition increases total expenditure per-capita. However, the increase is relatively small: a one-standard deviation increase in competition increases total expenditure per-capita by about 9%. Given these results, in columns (6) and (7) I study the effects of competition on the *productivity* of education expenditure. I define two proxies for productivity: the (normalized) ratio of test scores to total expenditure per student and the log of total expenditure per student, respectively. These are rough measures of productivity—i.e. test scores per unit of expenditure—that can be interpreted as proxies for agents effort, their key choice variable in my theoretical model. Results suggest that the effects of voucher-school competition on both measures of productivity are positive and significant. An increase of one-standard deviation of voucher school competition increases the productivity indexes by between 0.20 and 0.23 standard deviations . These results imply that voucher-school competition increases the productivity of schools, as emphasized in the theoretical model of this paper.

The last three columns of Table 10 study how competition affects the composition of students within schools. Again, this is not present in my theoretical model, but extensions where parents and/or school agents value homogeneity in their schools may predict that increases in

competition decrease the dispersion of student characteristics within schools.<sup>30</sup> I study this idea using an index of the distance of each student to the average student in her school. I use two measures of socioeconomic characteristics (mother's education and per-capita income) and test scores as measures of student characteristics. My results are not conclusive about the effect of competition on test scores, but imply a negative and significant effect of competition on the heterogeneity of mother's education within schools, a negative but insignificant effect on heterogeneity of income within schools, and a positive and marginally significant effect on the heterogeneity of test scores within schools.

## 2.8 Estimating Interaction Effects

In this section, I expand the previous analysis by studying the implication of my model that there should be interaction effects: public school response to exogenous changes in voucher school competition depends on how binding the minimum enrollment is. Corollary 3 predicts that the effect of voucher school entry on test scores is smaller for schools that have low minimum enrollment levels (which in the model corresponds to receiving big non-voucher transfers). If this is the case, public schools can meet the minimum enrollment constraint more easily. This result illustrates the theoretical mechanism at work in the model, which is related to the implicit incentives that the minimum enrollment constraint presents for public school agents. In this section, I test this prediction against the data using proxies for (i) the size of the education deficit as a percentage of education revenues (a proxy for non-voucher transfers) and (ii) the average size of public schools in different municipalities. I interpret these characteristics as the degree of softness of the public school budget constraints.<sup>31</sup> Using these proxies, I study whether differences in these variables affect the response of public schools to voucher-school competition. To do so, I split the sample of public schools into those located in municipalities that have

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<sup>30</sup>Results in Gallego and Hernando (2006) support this prediction: in equilibrium students in Santiago tend to attend schools with similar peers in terms of mother's education, income, gender, and preferences for the teaching of values. Work in progress is trying to disentangle the effects of supply and demand factors to explain this equilibrium allocation of students.

<sup>31</sup>In general, non-voucher transfers are not allocated to local government in a transparent way. Serrano and Berner (2002) document the transfer process for the case of local government education debts related to teacher pensions. As the authors document, it is not easy to follow the actual decision process in part because central government authorities did not want to establish precedents to be used by other mayors.

education deficits above and below the median, and public schools located in municipalities that have average school sizes above and below the median of the distribution. I expect the effect of voucher-school competition to be larger in the samples in which education deficits are relatively low and average school sizes are relatively big.

I use a short-lived change in the Chilean electoral law that allows me to identify the short-run variation in deficits and average school size and, therefore, to control for potential selection bias in my estimates. The electoral law operating between 1999 and 2003 establishes that a mayor (who manages the public schools) is the elected member of the municipal council who receives the most votes (conditional on getting at least 20% of the votes). This source of variation is useful for my identification strategy because, as previously discussed, municipalities receive discretionary transfers from the central government and pro-government mayors are able to raise more of these funds.

I implement a difference-in-difference regression to study the effects of the 1999 electoral law on my two proxies for the degree of bindingness of the minimum enrollment level in the context of a selection model of the form:

$$P_m = \mathbf{1} \left( \varphi V_m K_m + \varpi V_m + \phi K_m + \zeta Z_m + M'_m \varkappa + Y'_m \tau + \mu_m > 0 \right), \quad (2.6)$$

where  $P_m$  is an indicator function that takes a value of one if the municipality has an education deficit above the median or an average public school size below the median;  $V_m$  is the share of votes that goes to the pro-government coalition; and  $K_m$  is a dummy that takes a value of one if the mayor belongs to the pro-government coalition. I exclude the interaction of  $V_m$  and  $K_m$  from (2.4) and include each variable separately, as well as the estimated inverse of the Mills-ratio in (2.4). Table 11 presents my marginal probit estimates of equation (2.6). The results indicate that the interaction variable has a positive and significant effect: the probability that a municipality has an education deficit above the median increases by 50% and average school size below the median increases by about 40% if the mayor belongs to the pro-government coalition, given the vote obtained by the pro-government coalition.

Table 12 presents estimated interaction effects. I present estimates including selection correction in the top panel and without including selection correction in the bottom panel. Results

in both cases are qualitatively similar. The results for the subsample of students attending public schools that have high education deficits and low average school sizes suggest that the schools tend to respond by less than the other schools (and only in one case is the reaction positive and statistically significant). Overall, these results show that proxies for the bindingness of the minimum enrollment level affect the degree of response of public schools to voucher-school competition, as predicted by my model and support the existence of heterogeneous effects of voucher school competition on public schools. These results are hard to reconcile with alternative explanations for the positive effects of voucher school competition.

## 2.9 Concluding Comments

The potential effects of school vouchers and inter-school competition on student outcomes has been a much debated topic in the US and elsewhere. My study of the Chilean voucher system, which has operated for more than 20 years in the complete K-12 system, can help us to understand the effects of vouchers on educational outcomes. Previous research has been stymied by endogeneity problems. I argue that the interaction of the variation in the number of priests per person across Chilean areas in 1950, and the institution of the voucher system in 1981, allows me to identify the effects of voucher-school competition on test scores. I document that the number of Catholic priests *is not* correlated with educational outcomes in the pre-voucher period and *is* correlated with educational outcomes in the post-1981 period. This result allows me to use the number of priests per person in 1950 as an instrument for voucher-school entry during the voucher period.

I find that once I instrument for the ratio of voucher-to-public schools in an area, one additional voucher school per public school increases test scores by about 0.14 standard deviations. The magnitude of this effect on test scores is equivalent to about half of the effect of increasing a mother's attainment from primary to secondary education. These results are roughly similar for students attending public schools and students attending non-Catholic voucher schools.

My estimates of the effects of school competition on test scores are smaller for students attending public schools that face less binding minimum enrollment, measured using two alternative proxies. While agents operating voucher schools receive higher payoffs if they increase

enrollment, agents operating public schools receive fixed wages and only have to meet a minimum enrollment constraint. Therefore, agents operating in areas where the minimum enrollment constraint is less binding react less to voucher-school competition, as predicted by the theoretical model presented in the paper. Overall, the evidence is consistent with a theoretical rationale that emphasizes the role of incentives provided by voucher-school competition.

My results do not imply that selection or segregation are not relevant issues in the Chilean case. Rather, controlling for characteristics of students and markets, there are sizeable direct effects of competition on test scores. More than 20% of educational markets in Chile have no voucher school in operation. Similarly, there are heterogeneous effects of voucher school competition for public school students, depending on how binding minimum enrollment constraints are. Thus, the introduction of the voucher system does increase educational inequality in Chile. The paradox, though, is that the Chilean system does not become more unequal because of the existence of voucher schools, but rather because of the absence of voucher schools in some areas, and the absence of strong incentives for some public school agents. The government could correct this inequality while preserving school choice by using the right incentives, such as letting per-student subsidies depend upon student characteristics, as proposed by Gonzalez et al. (2002), Hoxby (2001), and Sapelli (2003), or by creating explicit incentives that relate the welfare of public school agents to student outcomes.

## 2.10 Appendix: Proofs

### 2.10.1 Result 1

First, notice that if  $N = 0$ ,  $n_P = \bar{L}$ .

Second, I analyze the case when  $N = 0$ . Define  $\bar{x}$  as the location of parents that are indifferent toward both types of schools. These parents determine the share of the market going to each school.  $\bar{x}$  is given by:

$$\bar{x} = \frac{q_P - q_V + t}{2t} = \frac{q_P - q_V}{2t} + \frac{1}{2}.$$

This expression implies that the number of students attending public and voucher schools are



$\bar{x}\bar{L}$  and  $(1 - \bar{x})\bar{L}$ , respectively. Therefore,

$$n_P = \bar{L} \frac{q_P - q_V}{2t} + \frac{\bar{L}}{2}, \text{ and}$$

$$n_V = \bar{L} \frac{q_V - q_P}{2t} + \frac{\bar{L}}{2}.$$

Regarding the distribution of students among voucher schools. If  $N = 1$  obviously the enrollment of the only market school in the market is  $n_V$ . If  $N \geq 1$ , since parents randomize among all schools that offer the same quality, the probability that each of them is selected is  $\frac{1}{N}$ , which implies that:

$$n_{Vi} = \frac{n_V}{N} \quad \text{if } N \geq 1.$$

### 2.10.2 Result 2

Since quality is costly and that the only incentive to increase quality above the minimum level is to meet the minimum enrollment constraint, always one of the two constraints will bind in equilibrium. The simplest case is when  $N = 0$ , then optimal public school quality is  $q_P^M$ .

If  $N > 0$  and the minimum quality constraint binds (i.e. Condition 1 does not hold),  $q_P = q_P^M$ . This will be the case if:

$$\left(\frac{\bar{n}}{\bar{L}} - \frac{1}{2}\right) < \frac{q_P^M - q_V}{2t}. \quad (2.7)$$

In this case, the number of students attending public schools is:

$$n_P = \bar{L} \frac{q_P^M - q_V}{2t} + \frac{\bar{L}}{2}.$$

If Condition 1 holds, then the minimum enrollment constraint binds and, therefore,  $n_P = \bar{n}$ .

Given Result 1, optimal public school quality is:

$$q_P = 2t \left(\frac{\bar{n}}{\bar{L}} - \frac{1}{2}\right) + q_V.$$

### 2.10.3 Result 3

Voucher schools enter the market if:

$$\left[ (v - c^V(q_V)) \frac{n_V}{N} - F \right] \geq 0.$$

$N^* = 0$  if

$$(v - c^V(q_V^M)) n_V < F.$$

because in this case, even producing the lowest possible level produces negative profits.

Using a similar argument,  $N^* = 1$  when:

$$\begin{aligned} (v - c^V(q_V^M)) n_V &\geq F, \text{ and} \\ (v - c^V(q_V^M)) \frac{n_V}{2} &< F. \end{aligned}$$

Analogously,  $N^* = 2$  when:

$$\begin{aligned} (v - c^V(q_V^M)) \frac{n_V}{2} &\geq F, \text{ and} \\ (v - c^V(q_V^M)) \frac{n_V}{3} &< F. \end{aligned}$$

Generalizing this argument,  $N^*$  has to satisfy:

$$\begin{aligned} (v - c^V(q_V^M)) \frac{n_V}{N} &\geq F, \text{ and} \\ (v - c^V(q_V^M)) \frac{n_V}{N+1} &< F. \end{aligned}$$

Rearranging terms:

$$(v - c^V(q_V^M)) \frac{n_V}{N+1} < F \leq (v - c^V(q_V^M)) \frac{n_V}{N}.$$

### 2.10.4 Result 5

If Condition 1 holds,  $N = 1$ , and  $N^P = 1$ , voucher schools face no competition from other voucher schools and public schools will respond to their choices in order to meet the minimum enrollment constraint. Therefore, voucher schools face a constant demand  $n_V = (\bar{L} - \bar{n})$ , for any level of quality they offer. Then, profit maximization implies that voucher schools offer:

$$q_V = q_V^M.$$

If  $N = 1$ , but  $N^P = 2$ , and Condition 1 holds, the incumbent voucher has to offer a quality level such that the potential entrant is indifferent, i.e., profits have to be 0. Thus,

$$q_V = c^{V-1} \left( v - \frac{NF}{\bar{L} - \bar{n}} \right).$$

If Condition 1 does not hold, and  $N = 1$ ,  $N^P = 1$ , the only difference with the previous case is that enrollment in the voucher school is not constant. Moreover, Result 1 implies that voucher school enrollment is increasing in voucher school quality (notice that the public school produces  $q_P^M$ ). Therefore, the optimization of the voucher school is:

$$\text{Max}_{q_V} \left[ (v - c^V(q_V)) \bar{L} \left( \frac{q_V - q_P^M}{2t} + \frac{1}{2} \right) - F \right],$$

the first order condition of this problem is (assuming an interior solution):

$$c^{V'}(q_V) n_V - \frac{c^V(q_V) \bar{L}}{2t} = 0 \Leftrightarrow \frac{c^V(q_V)}{c^{V'}(q_V)} = 2t \frac{n_V}{\bar{L}}.$$

Finally, If Condition 1 does not hold, and  $N \geq 1$ , and  $N^P \geq 2$ , competition between voucher schools imply that profits of incumbents go to 0, and, therefore:

$$q_V = c^{V-1} \left( v - \frac{NF}{n_V} \right).$$

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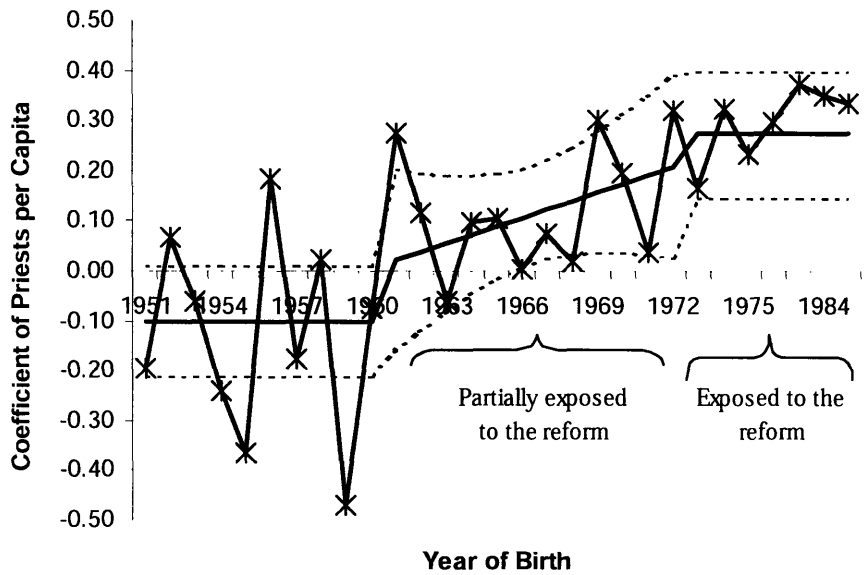
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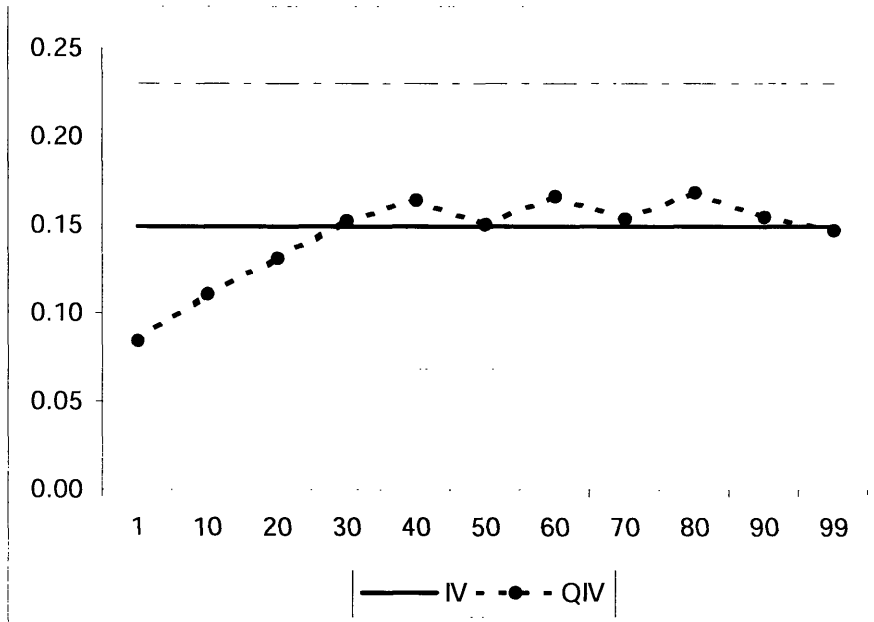
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**Figure 1:**  
**Estimated relationship of priests with high-school graduation rate, by age.**



**Figure 2:**  
**Quantile-IV and IV regression estimates of the effect of voucher-school competition on test scores**



**Table 1: Descriptive Statistics**

Variable	Obs.	Mean	Median	Standard Deviation	5th percentile	95th percentile	Source
<b>Student-level variables</b>							
Test scores (standardized)	187610	-0.03	-0.03	0.97	-1.71	1.49	SIMCE
Mother's education							
Primary	187610	0.35	0.00	0.48	0.00	1.00	SIMCE
Secondary-General	187610	0.32	0.00	0.47	0.00	1.00	SIMCE
Secondary-Technical	187610	0.16	0.00	0.37	0.00	1.00	SIMCE
Higher-General	187610	0.08	0.00	0.27	0.00	1.00	SIMCE
Higher-Technical	187610	0.09	0.00	0.28	0.00	1.00	SIMCE
Average Years of Schooling	187610	9.84	11.00	3.31	5.00	15.00	SIMCE
Log(Per-Capita Income)	187610	10.27	10.31	0.90	8.87	11.83	SIMCE
Values among the three most important reasons for choosing a school	187610	0.28	0.00	0.45	0.00	1.00	SIMCE
Voucher school	187610	0.43	0.00	0.50	0.00	1.00	SIMCE
Catholic voucher school	187610	0.15	0.00	0.39	0.00	1.00	<a href="http://www.iglesia.cl/">http://www.iglesia.cl/</a>
Public expenditure per-capita	161563	27451	22128	12986	19219	52540	SIMCE, <a href="http://www.sinim.cl/">http://www.sinim.cl/</a> , MINEDUC
Private expenditure per-capita	180288	19309	12500	21548	2500	60000	SIMCE
Municipal transfers per-capita	96564	4115	1688	8332	0	12698	<a href="http://www.sinim.cl/">http://www.sinim.cl/</a>
Total expenditure per-capita	155197	46643	40971	22261	23465	87582	Author's calculations
Copayments	183035	5730	2500	10288	0	25000	SIMCE
Productivity index 1 (test scores divided by total expenditure)	155197	-0.04	0.03	0.99	-1.79	1.47	Author's calculations
Productivity index 2 (test scores divided by log total expenditure)	155197	0.02	0.08	1.00	-1.71	1.58	Author's calculations
<b>Individual-level variables</b>							
High school graduation dummy	75805	0.40	0.00	0.49	0.00	1.00	CASEN
Immigration dummy	8857	0.17	0.00	0.37	0.00	1.00	Social Protection Survey
<b>Market-level variables</b>							
Ratio of Voucher to Public Schools	298	0.47	0.25	0.70	0.00	1.6	Ministry of Education
Mean years of schooling	298	8.82	8.66	1.29	7.21	10.96	SIMCE
Standard Deviation of Years of schooling	298	3.45	3.47	0.47	2.70	12	SIMCE
Mean Log Income	298	10.02	9.94	0.37	9.55	10.71	SIMCE
Standard Deviation of Log Income	298	0.85	0.85	0.14	0.66	1.08	SIMCE
Log School-Age Population	298	8.38	8.36	1.28	6.32	10.7	<a href="http://www.sinim.cl/">http://www.sinim.cl/</a>
Urbanization Rate	298	0.34	0.25	0.28	0.00	0.93	Ministry of Education
High-School Graduation Rate							
37<age	304	0.28	0.26	0.14	0.08	0.56	CASEN
25<age<38	304	0.46	0.45	0.17	0.20	0.74	CASEN
age<26	304	0.52	0.53	0.16	0.24	0.79	CASEN
Pro-Government Mayor	331	0.51	0.00	0.50	0.00	1.00	Electoral Office
Pro-Government Vote	331	0.53	0.52	0.15	0.25	0.78	Electoral Office
<b>Diocese-level variables</b>							
Priests per 1000 people in 1950	26	0.32	0.31	0.13	0.15	0.54	Annuario Pontificio
Priests per 1000 people in 2000	26	0.15	0.14	0.04	0.08	0.21	Annuario Pontificio
Catholic Affiliation	26	0.78	0.79	0.08	0.68	0.90	Annuario Pontificio
Ratio of Religious to Total Priests	26	0.45	0.44	0.16	0.17	0.66	Annuario Pontificio
<b>Region x Urban/Rural variables</b>							
High-School Graduation Rate							
39<age	26	0.27	0.27	0.17	0.05	0.5	Social Protection Survey
27<age<40	26	0.47	0.59	0.22	0.17	0.71	Social Protection Survey
age<28	26	0.60	0.65	0.24	0.22	1	Social Protection Survey
High-School Graduation Rate in Public Schools							
39<age	26	0.26	0.27	0.16	0.08	0.5	Social Protection Survey
27<age<40	26	0.45	0.54	0.20	0.17	0.67	Social Protection Survey
age<28	26	0.55	0.62	0.26	0.00	1	Social Protection Survey
Voucher school attendance (% of total population)							
39<age	26	0.05	0.05	0.04	0.00	0.12	Social Protection Survey
27<age<40	26	0.08	0.07	0.06	0.00	0.23	Social Protection Survey
age<28	26	0.11	0.12	0.09	0.00	0.27	Social Protection Survey

Notes: Detailed definitions of each variable appear in the main text

Table 2  
 Determinants of Priests per Capita in 1950:  
 Religious Order Effects

Dependent Variable:	Log of Priests per 1,000 people in 1950			
	(1)	(2)	(3)	(4)
Log(income)	0.28 (0.27)		0.10 (0.26)	
Schooling		0.13 (0.09)		0.06 (0.09)
Ratio of order to total priests			1.25 (0.52)	1.19 (0.53)
R <sup>2</sup>	0.0462	0.0783	0.2415	0.2494
Number of dioceses	26	26	26	26

Cross section regressions, each observation represents the value for a dioceses.

Robust standard errors in parentheses. Constants are not reported

Table 3  
Municipal level regressions for  
educational outcomes *before* and *after*  
the reform

Dependent Variable:	High-School Graduation Rate		
Sample:	Age >37	37>=Age>=26	Age<26
	(1)	(2)	(3)
Log(Priests per 1000 people)	0.05 (0.13)	0.08 (0.14)	0.17 (0.10)
Catholic affiliation	0.02 (0.07)	0.10 (0.35)	0.01 (0.25)
Urbanization Rate	0.29 (0.03)	0.33 (0.04)	0.26 (0.03)
Log(population)	-0.02 0.05	0.01 (0.03)	0.04 (0.02)
R <sup>2</sup>	0.49	0.55	0.46
Number of markets	300	300	300

Cross section regressions, each observation represents a value a for a market. Standard errors clustered at the diocese level in parenthesis. Region dummies and constants are not reported.

Table 4  
Availability of Voucher Schools

Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Ratio of voucher to public schools	Share of enrollment in voucher schools	Change in Public School Enrollment (Post-Pre Reform)	Ratio of Catholic to public schools	Ratio of Non-catholic to public schools	Share of Non-Catholic Schools (among Voucher Schools)	
Mean of mother's schooling	0.22 (0.08)	0.21 (0.09)	0.04 (0.01)	-0.03 (0.01)	0.05 (0.02)	0.15 (0.07)	-0.03 (0.05)
Standard Deviation of mother's schooling	-0.16 (0.23)	-0.07 (0.33)	0.02 (0.04)	-0.09 (0.04)	-0.06 (0.04)	-0.17 (0.23)	0.09 (0.09)
Mean of Log Income	0.16 (0.13)	0.20 (0.11)	-0.02 (0.02)	0.00 (0.01)	0.00 (0.01)	0.17 (0.12)	0.02 (0.03)
Standard Deviation of Log Income	-1.20 (0.24)	-1.28 (0.55)	-0.11 (0.07)	0.07 (0.08)	-0.15 (0.09)	-1.27 (0.35)	-0.13 (0.14)
Log(Population)	0.22 (0.08)	0.21 (0.09)	0.05 (0.01)	-0.03 (0.01)	0.02 (0.02)	0.19 (0.07)	0.02 (0.02)
Urbanization Rate	0.38 (0.23)	0.30 (0.23)	0.17 (0.05)	-0.16 (0.06)	0.02 (0.01)	0.00 (0.03)	0.13 (0.12)
Log(Priests per 1,000 people in 1950)	0.50 (0.10)		0.06 (0.02)	-0.08 (0.02)	0.05 (0.02)	0.36 (0.08)	0.03 (0.02)
Ratio of order to total priests		1.69 (0.69)					
Share of Catholics in total population	1.69 (0.69)	2.99 (0.75)	0.87 (0.14)	-0.71 (0.14)	0.90 (0.27)	0.54 (0.27)	-0.55 (0.20)
R <sup>2</sup>	0.72	0.76	0.71	0.69	0.47	0.61	0.25
Number of markets	298	298	298	298	298	298	203

Cross section regressions using the actual first stages. Clustered standard errors at the diocese level in parenthesis. Only estimates for variables at the market level are reported.

**Table 5**  
**Attendance to "Voucher" Schools, Pre and Post**  
**Reform**

Dependent Variable:	Dummy=1 if Person attended a subsidized private school	
Estimation Technique	(1)	(2)
	Probit	LPM
Log(Priests per 1,000 people in 1950)	-0.04 (0.12)	0.10 (0.04)
Log(Priests per 1,000 people in 1950)*Post Reform	0.26 (0.12)	0.29 (0.07)
Urban area	0.09 (0.02)	0.07 (0.01)
Urban area*post	-0.02 (0.03)	0.00 (0.01)
Pseudo-R <sup>2</sup> /R <sup>2</sup>	0.08	0.06
Number of observations	10566	10566

Cross section regressions weighted by expansion factors for individuals aged 19-50. Clustered standard errors at the diocese level in parenthesis. Estimates for age dummies, region dummies, and the interaction for region dummies and the post reform dummy are not reported.

Table 6  
**Priests and In-Migration Decisions**

Dependent Variable:	In-migration Dummy		In-migration Rates	
	(1)	(2)	(3)	(4)
Log(Priests per 1000 people, destination/origin)	0.04 (0.10)		0.03 (0.13)	
Ratio order to total priests, destination-origin		0.20 (0.24)		0.09 (0.31)
Econometric Technique	Marginal Probit		OLS Estimates	
Number of observations	8857		13	

Standard errors clustered at the region level in parenthesis. Constants are not reported.

Table 7  
Test Scores: OLS and IV Results

Dependent Variable:	Test scores									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Estimation Technique	OLS	OLS	IV	IV	IV	IV	IV	IV	IV	IV
Measure of Competition	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools	Ratio of Voucher to Public Schools
Voucher school competition	0.04 (0.01)	-0.02 (0.02)	0.17 (0.06)	0.15 (0.05)	0.16 (0.04)	0.13 (0.04)	0.14 (0.03)	0.98 (0.37)	12.17 (4.44)	-0.93 (0.36)
Mother Education:										
Secondary-General		0.27 (0.01)		0.28 (0.01)		0.28 (0.01)		0.27 (0.01)		0.28 (0.01)
Secondary-Technical		0.40 (0.02)		0.40 (0.02)		0.40 (0.02)		0.40 (0.02)		0.40 (0.02)
Higher-General		0.64 (0.02)		0.64 (0.02)		0.64 (0.02)		0.64 (0.02)		0.64 (0.02)
Higher-Technical		0.49 (0.02)		0.50 (0.02)		0.50 (0.02)		0.50 (0.02)		0.50 (0.02)
Log(Per-Capita Income)		0.23 (0.00)		0.23 (0.00)		0.23 (0.00)		0.24 (0.01)		0.23 (0.00)
Market Level Variables:										
Mean Education		0.02 (0.02)		-0.01 (0.02)		-0.01 (0.03)		-0.03 (0.03)		0.09 (0.02)
Standard Deviation of Education		0.03 (0.04)		0.05 (0.07)		0.05 (0.07)		-0.03 (0.06)		-0.16 (0.12)
Mean Log(Per-Capita Income)		0.18 (0.03)		0.12 (0.07)		0.13 (0.05)		0.14 (0.05)		0.17 (0.08)
Standard Deviation of Log(Per-Capita Income)		-0.27 (0.05)		-0.02 (0.11)		-0.05 (0.08)		-0.12 (0.07)		-0.25 (0.23)
Log(Population)		-0.03 (0.02)		-0.06 (0.02)		-0.06 (0.02)		-0.06 (0.01)		-0.38 (0.09)
Urbanization Rate		0.00 (0.09)		-0.08 (0.14)		-0.07 (0.12)		-0.20 (0.17)		0.09 (0.18)
Share of Catholic Population		-0.20 (0.17)		-0.48 (0.26)		-0.44 (0.21)		-1.00 (0.41)		-1.32 (0.56)
Instrumental Variable:	-	-	Priests	Priests	Order	Order	Priests, Order	Priests	Priests	Priests
Over-identification test (p-value)	-	-	-	-	-	-	0.83	-	-	-
Number of students	187610	187610	187610	187610	187610	187610	187610	187610	187610	187610
Number of schools	5433	5433	5433	5433	5433	5433	5433	5433	5433	5433
Number of markets	298	298	298	298	298	298	298	298	298	298

Cross section regressions. Standard errors clustered at the diocese level in parenthesis. Region dummies and constants are not reported.



Table 8  
Test Scores: Additional IV Results

Dependent Variable:	Test scores									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Voucher school competition	0.17 (0.05)	0.21 (0.05)	0.08 (0.02)	0.14 (0.04)	0.17 (0.06)	0.12 (0.04)	0.13 (0.04)	0.13 (0.05)	0.15 (0.04)	0.13 (0.05)
Mother Education:										
Secondary-General	0.27 (0.02)	0.27 (0.01)	0.27 (0.01)	0.27 (0.01)	0.26 (0.01)	0.26 (0.01)	0.26 (0.01)	0.18 (0.01)	0.23 (0.01)	0.24 (0.02)
Secondary-Technical	0.40 (0.02)	0.40 (0.02)	0.41 (0.02)	0.40 (0.01)	0.39 (0.02)	0.40 (0.02)	0.40 (0.02)	0.28 (0.02)	0.34 (0.02)	0.36 (0.03)
Higher-General	0.62 (0.02)	0.63 (0.02)	0.64 (0.02)	0.65 (0.01)	0.63 (0.02)	0.64 (0.02)	0.64 (0.02)	0.40 (0.02)	0.53 (0.02)	0.57 (0.02)
Higher-Technical	0.48 (0.02)	0.49 (0.02)	0.51 (0.02)	0.50 (0.01)	0.48 (0.02)	0.49 (0.02)	0.49 (0.02)	0.30 (0.02)	0.40 (0.02)	0.43 (0.03)
Log(Per-Capita Income)	0.24 (0.00)	0.24 (0.00)	0.24 (0.01)	0.24 (0.00)	0.23 (0.00)	0.23 (0.00)	0.23 (0.00)	0.13 (0.00)	0.16 (0.01)	0.20 (0.01)
School Level Variables:										
Mean Education								0.10 (0.01)		
Standard Deviation of Education								-0.01 (0.01)		
Mean Log(Per-Capita Income)								0.19 (0.02)		
Standard Deviation of Log(Per-Capita Income)								-0.14 (0.04)		
Market Level Variables:										
Mean Education	0.07 (0.03)	-0.06 (0.03)	0.00 (0.03)	-0.03 (0.02)	-0.03 (0.03)	-0.01 (0.02)	-0.03 (0.01)	-0.06 (0.02)	-0.04 (0.03)	0.00 (0.05)
Standard Deviation of Education	-0.01 (0.02)	0.09 (0.09)	0.06 (0.06)	0.07 (0.05)	0.03 (0.06)	0.05 (0.07)	0.01 (0.07)	0.08 (0.07)	0.04 (0.05)	0.10 (0.13)
Mean Log(Per-Capita Income)	-0.13 (0.10)	0.12 (0.07)	-0.04 (0.12)	0.08 (0.04)	0.13 (0.06)	0.06 (0.07)	0.12 (0.06)	-0.08 (0.04)	0.23 (0.06)	0.11 (0.09)
Standard Deviation of Log(Per-Capita Income)	0.12 (0.12)	0.06 (0.13)	0.11 (0.15)	0.13 (0.11)	0.03 (0.11)	-0.06 (0.10)	-0.03 (0.11)	0.18 (0.11)	-0.08 (0.05)	-0.22 (0.22)
Log(Population)	-0.07 (0.02)	-0.06 (0.02)	-0.02 (0.02)	-0.04 (0.02)	-0.05 (0.02)	-0.06 (0.02)	-0.07 (0.02)	-0.06 (0.02)	-0.05 (0.01)	-0.08 (0.01)
Urbanization Rate	-0.15 (0.13)	-0.13 (0.15)	-0.13 (0.11)	-0.12 (0.06)	-0.18 (0.14)	-0.09 (0.13)	-0.04 (0.13)	-0.05 (0.13)	-0.22 (0.12)	0.20 (0.18)
Share of Catholic Population	-0.49 (0.29)	-0.62 (0.27)	-0.38 (0.21)	-0.53 (0.19)	-0.54 (0.27)	-0.40 (0.26)	-0.39 (0.22)	-0.49 (0.23)	-0.58 (0.23)	-1.68 (0.46)
High-School Graduation Rate										
<i>he/fore</i> the Reform							1.67 (0.05)			
SIMCE Tests in 1991										
Instrumental Variable:										
Exclude if										
parents attended school after reform	Priests	Priests	Priests	Priests	Priests	Priests	Priests	Priests	Priests	Priests
Exclude 90% of Santiago MA sample, bootstrapping										
Exclude 50% of Santiago MA sample, bootstrapping										
Exclude only public school students, selection model										
Include only Catholic voucher school students, selection model										
Sample										
Number of students	85819	148860	105045	124517	187610	184784	187545	187610	106094	53319
Number of schools	5267	3013	2963	3013	5433	5272	5426	5433	3355	1552
Number of markets	298	278	278	298	298	264	292	298	298	176

Cross section regressions. Standard errors clustered at the diocese level in parenthesis. Region dummies and constants are not reported

**Table 9**  
**Choice of Schools: Marginal Probit**  
**Estimates**

Dependent Variable: Dummy takes a value of 1 if:	Student attends a public school versus a voucher school	Student attends a non-Catholic versus a Catholic voucher school
	(1)	(3)
Values among top priorities when choosing among schools	-0.36 (0.01)	-0.28 (0.01)
Mother Education:		
Secondary-General	-0.07 (0.01)	-0.03 (0.01)
Secondary-Technical	-0.10 (0.01)	-0.05 (0.02)
Higher-General	-0.21 (0.02)	-0.07 (0.02)
Higher-Technical	-0.19 (0.02)	-0.06 (0.02)
Log(Per-Capita Income)	-0.11 (0.01)	-0.03 (0.01)
Market Level Variables:		
Mean of Mother Education	-0.02 (0.02)	-0.01 (0.07)
Standard Deviation of Mother Education	-0.09 (0.06)	0.15 (0.07)
Mean of Log(Per-Capita Income)	-0.11 (0.01)	-0.14 (0.07)
Standard Deviation of Log(Per- Capita Income)	0.00 (0.10)	-0.17 (0.25)
Log(Population)	-0.06 (0.01)	0.09 (0.03)
Urbanization Rate	-0.14 (0.10)	0.08 (0.15)
Log of (Priests per 1,000 people)	-0.07 (0.02)	0.04 (0.03)
Ratio of order to total priests		
Share of Catholic Population	-1.07 (0.15)	-0.63 (0.22)
Pseudo R <sup>2</sup>	0.22	0.15
Number of students	172309	69937
Number of schools	5433	1701
Number of markets	285	203

Cross section regressions, each observation represents a value a for a student. Standard errors clustered at the diocese level in parenthesis. Region dummies and constants are not reported.

Table 10  
Expenditures in Education, Productivity, and Student Composition: IV Results

Dependent Variable:	Public Expenditures per student		Private Expenditures per student		Total expenditures per student		Municipal Expenditures per student		Copayment		Normalized Productivity Index 1		Normalized Productivity Index 2		Distance of mother's education to school mean		Distance of per-capita income to school mean		Distance of test score to school mean	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)										
Voucher school competition	3761.94 (1463.37)	867.71 (635.96)	4464.08 (1701.04)	3572.42 (493.12)	-2513.69 (1067.13)	0.23 (0.07)	0.20 (0.07)	-0.09 (0.04)	-0.01 (0.01)	0.007 (0.003)										
Instrumental Variable:	Priests	Priests	Priests	Priests	Priests	Priests	Priests	Priests	Priests	Priests										
Sample	Voucher school students w/ selection correction																			
Number of students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students	All students
Number of schools	165163	180288	155197	96564	80148	155197	155197	187538	187610	187610	155197	155197	187538	187610	187610	187610	187610	187610	187610	187610
Number of markets	4488	5427	4452	2845	2076	4452	4452	5404	5433	5433	4452	4452	5404	5433	5433	5433	5433	5433	5433	5433
	261	298	261	222	203	261	261	298	298	298	261	261	298	298	298	298	298	298	298	298

Cross section regressions. Standard errors clustered at the diocese level in parenthesis. Estimates for other covariates are not reported.

**Table 11**  
**Proxies for Soft Budget Constraints in**  
**Public Schools: Marginal Probit Estimates**

Dependent Variable: Dummy takes a value of 1 if municipality	has Education Deficit above the Median	has Average School Size below the Median
	(1)	(2)
Pro-Government Mayor*Pro- Government Vote	0.50 (0.26)	0.41 (0.10)
Pro-Government Mayor	-0.07 (0.14)	-0.16 (0.06)
Pro-Government Vote	-0.51 (0.17)	-0.30 (0.07)
Mean of Mother Education	-0.14 (0.03)	-0.01 (0.01)
Standard Deviation of Mother Education	-0.30 (0.08)	0.04 (0.02)
Mean of Log(Per-Capita Income)	0.25 (0.07)	-0.02 (0.02)
Standard Deviation of Log(Per- Capita Income)	-0.37 (0.21)	-0.08 (0.06)
Log(Population)	0.06 (0.02)	-0.06 (0.01)
Urbanization Rate	0.30 (0.10)	0.13 (0.03)
Log of (Priests per 1,000 people)	-0.13 (0.05)	-0.05 (0.02)
Share of Catholic Population	-0.05 (0.27)	-0.22 (0.09)
Pseudo R <sup>2</sup>	0.17	0.38
Number of municipalities	299	249

Cross section regressions, each observation represents a value a for a municipality, estimates from the selection equation actually used in the paper.

Table 12  
Test Scores: IV Estimates, Interaction Effects

	(1)	(2)	(3)	(4)
Second stage estimates with selection correction				
Ratio of voucher to public schools	0.09 (0.07)	0.52 (0.31)	0.03 (0.20)	0.18 (0.06)
Second stage estimates without selection correction				
Ratio of voucher to public schools	0.08 (0.04)	0.52 (0.21)	0.06 (0.20)	0.17 (0.03)
Sample: Municipalities with	Big education deficits	Small education deficits	Low school size	High school size
Number of students	46819	59275	18234	87860
Number of schools	1309	2046	885	2470
Number of municipalities	108	191	104	194

Cross section regressions, each observation represents a value a for a student. Standard errors clustered at the diocese level in parenthesis. Coefficients of all other control variables included in the second and first stage equations are not reported.



## Chapter 3

# Historical Origins of Schooling: The Role of Political Decentralization<sup>1</sup>

### 3.1 Introduction

Educational attainment varies widely across countries. Among the former colonies, the adult population in Ethiopia and Mali had on average one year of schooling between 1985 and 1995, whereas the adult population in the Neo-Europes (Australia, Canada, New Zealand, the US) had more than 10 years of schooling in this period. Median years of schooling for the adult population was slightly more than 4 years in the same time period. Even within narrower groups of countries differences are significant. For instance, among former British colonies the Neo-Europes coexist with countries such as Bangladesh and Sierra Leone that have two years of schooling on average. While the adult population of Sri Lanka had on average 6 years of schooling in 1985-1995, in neighboring India average years of schooling were only 4. Moreover, differences in schooling often predate the present. In 1900 the primary enrollment rates in the Neo-Europes were above 85% and in countries such as Haiti, Morocco, and Vietnam were less than 2%. While India's enrollment rate was 4% in 1900, Sri-Lanka's was 22%.

Why does schooling vary widely across countries? Why are differences in schooling highly

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<sup>1</sup>I would like to thank Daron Acemoglu and Dora Costa for their comments and advice; José Tessada, Kenneth Sokoloff, and seminar participants at MIT, the 2004 NBER Summer Institute, and the University of Chile for useful feedback; and Pamela Siska for editing help. The usual disclaimer applies.

persistent? In this paper, I study the connection between historical variables, political institutions, and educational outcomes in former colonies. Theoretically, I argue that historical variables determine the distribution of political power among different agents and affect the political institutions established in the past. These institutions present a high degree of inertia and affect educational institutions and outcomes. I argue that two important political institutions that affect schooling are democracy and *local* democracy (decentralization of political power). My main hypothesis is that these political institutions explain the effect of historical factors on past and current levels of schooling.

To test these hypotheses empirically, I use settler mortality (Acemoglu et al., 2001), population density in 1500 (Acemoglu et al., 2002), and pre-existing factor endowments (Engerman and Sokoloff (1997, 2002) as proxies for the historical factors that affect political institutions. In addition, I use the number of native cultures before colonization as a source of exogenous variation for political decentralization. The number of native cultures before colonization affected the colonization strategy in each former colony. Colonizers tended to establish (or take up) centralized states in colonies with one (or no) strong ethnic group(s) and relatively decentralized governments in colonies with several ethnic groups. Current political structures resemble at least partially these initial structures. Thus, I expect areas where colonizers established more centralized states to have more centralized states in the present. By using the number of native cultures before colonization as an additional instrument for political decentralization, I am able to disentangle the effects of these two political institutions on schooling.

My results suggest that conditions faced by colonizers and pre-existing factor endowments affected the characteristics of educational systems established in the past. Cross-country differences in schooling levels persist to the present because colonial factors influence the extent of democracy and decentralization of political power. I show that the degree of democratization positively affects the development of primary education, whereas the decentralization of political power is the most important explanation for differences in higher levels of schooling, such as secondary and higher education. Results suggest that the decentralization of school management at the local level explains the effect of political decentralization on current levels of schooling. These results confirm my hypothesis that while democratization should be more relevant for variables related to the quantity of education (such as primary enrollment), decen-



tralization of political power should be more related with variables capturing differences in the quality of education (such as years of schooling or secondary and higher enrollment).

These results for the effect of local democracy on schooling give support to the theories that emphasize the importance of decentralization in the provision of goods such as education (See Oates, 1972 and Inman and Rubinfeld, 1997). In addition, by using evidence from a comprehensive sample of former colonies and instrumental variables, I give broader support to historical papers underlining the role of decentralization in the expansion of primary schooling in the 19th and 20th centuries (See Lindert, 1999 for Europe and the US, Engerman et al., 1997 for the Americas, and Goldin and Katz 2003 for the US). In addition, my results about the effects of political institutions on schooling are related to the literature on the determinants of the quality and quantity of education. The literature suggests that the link between resources spent on education and *quantity* of education is stronger than the link between resources and *quality* of education. While a salient feature of democracies is the ability to increase public expenditure in areas such as education, political decentralization tends to raise local pressures to increase the efficiency of educational systems. This argument implies that democratic countries may have better access to education and that decentralized democracies may have a stronger effect on the efficiency of the educational system. My results support this view.

The paper is organized as follows. Section 3.2 briefly presents theoretical background about the determinants of schooling and theories that relate historical factors to schooling. Section 3.3 presents some historical background. Section 3.4 describes the empirical strategy I implement in this paper. Section 3.5 discusses the data used in this paper. Section 3.6 analyzes the relationship between historical factors and schooling. Section 3.7 tries to disentangle the role of political decentralization and democracy on schooling and section 3.8 briefly concludes.

## **3.2 Theoretical Background**

### **3.2.1 Political and Social Institutions and Schooling**

A series of theories relates human capital accumulation to government action and to societal characteristics. A first group of arguments emphasizes the role of public policies in overcoming such market failures as credit constraints in financing education. A second group of arguments

emphasizes the notion that the implementation of educational policies depends on political institutions. In these theories, the higher the level of enfranchisement, the greater public expenditures on education. A third line of research stresses collective action problems in the provision of schooling. For instance, inequality and ethnic and linguistic fractionalization lower the likelihood of educational transfers (Engerman et al 1997). All these theories suggest that countries with institutions more capable of dealing with these kinds of problems impart more schooling.

While the previous theories emphasize the ability of different institutions to channel more resources to schooling and improve access to education, other studies stress the role of the efficiency of the educational system. Several authors highlight the idea that less centralized governments tend to provide better education (Engerman et al., 1997; Lindert, 1999 and 2002). Efficiency and political economy arguments show that decentralized administration and, in some cases, financing of schooling produces a quantity and quality of education closer to the social optimum (See Oates, 1972; Inman and Rubinfeld, 1997). The evidence on the relationship between resources and educational quality tends to be weak (e.g., Hanushek and Kimko, 2000).<sup>2</sup> In addition, papers studying the effects of different educational systems on school outcomes using microeconomic evidence find that school autonomy in personnel and process decisions, teacher influence on teaching methods, and within-school budget allocations tend to produce positive effects on educational results; while at the same time, centralized examinations and allocation of resources have a positive impact on school quality (Fuchs and Woessman, 2004; Woessman, 2003). Thus, this discussion suggests that while democratization should be more able to increase the resources used in education and expand the quantity of education, decentralization of local power and of the management of schools should be more related to the quantity of education.

In contrast, some papers argue that decentralization can create inefficient provision of education (See Haggard, 1999 and Bardhan, 2002 for reviews, Kremer et al., 2002 for empirical evidence, and Gennaioli and Rainer, 2004 for a theoretical model). For instance, decentraliza-

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<sup>2</sup>For instance, from a policy perspective, UNESCO (2005) argues that "In a good number of countries, large increases in average real expenditure per student and other measures of school resources in primary and secondary schools over the last four or five decades have not remotely been matched by a comparable increase in average test scores." (p. 60).

tion in the absence of local checks and balances could allow local elites to capture the local government and block the provision of public goods or to channel expenditures towards their members. Hence, the empirical evidence examined in this paper should give a more definitive answer to the question of the effects of decentralization on educational outcomes and the relative importance of democratization and decentralization on different educational outcomes.

Finally, there are other social characteristics affecting schooling. First, some authors suggest that the process of consolidation of mass schooling during the 20th century is related to the consolidation of national identity of several independent countries (Meyer, et al., 1992; Ramirez and Boli, 1987). Second, other factors such as religion and cultural heritage can affect schooling because various civilizations and faiths put different emphases on formal instruction (Engerman et al., 1997; Lindert, 2002). A variant of this explanation is that the effects of colonial origins on schooling are explained by different policies and regulations affecting Christian missionaries (Gallego and Woodberry, 2006).

These explanations propose a number of patterns that can affect the level of schooling of a country. Interestingly, most of them are related to institutional factors that have historical roots. This connection suggests a link between theories explaining a country's social organization using colonial factors and theories explaining the development of educational institutions. The next section expands this argument.

### **3.2.2 Historical Origins of Schooling**

I assume that European colonization was an exogenous shock that affected the social institutions of former colonies (Acemoglu et al., 2001, 2002, and 2005, and Engerman and Sokoloff, 1997 and 2002). The education system was one of those institutions affected by colonization. European colonizers settling in an area were more willing to spend resources in instruction for their children and for the native population. In contrast, extractive colonizers are not interested in investing in an activity that has low and uncertain returns. Extractive colonizers settle in high mortality areas with profitable opportunities in producing crops or minerals with large economies of scale in native (and illiterate) populations. Then, educational investments have low returns for the powerful elite that makes most of the public policy decisions.

Colonizers also established political institutions that were consistent with the distribution

of political power that they faced. Colonizers established centralized administrations in areas with one (or no) indigenous group(s) but tended to establish decentralized institutions in areas with more than one ethnic group with power.<sup>3</sup>

Political institutions established by colonizers also affect their educational institutions because inclusive institutions are more democratic and locally decentralized and give the masses the political power to demand and receive education. Finally, political institutions also affect individuals' willingness to invest in human capital. Institutional settings assuring the respect for property and civil rights provide an incentive to accumulate human capital (i) directly, because there is less (political) income uncertainty, in the sense that expropriation is less likely,<sup>4</sup> and (ii) indirectly, because these institutions provide more incentives to the accumulation of other forms of capital that are complementary with human capital.<sup>5</sup>

A simple way to illustrate the relationship between current educational institutions and outcomes and historical factors is to show that early and current educational institutions and outcomes are related, i.e., there is inertia in schooling. Many authors have emphasized the existence of institutional performance (e.g., Acemoglu et al., 2001), but delineating this persistence has been difficult. There are several reasons why institutional persistence is plausible in the case of education. Firstly, as pointed out by Acemoglu et al. 2001, setting up institutions is costly, the gains of the extractive strategy are shared among the small elite, and there are irreversible complementary investments. This means that educational policies, as part of a *long lasting* and *multidimensional* cluster of institutions, are persistent. Secondly, intergenerational inertia creates persistence in educational levels among members of several cohorts. Thirdly, the accumulation of human capital is endogenous. Increases in the supply of education make

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<sup>3</sup>The conventional wisdom is that the British tended to establish more decentralized structures of colonial government than the French. However, the evidence suggests that there is some variation within this general practice. For instance, Ollowu and Wunsch (2004) describe decentralization in several cities controlled by the French in the presence of various ethnic groups starting with the municipal law of 1884; Brown and Roger-Luois (1999) and Herbst (2000) argue that the British applied the indirect rule system in areas in which local groups were more powerful.

<sup>4</sup>In particular, consider the case of "extractive institutions" in which the concentration of political and social power in the hands of a small elite implies that the majority of the population risks being held up by the powerful after they undertake investments (Acemoglu et al., 2002, p. 1263). Nugent and Robinson (2001) present a model that links incentives to invest in human capital with the legal environment affecting access to land.

<sup>5</sup>Krusell et al. (2000) argue that there is a high degree of complementarity between human and equipment capital. Clemens and Williamson (2000) confirm this view by showing that the fraction of population enrolled in schools in the early 1900s had a significant effect on British capital inflows going to different countries.

investment in human capital-related technologies more profitable which, in turn, encourages schooling (Acemoglu, 2002). Finally, peer effects can explain low levels of education over several generations even though there are policies aiming to expand schooling. I present evidence that cross-country differences in schooling are highly persistent in Section 3.6. Clemens (2004) also presents evidence of a high degree of inertia of schooling in different countries.

Several papers have related colonial or historical factors to schooling and educational institutions. First, Acemoglu et al. (2001) mention that educational policies are both part of the cluster of institutions established by colonizers that persist to the present and that human capital accumulation is a consequence of the development of democratic and neo-European social structures. Engerman et al. (1997) and Engerman and Sokoloff (2002) present a review of country experiences and empirical evidence showing that suffrage institutions in the early 1900s are associated with schooling. Easterly (2002) provides evidence that the share of income going to the three middle income quintiles is associated with schooling results and that this variable in turn is explained by a group of factors related to endowments and settler mortality.

### **3.3 Historical Background**

Using the theoretical insights presented above, in this section I first review the historical record looking for initial evidence on the relevance of the extent of the franchise and the degree of political decentralization in accounting for the relationship among historical factors and schooling. Probably the leading group of evidence comes from the impressive performance in terms of schooling of former colonies like Australia, Canada, New Zealand, and the US around 1900. Engerman et al. (1997) and Goldin and Katz (2003) explain this pattern by describing the experience of Canada and the United States as related to the development of schooling at regional levels. Local authorities were able to organize and finance vast educational systems from the very beginning of the independence in the two countries. Australia and New Zealand present similar features. Both nations developed a massive and heterogeneous educational system from the early 1800s. Both countries had several areas with European settlers in a relatively competitive environment and, thus, there was space for the development of different schools in each region. These schools were closely associated with the specific characteristics of

people in each sector (in terms of religious, cultural, and ethnic aspects).<sup>6</sup>

Argentina provides another interesting case because it is the former Spanish colony having the highest primary enrollment rate in Latin America in 1870-1930 and the highest educational attainment in the 1985-1995 period. The educational expansion was accomplished by the provinces with federal involvement, especially after the 1860s, when President Sarmiento expanded state participation in instruction. The Argentine case contrasts with the Mexican experience where the central bureaucracy (from the colonial times) had a lot of power and provinces did not have autonomy in most areas. This point is emphasized by Engerman et al. (1997), who relate this lack of independence of local areas with the relative delay of Mexico in terms of schooling in 1900.

Also concerning Latin America, Nugent and Robinson (2001) compare differences in the paths of development of two groups of coffee producers: Colombia-Costa Rica (CRC) and El Salvador-Guatemala (ESG). While the former developed smallholder economies, the latter developed plantation economies. Nugent and Robinson (2001) present historical evidence that these differences in economic structure are ultimately related to differences in the nature of political competition. CRC had elites that were more polarized and competitive than ESG and were more oriented toward mercantile activities. They present evidence that CRC have reached higher levels of development than ESG (in terms of GDP, schooling, democratic institutions, and human development). In their model, this divergence is a result of the lack of incentives to accumulate human capital in the plantation economies, where peasants are held up as a consequence of the monopsony power of landowners. Thus, this case study suggests that political institutions that are historically rooted affect human capital accumulation.

Sierra Leone is an interesting case illustrating the relevance of decentralization. Reno (1995) shows that after independence, some state initiatives to expand and decentralize social services were ineffective because corrupt and autocratic chiefs controlled local governments. Gennaioli and Rainer (2004) generalize this result for other African countries. This evidence highlights the difference between the mere existence of various areas, and the existence of voice or democratic power at the local level, which seems to be key for the expansion of education opportunities. Not surprisingly, in 1985-1995 the adult population of Sierra Leone had an average of 2.1

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<sup>6</sup>See Shaw (1967) for a description of the existence of heterogeneous local schools in Australia.

years of schooling. A contrast comes from Botswana. From colonial times, democratic chiefs bound by local checks and balances characterized Botswana that had an average of 5 years of schooling among the adult population in 1985-1995. In addition, from the beginning of independence, Botswana has invested significant resources in education, health and other social services (Acemoglu et al, 2003).

Lindert (2002) emphasizes differences in the extent of the franchise among India, Pakistan, and Sri Lanka as sources of divergent educational development. While Britain gave Sri Lanka universal adult suffrage in 1931 (including provincial elections in 1931 and 1936), India received only a very limited franchise in 1919. Lindert (2002) relates these disparities in political power to educational results in the three countries. Whereas Sri Lanka had a primary enrollment rate of more than 50% in 1935-40, India had an enrollment rate of less than 15% in the same period. However, these developments do not necessarily reflect a causal connection between electoral rights and schooling because in 1900 (before the formal extension of the franchise) schooling differences were also significant. While Sri Lanka had a primary enrollment rate of more than 20%, India had an enrollment rate of less than 5%. The dissimilarity likely arises from the Colebrooke-Cameron Reforms instituted in Sri Lanka during the first half of the 1800s. These reforms unified the country and gave power and political participation to local citizens. The reforms can be interpreted as an exogenous shock to the country's institutions that produced a number of differences in the extent of the franchise, schooling, and other institutions compared to India. This historical event probably explains the success of Sri Lanka in expanding the franchise vis-à-vis India and Pakistan.

Finally, Lindert (1999) studies the experience of European countries in the early 1900s and strongly stresses the role played by school decentralization in schooling outcomes before 1914. Countries with very different political regimes, such as Prussia and the United States, had high enrollment rates. Lindert argues that Prussia, a central autocracy, left its schooling more to local forces than has been realized, and the notorious Junker dominance in national politics was largely irrelevant to the provision of schooling. School decentralization helps explain how Germany and North America, although poles apart in their national politics, both led in mass education.

### 3.4 Empirical Framework

Using the theoretical and historical background described above, I develop in this section an empirical investigation of the effects of historical factors on schooling. My main hypotheses are the following:

- First, educational outcomes and institutions are persistent and, therefore, differences among countries in levels of schooling can have historical origins.
- Second, certain characteristics of the countries that are historically given and that affect the political institutions established by these countries may be able to explain the relationship between historical factors and schooling.
- Third, among these institutional characteristics, the historical background and theoretical arguments suggest that democracy and the degree of political decentralization are potential candidates to account for this relationship. In particular, democracy may be more correlated with measures of quantity of education (e.g., primary enrollment rates) and decentralization of political power with measures of quality of education (e.g., average years of education, secondary and higher education enrollment rates).

In this section I describe the empirical methodology I use to study these hypotheses. I use two basic approaches to analyze the effects of historical factors on cross-country differences in schooling. First, I study whether historical factors are correlated with current and past levels of schooling. To do so, I first run reduced form equations of the following form:

$$S_i = \mathbf{Z}'_i \alpha + \mathbf{X}'_i \beta + e_i, \quad (3.1)$$

where  $i$  refers to country,  $S$  is a schooling indicator,  $\mathbf{Z}$  is a vector of historical variables (settler mortality, population density in 1500, factor endowments less and more favorable to development, and presence of various natives cultures before colonization),  $\mathbf{X}$  is a vector of control variables (religion shares, the national identity of the colonizer and, in some regressions, GDP per capita), and  $e$  is an error term. Equation (3.1) correlates schooling with historical factors, without considering the specific mechanisms that could explain the association.



Next, I study how institutions mediate the effects of colonial factors on schooling. To do so, I estimate the following system of equations using two-stage least squares:

$$S_i = \gamma_1 Y_{1i} + \gamma_2 Y_{2i} + \mathbf{X}'_i \delta + u_i, \quad (3.2)$$

$$Y_{1i} = \mathbf{Z}'_{1i} \eta_{11} + \eta_{12} Z_{2i} + \mathbf{X}'_i \theta_1 + \epsilon_{1i}, \quad (3.3)$$

$$Y_{2i} = \mathbf{Z}'_{1i} \eta_{21} + \eta_{22} Z_{2i} + \mathbf{X}'_i \theta_2 + \epsilon_{2i}, \quad (3.4)$$

where  $Y_1$  is a measure of democracy,  $Y_2$  is a measure of political decentralization,  $\mathbf{Z}_1$  is a vector of instrumental variables for  $Y_1$  and  $Y_2$  (settler mortality, population density in 1500, and factor endowments less and more favorable to development) that allows me to identify an exogenous source of variation for  $Y_1$  and  $Z_2$  is an instrumental variable for  $Y_2$  (the number of indigenous cultures before colonization started) that allows me to identify an exogenous source of variation for  $Y_2$ . In particular, as I show later,  $\eta_{12}$  is equal to zero in all regressions.  $\mathbf{Z}$  will be a valid instrument for  $Y$  as long as it is uncorrelated with  $u$ . Put it differently, the key exclusion restriction is that in the population  $Cov(u_i; Z_{1ji}) = Cov(u_i; Z_{2i}) = 0$  for  $j = 1, \dots, 4$  (i.e., the variables included in  $\mathbf{Z}'_1 = \begin{bmatrix} Z_1 & \dots & Z_4 \end{bmatrix}$ ). An over-identification test is a useful approximation to check this set of conditions.<sup>7</sup>

The motivation for this strategy is that I use two different sources of exogenous variation that allow me to unbundle the contribution of two different political institutions on schooling. By doing so, I am able to identify specific mechanisms for the effect of political institutions on different educational outcomes.<sup>8</sup>

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<sup>7</sup>The over-identification test is a Lagrange multiplier test statistic that, under the null hypothesis, is distributed  $\chi^2_Q$ , where  $Q$  equals the number of excluded exogenous variables minus the number of endogenous variables included as regressors in (3.1). Hall and Jones (1999), Acemoglu et al. (2001,2002), Easterly and Levine (2003), and Persson (2005) among others also use an over-identification test to study the validity of using historical variables to explain current institutions.

<sup>8</sup>Acemoglu (2005) discusses the idea of unbundling institutions in the general context of comparative political economy and Acemoglu and Johnson (2005) apply this idea to distinguish the effects of contracting and property rights institutions on cross-country differences in economic development.

### 3.5 Data

I use a dataset including more than 50 former colonies. Table 1 presents descriptive statistics and data sources.

My indicators of current educational attainment is average years of schooling of the population above 15 years of age (from Barro and Lee, 2001 and Cohen and Soto, 2001) and primary, secondary, and higher education enrollment from the Global Development Network Growth database in 1985-1995. To measure schooling in 1900, I use data from Benavot and Riddle (1988) on gross primary enrollment rates for a sample of countries. Because this database has not been widely used in the economic literature, a more detailed description of it is provided in the Appendix to this chapter.

I use two indicators of democracy: (1) institutionalized democracy in 1900 and 1985-1995 from the Polity IV data set, (2) the Gastil index of civil rights from Freedom House for 1985-1995.

Political decentralization is an indicator of the extent of local democracy and local political power. This variable is constructed using information from Beck et al. (2000) and the Polity IV data set. Using Beck et al. (2000), I construct a proxy for decentralization that takes a value of 0 if neither the local executive nor the local legislature is directly elected by the local population, 1 if either is directly elected and the other is indirectly elected or appointed, and 2 if both are directly and locally elected. The decentralization variable in the Polity dataset takes three values: 1 refers to a centralized state (unitary state: no more than moderate decision-making authority is vested in local or regional governments), 2 to an intermediate category, and 3 to decentralized states (federal state: local and/or regional governments have substantial decision-making authority). For 1985-1995, I use the average of the Beck et al. (2000) and Polity normalized indices and the Polity index for 1900.<sup>9</sup>

I also construct two measures of the degree of decentralization of education systems using data from the UNESCO World Data on Education databank. The first measure is a dummy that

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<sup>9</sup>Notice that my decentralization index is different from other measures used in the literature. While decentralization is typically measured as the subnational share of total government spending (e.g., Fisman and Gatti, 2002), my indicator is related more to a measure of local democracy. This distinction is important because the lack of local checks and balances is one of the factors that explain why some theories predict a potentially negative effect of decentralization on education and other social outcomes (Bardhan and Mokerjee, 2000; Bardhan, 2002; Gennaioli and Rainer, 2004). My measure combines both centralization of government and local democracy.

takes a value of 1 if the administration of schools is decentralized to the provincial or municipal level, and 0 otherwise. This measure aims to capture local autonomy to manage schools. The second measure of decentralization aims to capture the degree of financial decentralization of schools. The variable takes a value of 0 if provincial/municipal levels have no financial autonomy to manage and raise school resources, 1 if the local level has some autonomy to manage and raise education funds, and 2 if local levels have complete or almost complete autonomy to raise and manage education funds.

I use two historical colonial variables from Acemoglu et al. (2001, 2002): settler mortality risk and population density in 1500. Settler mortality represents the potential mortality risk faced by colonizers (see Acemoglu et al 2001). Population density in 1500 is a measure of the density of the native population and, therefore, adds information about the colony's labor supply and the opportunities of taking over the pre-colonial tax system and establishing extractive institutions (Acemoglu et al 2002; Engerman and Sokoloff 2002).

I classify a country's agricultural and mineral endowments as "good" for development or as "bad" for development. Easterly (2002) and Easterly and Levine (2003) use a group of 11 dummies to indicate whether a country produced any of a given set of leading commodities (crops and minerals) in 1998-1999. Following the rationale of Engerman and Sokoloff (2002) the commodities less favorable to development are bananas, coffee, copper, rice, rubber, silver, and sugarcane. The commodities more favorable to development are maize, millet, and wheat.

I use data from Murdock and White (1969) on the number of indigenous cultures as a measure of the number of ethnic groups living in a country when colonizers arrived. I use a dummy that takes a value of 1 if there was more than one ethnic group and 0 otherwise. Because colonizers established a state that, at least partially, resembled the preexistent distribution of power, societies having only one ethnic culture tended to develop more centralized states.

I proxy for religious and cultural heritage with the share of the population that is Roman Catholic, Muslim, or another non-Protestant religion and with the national identity of the colonizer (British, French, and Spanish). The shares of a religious denomination are from Barrett (1982) for 1900 and La-Porta et al. (1999) for 1985-1995. The identity of the colonizer is from CIA (2002).

### 3.6 The Effects of Historical Factors on Schooling

In this section, I study the relationship between schooling and historical factors. I first show that cross-country differences in schooling are persistent. Next, I show that schooling is related to historical factors such as settler mortality, population density, factor endowments, and the number of native cultures before colonization.

Before estimating the reduced form equation (3.1) I implement three raw tests to assess some of the underlying assumptions of using historical factors to explain schooling. First, I evaluate the persistence of the cross-country variability of schooling. Figure 1 presents the results of regressing education attainment in 1985-1995 on primary enrollment in 1900. Results suggest that there is a high degree of persistence in cross-country differences (even if I do not incorporate the countries with higher levels of enrollment). The regression for the complete sample explains 63% of the cross-country variation in current levels of schooling. The Spearman rank correlation is 0.69 (a test rejects the null hypothesis that schooling variables in the past and today are independent). This evidence suggests that schooling is highly persistent and that its early and current levels are closely related.<sup>10</sup>

Second, I explicitly assume that the causality goes from political institutions to schooling. An implication of this result is that changes in democracy should precede changes in primary enrollment. Panel A of Table 2 presents results along those lines. Taking a sample of former colonies with data for primary enrollment and democracy from 1870 to 1940, I find that changes in democracy precede changes in primary enrollment and that changes in primary enrollment do not precede changes in democracy. Thus, these results provide an indirect test of my assumption supporting the idea that causality comes from institutions to schooling and not vice versa.<sup>11</sup>

Third, a recent alternative hypothesis offered by Rajan and Zingales (2006) suggests that

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<sup>10</sup>As a comparison, Acemoglu et al. (2001) conclude that the degree of persistence of institutions is high when their measures of early institutions explain about 20% of the variability of current institutions (and the rank correlation between both variables is 0.20).

<sup>11</sup>Gleaser et al. (2004) find that education precedes democracy and not vice versa, using data for 1960-2000. In contrast, Acemoglu et al. (2004) find that education does not foster democracy, using data from 1965 to 2000 when including time fixed effects. I do not have a comparable dataset of my primary enrollment measure after 1940 so I cannot extend the analysis forward. More importantly, my exercises capture a period in which both education and democracy were developed basically from a country perspective. In subsequent periods both variables have been pushed by global and external policies and, therefore, may not accurately capture country-specific variation (even though the time dummies should take care of this, they may not do so perfectly). Clemens (2004) presents a detailed review of international policies aimed to increase education levels in poor countries.

institutions have no direct effect on measures of development, after controlling for the share of the European population in 1900. They interpret the share of the European population as an indicator of education homogeneity in 1900. Certainly, many alternative interpretations for the same variable are also plausible. For instance, Acemoglu et al. (2001) interpret the same variable as an indicator of the existence of the share of the population wanting to establish a broad set of good institutions. More importantly, Rajan and Zingales (2006) support their claims by including measures of democracy, the share of the European population, and primary enrollment in 1900 as regressors in a regression of educational outcomes in the present. This regression is hard to interpret because at least some of these variables may be jointly determined and affect each other and probably have a lot of measurement error.<sup>12</sup> Therefore, an OLS regression on these variables is not identified. One needs to find potentially valid sources of exogenous variation for each dependent variable to identify the causal effect of these historical variables on schooling. In Panel B of Table 2 I implement such an exercise using three plausible instruments for the three endogenous variables: settler mortality as an instrument for democracy, population density in 1500 for the share of the European population, and the number of Protestant missionaries per capita in c. 1900 for primary enrollment (from Woodberry, 2002, and Gallego and Woodberry, 2006). Results suggest that, using these three instruments, conclusions change dramatically. Only democracy and primary enrollment have positive effects on years of schooling in the present (effects are in general marginally significant). Moreover, the effects are economically relevant: a one standard deviation increase of democracy in 1900 increases years of schooling by about 4.5 years in the regression including controls (and by about three years in the regression without including controls). Similarly, a one standard deviation increase of primary enrollment in 1900 increases education today by about 2.5 years (about 2.7 years in the regression without including controls).<sup>13</sup> Overall, evidence in both panels of Table 2 provide a first group of evidence that suggests that institutions established in the past affect educational outcomes today.

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<sup>12</sup>For instance, measuring the share of the European population is much easier than measuring the number of children that go to school, which is much easier than measuring a subjective concept like democracy.

<sup>13</sup>In the first stages (unreported in the text but available from the author), as expected, the instruments I postulate are statistically significant (settler mortality for democracy, population density for the share of the European population, and Protestant missionaries for primary enrollment) and the other variables are not statistically significant in the regressions without controls.

Table 3 presents reduced form estimates for my main measures of schooling in 1900 (primary enrollment rate) and 1985-1995 (average years of schooling of the adult population, primary, secondary, and higher education enrollment rates), based on equation (3.1). Odd numbered columns present results without including covariates and even numbered columns present results including covariates (the identity of the main colonizer, and religion variables). Most historical variables are statistically significant considering conventional significance levels and explain a relevant share of cross-country variability (more than 50%).

Regarding the estimated effects of historical factors, settler mortality, population density in 1500 and the dummy for good factor endowments present the expected signs (i.e., higher settler mortality and population density decrease schooling, and having good endowments increases schooling). Results for the dummy for bad endowments present the expected sign but are statistically significant in only about half of the specifications.

Results for the variable measuring the number of cultures before colonization are interesting. This variable has a positive and significant effect only for regressions measuring average years of schooling and secondary and higher education enrollment. In contrast, the number of native cultures before colonization is not statistically significant in the regressions for primary enrollment levels both in 1900 and 1985-1995. This evidence brings indirect support to my theoretical discussion in Section 3.2. I argue that the number of native cultures before colonization captures an exogenous source of variation of decentralization of political power. If decentralization is more important for advanced levels of schooling, which, as I argue, are more related to quality of education as I argue, I would expect the number of native cultures to be significant only in regressions measuring advanced levels of schooling. The evidence in Table 3 supports this view.

The inclusion of controls for the religious denomination of the population and the national identity of the colonizer does not affect the significance of the effects of historical variables on schooling. Results confirm previous findings that former British colonies and Protestant countries tended to develop more extensive educational systems circa 1900 and that these variables are not correlated with educational outcomes when using modern data (Benavot and Riddle, 1988).

As a whole, Table 3 shows that there is a robust and significant relationship between his-

torical factors and schooling variables. For example, after controlling for religion variables, a country having settler mortality in the lower 25% of the distribution has a population with 1.5 additional years of education than a country located in the upper 25% of the distribution of the same variable (column 4). Analogously, a country situated in the lower 25% of the distribution of the population density in 1500 has 1.4 more average years of education than a country in the upper 25% of the distribution. Results for endowments are similar. A country having good endowments has a population with an average of 2.2 more years of education than countries not having good endowments. Countries having “bad” endowments have 1.9 fewer years of education than countries not having bad endowments. Finally, countries with more than one native culture at the time of colonization have about 0.8 more years of education.

Overall, evidence in this section reports a strong correlation between historical factors and educational outcomes in 1900 and 1985-1995. The effect of these historical factors may operate through some specific institutional factors such as democratic institutions and political decentralization. The next section studies empirically this hypothesis.

### **3.7 Institutions and Schooling: Democracy or Political Decentralization?**

In this section, I present structural estimates of the relationship between historical factors, political institutions and educational outcomes. To do so, I estimate the system of equations composed by (3.2), (3.3), and, (3.4) to determine whether (i) there is a significant relationship between democratization and decentralization of political power and the historical variables, (ii) the proposed institutional variable has a significant effect on schooling, and (iii) the effects of the historical factors on schooling do not go beyond their effects on the proposed institutional variable, i.e., the over-identification test confirms that the instruments are valid.

Table 4 presents structural estimates for educational outcomes in 1900. I start discussing first-stages regressions (presented in Panel B). The first-stage results for democracy in 1900 suggest that settler mortality, population density in 1500, and the proxies for factor endowments present the expected signs and are statistically significant (except for bad endowments). The dummy for the presence of several native cultures before colonization is not statistically related

with democracy in 1900. In contrast, the number of native cultures before colonization has a positive and significant impact on my measure of political decentralization in 1900. This evidence validates my theoretical assumption that the number of native cultures captures a different source of exogenous variation than the historical variables stressed by Acemoglu et al. (2001, 2002) and Engerman and Sokoloff (1997, 2002). Therefore, this variable allows me to pin down a potentially valid source of exogenous variation that is different from the other historical variables I use as instruments.

Second-stage results in Panel A of Table 4 presents estimates of the “horse-race” between the two institutional dimensions, democracy and political decentralization.<sup>14</sup> Results suggest that what matters more for primary enrollment in 1900 is democracy, which has a positive and significant effect on primary enrollment. At the same time, the political decentralization index is positive but statistically insignificant.

Table 5 presents results of structural estimates using data for 1985-1995. I use two measures of democracy (the Polity indicator and the Gastil index). In all these regressions, I include log of per-capita GDP as a control variable to capture the effect of income and other omitted variables related to the effects of development on schooling (See Banerjee, 2003 for a theoretical rationale for the effects of income on schooling that go beyond the traditional argument emphasizing the existence of liquidity or borrowing constraints). However, there is a potential endogeneity problem here because schooling also may affect per-capita GDP and the instruments are also related to this variable. Thus, in order to identify the effect of per-capita GDP on schooling, I use terms of trade shocks as an instrument for the level of income.<sup>15</sup> Arguably, this variable should not have a direct effect on schooling and on other variables and, therefore, can be used as an instrument for income.

First-stage results in Panel B of Table 5 confirm my theoretical assumptions.<sup>16</sup> The pres-

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<sup>14</sup>In previous versions of this paper I also included the share of income that goes to the middle class in 1900 and 1985-1995 as a potential variable related to historical factors and schooling. However, historical variables were only marginally significant in the first stage regression and can only account for 10% of the variability of the middle class share. These results suggest that middle class share is not a good candidate as a channel for explaining the effects of colonial factors on schooling in my sample of former colonies. Results available upon request.

<sup>15</sup>Specifically, I compute terms of trade shocks as the ratio of the average level of terms of trade in 1985-1995 with respect to 1960-1984.

<sup>16</sup>I only present the first-stage results for regressions using average years of schooling as the dependent variable to save space. The other first-stage regressions are qualitatively similar.



ence of native cultures is related only with decentralization (and uncorrelated with democracy and GDP per capita) and terms of trade shocks are correlated only with GDP. Settler mortality, population density and good factor endowments are correlated with both measures of democracy.

Second-stage results in Panel A of Table 5 present a pattern that suggests that democratization wins the race with decentralization when analyzing primary enrollment. In contrast, decentralization wins the race in most of the specifications for variables containing information on more advanced levels of schooling (the only exception is column 6).

These results confirm the theoretical discussion presented above and the historical background presented in Section 3.3: while democracy affects strongly development of initial instructional institutions and the quantity of education (related to the expansion of primary education), political decentralization is more important to explain the development of more advanced levels of education (related to secondary and higher education and the quality of education) that require instructional structures closer to the users. Both current and historical data support the idea that the relative importance of democracy and political decentralization changes for different levels of schooling.

The results presented in Table 5 suggest that local political power is a key feature in linking the colonial factors stressed in this paper and schooling outcomes. Note that the effects are not only statistically significant but also economically important. Using the results in columns (1) and (2), a country located in the upper 25% of the distribution of political decentralization has one year more of education than a country from the lower 25% of the distribution.<sup>17</sup>

Decentralization of political power may affect different dimensions of the management of the educational system by increasing the proximity between schools and users. This proximity may refer to the ability of educational systems to produce both a better match between curriculum and student needs and structures more accountable and reactive to the voice of users. An

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<sup>17</sup>These results contrast with those of Gennaioli and Rainer (2004), who present evidence that pre-colonial decentralization has a negative effect on the provision of education. Two factors could explain the differences. First, while my measure of decentralization already incorporates the relevance of local checks and balances, their measure captures only the degree of centralization of government (see footnote 9). Second, the interpretation of their results is not straight-forward because their measure of pre-colonial decentralization is difficult to disentangle from a proxy for state/stateless societies. In particular, the data suggest that their measure of pre-colonial decentralization *is not* correlated with current level of decentralization and *is negatively* correlated with measures of current and past democracy and current measures of governance.

alternative interpretation is that more decentralized systems are able to raise more resources from the local level.

Figure 2 presents initial evidence of the partial correlation between my two measures of school decentralization (decentralization of the management of schools and financial decentralization) and schooling, after controlling for democracy and the level of income. Results suggest that only decentralization of the management of schools is correlated with attainment.

I study formally which dimension of decentralization seems to be more related to school outcomes in Table 6. Panel A presents an IV regression of both indices of school decentralization on democracy, political decentralization, income, and the other control variables. Results suggest that decentralization of political power has a positive and significant effect on decentralization of school management, but an insignificant effect on decentralization of education finance. In turn, results in panel B suggest that decentralization of the management of schools has a positive and significant impact on educational attainment, secondary and higher education enrollment today. In contrast, estimates for primary enrollment show no effect of decentralization on school management.

Estimates for the effects of financial decentralization suggest that this variable has no significant effect on current educational outcomes. Moreover, over-identification tests indicate that the effect of the historical variables on advanced levels of schooling is not captured by financial decentralization. These results contrast with the over-identification tests when I include decentralization of school management: in this case, over-identification tests do not reject the null hypothesis that all the effects of historical variables on schooling are captured by democracy and decentralization of school management.

Overall, these results suggest that decentralization of management of schools at the local level is the variable that seems to explain the effect of political decentralization on current levels of schooling. In addition, as previously discussed, these results are consistent with Fuchs and Woessman (2004) and Woessman (2003), who stress the positive effects of decentralization of school management on educational outcomes and find negative or no effects of decentralization of school finance.<sup>18</sup>

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<sup>18</sup>I also run a series of robustness checks. Regressions excluding the so-called Neo-Europes and excluding countries with imputed schooling data present similar results to those reported in the main text. Also, I run a regression for primary enrollment in 1900 including a proxy for the level of per-capita income circa 1870 from

## 3.8 Conclusions

My paper shows how history affects schooling differences across countries today. I argue that differences in conditions faced by colonizers had a significant influence on educational policies in the past that persist to the present. Factors such as potential settler mortality, density of native population, the characteristics of factor endowments, and the numbers of native cultures before colonization have a considerable influence on schooling levels observed in 1900 and 1985-1995.

I also present evidence that a key channel behind the influence of historical factors on schooling is the extent of democracy and political decentralization. These results confirm some theoretical and empirical findings presented in the literature, but also qualify the traditionally emphasized effect of franchisement and democracy on schooling. In particular, I find that while democracy is a significant determinant of primary or elementary schooling, the degree of decentralization of political power and, particularly, the degree of decentralization of the management of schools at the local level are much more relevant to explain more advanced levels of instruction, such as secondary and higher education. The estimated effects are also economically relevant. For instance, my estimates imply that higher decentralization of school management in Latin America explains about 40% of the difference in schooling levels with Africa (equivalent to about 3 years of schooling). Similarly, my estimates for the effect of democracy on primary enrollment in 1900 can also account for about 40% of the differences in primary enrollment between African and Latin American countries in the same year (equivalent to 14 percentage points of enrollment).

Does the evidence in this paper imply that history is destiny and schooling levels can not be changed? No. The evidence in this paper suggests that educational institutions are endogenous and related to history. Thus, changing educational institutions is possible, but costly because it implies changing the distribution of political power in a society. The example of Malaysia is an interesting case study. While primary enrollment was close to the median enrollment in 1900, schooling in 1985-1995 was in the upper 25% of the distribution. Malaysia started having elections at the local level in the late 1960s and years of schooling increased sharply in the late 1970s. This example suggests an interesting line of future research: understanding

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Madison (2003) as an additional exogenous regressor. In this case, the basic results also remain unchanged.

the role of the expansion of local democracy in explaining the experiences of countries having “bad” historical factors, very low levels of educational systems in the past and high levels of human capital in the present. Putting it more broadly, can local power foster schooling even in countries with bad historical conditions?

### 3.9 Appendix: Benavot and Riddle (1988)

Benavot and Riddle (1988) build their database using a number of international and local sources of information. Some of the sources (such as Banks, 1971 and 1975; Mitchell, 1980, 1982, and 1983; and the Statesman’s Yearbook, various issues) have been used by economic historians.<sup>19</sup> However, the authors make three main contributions. First, they make a systematic effort to make compatible data from different sources. Second, they produce enrollment ratios using a similar and reasonable denominator for all countries (for the population ages 5-14).<sup>20</sup> Third, they add information on colonies and other less developed countries. These sources include documents by Colonial Office for 1890-1940 for a number of British colonies; Ortal, 1977 for Latin American countries; Flora et al., 1983 for Western European countries; early volumes of the U.S. Bureau of Education’s Report of the Commissioner of Education that reports the state of education in territories outside the US; publications in the area of comparative education presenting information for selected countries and colonies, such as Matthews and Akravi (1949) for Arab countries; and a number of government documents reporting information on education and population).<sup>21</sup>

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<sup>19</sup>Easterlin (1981) uses information from Banks and the Statesman’s Yearbook to construct his dataset of primary enrollments for 25 countries for 1830-1970. Clemens and Williamson (2000) use data from Easterlin (1981), Banks and Mitchell to construct a dataset of school enrollment for 34 countries for the 1970-1913 period. Lindert (2002) uses information from Banks to construct his dataset of public primary enrollment for 24 countries for the 1881-1937 period. Engerman et al. (1997) use data from Easterlin (1981), who, as mentioned, uses information from Banks and the Statesman’s Yearbook. Finally, Glaeser et al. (2004) use data from Lindert (2002).

<sup>20</sup>The age category used in the denominator comes from the classification used by UNESCO. The use of a similar age category for all countries has the benefit of giving a similar base to compare the intensity of primary education across countries. However, other sources, such as the data from the Global Development Network growth database, use measures of gross enrollment considering national definitions of age for primary education, and others present net enrollments in the numerator (i.e., considering only primary students of ages consistent with the denominator). Of course, it has to be said that the correlation among alternative measures of enrollment is quite high (Benavot and Riddle, 1988).

<sup>21</sup>The availability of information for a big group of countries creates a tremendous difference for the purposes of this paper. For example, Easterlin (1981) incorporates data for only 9 former colonies; Lindert (2002) for only

The figures reported by Benavot and Riddle (1988) are correlated with those found in other databases, suggesting that there are no important methodological differences or differences in underlying assumptions across different databases. The correlation of Benavot and Riddle's (1988) enrollment rates with those of Easterlin (1981) is 0.995 and with those of Lindert (2002) is 0.996. In addition, the correlation between literacy rates presented by Engerman and Sokoloff (2002) for a sample of 17 former colonies of the Americas and Benavot and Riddle's (1988) primary enrollment rates is 0.84 circa 1900. This last correlation shows that different measures of schooling were related in 1900 and thus supports the implicit assumption of this paper, i.e., that primary enrollment rates are good proxies for education in 1900.

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7 former colonies; and Clemens and Williamson (2000) for only 15 former colonies.

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**Table 1: Descriptive Statistics**

	Observations	Average	Median	Standard Deviation	Percentile 5	Percentile 95	Source
<b>Schooling Variables</b>							
Primary Enrolment in 1900	76	17.6	7.9	23.8	0.2	87.3	Benavot and Riddle (1988)
Average years of education in 1985-1995	69	4.6	4.2	2.7	0.8	11.0	Barro and Lee (2001), Cohen and Soto (2001)
Primary enrollment in 1985-1995	58	66.6	66.9	23.9	2.4	98	GDN Growth Dataset
Secondary enrollment in 1985-1995	58	29.7	26.9	19.7	3.2	77.7	GDN Growth Dataset
Higher education enrollment in 1985-1995	58	6.7	3.5	9.3	0.4	34.9	GDN Growth Dataset
<b>Historical Variables</b>							
Log of Settler Mortality	72	4.6	4.4	1.2	2.7	6.5	Acemoglu et al. (2001, 2002)
Log of Population Density in 1500	72	0.53	0.43	1.71	-2.41	3.17	Acemoglu et al. (2002)
Good Endowments	72	0.69	1.00	0.46	0	1	Easterly and Levine (2004)
Bad Endowments	72	0.81	1.00	0.40	0	1	Easterly and Levine (2004)
Several Indigenous Ethnic groups	75	0.33	0	0.47	0	1	Murdock (1967)
Catholic, 1985	72	40.1	27.3	36.2	0.2	92.4	La Porta et al. (1999)
Muslim, 1985	72	22.3	3.9	33.0	0	99.1	La Porta et al. (1999)
Other (Non-Protestant) Religion, 1985	72	25.9	20.4	24.5	0.5	84.1	La Porta et al. (1999)
Catholic, 1900	72	28.8	3.2	39.7	0	98.0	Barrett (1982)
Muslim, 1900	72	16.0	0.5	28.5	0	86.6	Barrett (1982)
Other (Non-Protestant) Religion, 1900	72	42.8	34.7	39.3	0.5	99.4	Barrett (1982)
British	76	0.37	0	0.49	0	1	CIA
French	76	0.28	0	0.45	0	1	CIA
Spanish	76	0.24	0	0.42	0	1	CIA
<b>Institutional and Economic Variables</b>							
Democracy in 1900	76	1.1	0	2.46	0	9	Polity IV
Democracy, 1985-1995	59	4.4	4.0	3.49	0	10	Polity IV
Castil Index, 1985-1995	59	0.53	0.53	0.26	0.18	1	Freedom House
Political Decentralization, 1985-1995	69	0.03	-0.16	0.86	-0.85	1.97	Beck et al. (2000) and Polity IV
Political Decentralization, 1900	76	1.15	1	0.49	1	3	Polity IV
Decentralization of school management	65	0.32	0	0.47	0	1	UNESCO World Data on Education
Decentralization of school finance	65	0.43	0	0.68	0	2	UNESCO World Data on Education
Log Per-Capita GDP 1995	76	7.18	6.99	1.42	5.26	10	GDN Growth Dataset
Terms of Trade Growth (ratio)	63	1.14	1.10	0.26	0.77	1.71	GDN Growth Dataset

**Table 2: Democracy and Schooling**

Panel A: Panel Data Estimates: Primary Enrollment and Democracy, 1870-1940						
	Primary Enrollment			Democracy		
Democracy (-10)	0.140 (0.243)			0.312 (0.052)		
Democracy (-20)		0.670 (0.292)			0.059 (0.145)	
Democracy (-30)			0.702 (0.362)			-0.143 (0.173)
Primary Enr. (-10)	0.586 (0.040)			0.001 (0.009)		
Primary Enr. (-20)		0.293 (0.043)			-0.004 (0.140)	
Primary Enr. (-30)			0.069 (0.054)			0.006 (0.011)
N/countries	403/73	334/71	263/67	409/72	337/72	265/67

Notes: This panel presents panel data regressions for the equation  $S_{jt} = \alpha + \beta D_{j(t-n)} + \delta S_{j(t-n)} + \eta_j + t_t + \varepsilon_{jt}$ , where  $S_{jt}$  is primary enrollment in country  $j$  and year  $t$ ,  $D$  is democracy,  $\eta$  are country fixed-effects, and  $t$  are time fixed-effects.

Panel B: Cross-section estimates: Schooling today and Institutions in 1900				
Democracy in 1900	-0.26 (0.11)	-0.24 (0.14)	1.20 (0.93)	1.94 (1.32)
European Population in 1900	5.60 (1.30)	5.62 (1.60)	-0.63 (5.44)	4.31 (7.76)
Primary Enrollment in 1900	0.06 (0.01)	0.05 (0.01)	0.16 (0.04)	0.14 (0.09)
Observations	69	69	59	59
Estimation technique	OLS	OLS	IV	IV
Including controls?	No	Yes	No	Yes

Notes: This panel presents cross-section regressions for the equation  $S_i = \alpha + \beta_1 Dem_i + \beta_2 Eur_i + \beta_3 Enroll_i + X' \gamma + \varepsilon_i$ , where  $S_i$  is an educational outcome in 1995,  $Dem$  is democracy in 1900,  $Eur$  is the share of the European population in 1900,  $Enroll$  is primary enrollment in 1900, and  $X$  is a vector of controls (including religion variables and the identity of the main colonizer). Instruments for  $Dem$ ,  $Eur$ , and  $Enroll$  are settler mortality, population density in 1500, and Protestant missionaries in 1900, respectively. F-Test presents the p-value for the global significance of the second stage and the over-identification test presents the p-value for a test that the instruments are orthogonal to the second-stage residuals. White-Huber robust standard errors are shown in parentheses. Constants and religion and colonizer variables are not reported.

**Table 3**  
**Reduced-Form Estimates: Educational Outcomes in 1900 and 1985-1995**

Dependent Variable	Primary enrollment in 1900	Average Years of Schooling in 1985-1995	Primary education enrollment in 1985-1995	Secondary education enrollment in 1985-1995	Higher education enrollment in 1985-1995					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Log of settler mortality	-0.08 (0.02)	-0.02 (0.02)	-1.21 (0.17)	-0.98 (0.17)	-0.13 (0.02)	-0.09 (0.02)	-0.09 (0.02)	-0.06 (0.02)	-0.03 (0.01)	-0.02 (0.01)
Log of population density in 1500	-0.06 (0.01)	-0.04 (0.01)	-0.54 (0.10)	-0.39 (0.11)	-0.05 (0.01)	-0.03 (0.01)	-0.03 (0.01)	-0.03 (0.01)	-0.02 (0.01)	-0.02 (0.01)
"Good endowments"	0.67 (0.13)	0.36 (0.10)	2.09 (1.23)	2.15 (1.20)	0.12 (0.05)	0.13 (0.11)	0.22 (0.05)	0.22 (0.09)	0.25 (0.05)	0.20 (0.05)
"Bad endowments"	-0.22 (0.14)	-0.14 (0.07)	-1.56 (0.89)	-1.96 (0.71)	0.09 (0.05)	-0.04 (0.06)	-0.11 (0.07)	-0.09 (0.07)	-0.13 (0.06)	-0.13 (0.06)
Several native cultures	-0.03 (0.04)	0.01 (0.03)	0.78 (0.37)	0.81 (0.36)	0.05 (0.08)	0.00 (0.08)	0.07 (0.04)	0.08 (0.04)	0.05 (0.02)	0.05 (0.02)
British colony		0.07 (0.05)		-1.01 (0.70)		-0.03 (0.07)		0.23 (0.10)		0.07 (0.06)
French colony		-0.02 (0.05)		0.25 (0.70)		-0.14 (0.08)		0.12 (0.10)		0.00 (0.05)
Spanish colony		0.05 (0.09)		1.22 (0.80)		-0.09 (0.07)		0.19 (0.09)		0.05 (0.05)
Catholic population		-0.51 (0.13)		-0.03 (0.02)		-0.22 (0.31)		-0.27 (0.33)		-0.17 (0.16)
Muslim population		-0.51 (0.10)		-0.03 (0.02)		-0.32 (0.26)		-0.25 (0.26)		-0.16 (0.13)
Other (Non-protestant) religion population		-0.57 (0.10)		-0.02 (0.02)		-0.17 (0.33)		-0.21 (0.31)		-0.21 (0.14)
R <sup>2</sup>	0.56	0.85	0.75	0.82	0.64	0.77	0.66	0.76	0.73	0.8
Number of Observations	68	68	60	60	51	51	44	44	44	44

Note: This panel presents OLS regressions for the cross-section of countries for the equation  $S_i = \alpha + C_i\beta + X_i'\gamma + \varepsilon_i$ , where  $S_i$  is an educational outcome in country  $i$ ,  $C$  is a vector of colonial and historical variables (settler mortality, population density in 1500, "good" endowments, "bad" endowments, and the presence of several cultures), and  $X$  is a matrix of controls (including religion variables and the identity of the main colonizer). White-Huber robust standard errors are shown in parentheses. Constants are not reported.

**Table 4**  
**Structural Estimates: Educational Outcomes 1985-1995**

<b>Panel A: Second Stage Regression</b>		
Dependent Variable	Primary Enrollment in 1900	
Democracy, 1900	3.45 (0.98)	
Political Decentralization, 1900	6.55 (5.21)	
F-Test (p-value)	0.00	
Number of Observations	68	
Over-identification test (p-value)	0.31	
<b>Panel B: First Stage Regressions</b>		
Dependent Variable	Political Decentralization	Democracy
"Several native cultures at colonization"	0.32 (0.14)	0.69 (0.52)
Log of settler mortality	-0.10 (0.05)	-0.87 (0.24)
Log of population density in 1500	-0.12 (0.04)	-0.50 (0.19)
"Good endowments"	0.77 (0.37)	6.61 (1.05)
"Bad endowments"	-0.15 (0.37)	-2.98 (1.82)
R <sup>2</sup>	0.40	0.54

Note: These tables present instrumental variables regressions for the cross-section of countries for the equation  $S_i = \alpha + \beta_1 Dec_i + \beta_2 Dem_i + X' \gamma + \varepsilon_{i.}$ , where  $S_i$  is primary enrollment in 1900 in country  $i$ ,  $Dec$  is decentralization in 1900,  $Dem$  is democracy in 1900, and  $X$  is a vector of controls (including religion variables and the identity of the main colonizer). Instruments for  $Dec$  and  $Dem$  are a group of historical variables (settler mortality, population density in 1500, and factor endowments) and a dummy if the number of indigenous cultures is greater than 1. F-Test presents the p-value for the global significance of the second stage and the overidentification test presents the p-value for a test that the instruments are orthogonal to the second-stage residuals. White-Huber robust standard errors are shown in parentheses. Constants and religion and colonizer variables are not reported.

**Table 5**  
**Structural Estimates: Educational Outcomes 1985-1995**

Dependent Variable	Panel A: Second-stage Regressions											
	Average Years of Schooling in 1985-1995	Primary education enrollment in 1985-1995	Secondary education enrollment in 1985-1995	Higher education enrollment in 1985-1995	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Democracy 1985-1995	0.04 (0.14)		3.38 (1.59)		-0.94 (1.92)	-17.30 (32.53)		0.56 (0.84)				16.6 (13.68)
Gastil Index, 1985-1995		0.55 (2.39)		53.72 (25.12)								2.55 (2.27)
Political Decentralization, 1985-1995	0.88 (0.47)	0.92 (0.53)	-2.84 (7.18)	-3.32 (7.39)	10.88 (5.76)	11.8 (6.85)		3.98 (2.47)				2.55 (2.27)
Log of Per-Capita GDP	1.05 (0.16)	1.02 (0.18)	10.27 (2.37)	9.09 (2.61)	7.26 (1.26)	7.51 (1.53)		2.81 (0.63)				2.34 (0.59)
Over-identification test (p-value)	0.30	0.30	0.19	0.18	0.93	0.94		0.35				0.38
Number of Observations	50	49	44	43	44	43		44		43	44	44



Table 5 cont'd

Dependent Variable	Panel B: First Stage Regression			Log of GDP
	Political Decentralization	Democracy	Civil Liberties	
"Several native cultures at colonization"	0.59 (0.27)	0.49 (0.85)	0.49 (0.85)	-0.12 (0.21)
Log of settler mortality	-0.16 (0.09)	-1.36 (0.30)	-1.36 (0.30)	-0.39 (0.07)
Log of population density in 1500	-0.13 (0.06)	-0.84 (0.19)	-0.84 (0.19)	-0.26 (0.05)
"Good endowments"	1.78 (0.22)	6.18 (1.07)	6.18 (1.07)	-0.14 (0.16)
"Bad endowments"	-0.42 (0.27)	1.50 (1.10)	1.50 (1.10)	-0.55 (0.21)
Terms of trade shocks	0.06 (0.46)	-0.99 (1.45)	0.00 (0.10)	0.68 (0.28)
R <sup>2</sup>	0.37	0.54	0.54	0.71
Number of Observations	54	56	56	61

Note: This panel presents instrumental variables regressions of the equation  $S_i = \alpha + \beta_1 Dec_i + \beta_2 Dem_i + \beta_3 Y_i + X' \gamma + \varepsilon_i$ , where  $S_i$  is an educational outcome in 1995,  $Dec$  is decentralization in 1995,  $Dem$  is democracy in 1995,  $Y$  is income and  $X$  is a vector of controls (including religion variables and the identity of the main colonizer). Instruments for  $Dec$ ,  $Dem$ , and  $Y$  are a group of historical variables (settler mortality, population density in 1500, and factor endowments), a dummy if the number of indigenous cultures is greater than 1, and terms of trade shocks, respectively. F-Test presents the p-value for the global significance of the second stage and the over-identification test presents the p-value for a test that the instruments are orthogonal to the second-stage residuals. White-Huber robust standard errors are shown in parentheses. Constants and religion and religion and colonizer variables are not reported.

**Table 6**

**Indices of Education Decentralization and Schooling**

**Panel A: Education Decentralization and Political Decentralization**

Dependent Variable:	Decentralization of School Management	Decentralization of School Finance
Democracy, 1985-1995	0.221 (0.472)	0.135 (0.086)
Political Decentralization, 1985-1995	0.327 (0.164)	0.212 (0.277)
Log of Per-Capita GDP	0.022 (0.342)	0.049 (0.076)
Number of Observations	46	46
Over-identification test (p-value)	0.524	0.288

Note: This panel presents instrumental variables regressions for the cross-section of countries for the equation  $SD_i = \alpha + \beta_1 Dec_i + \beta_2 Dem_i + \beta_3 Y_i + X_i' \gamma + \varepsilon_i$ , where  $SD_i$  is an index of school decentralization for country  $i$ ,  $Dec$  is decentralization,  $Dem$  is democracy,  $Y$  is income and  $X$  is a vector of controls (including religion variables and the identity of the main colonizer). Instruments for  $Dec$ ,  $Dem$ , and  $Y$  are a group of historical variables (settler mortality, population density in 1500, and factor endowments), a dummy if the number of indigenous cultures is greater than 1, and terms of trade shocks. F-Test presents the p-value for the global significance of the second stage and the over-identification test presents the p-value for a test that the instruments are orthogonal to the second-stage residuals. White-Huber robust standard errors are shown in parentheses. Constants and religion and colonizer variables are not reported.

**Table 6 cont'd**  
**Indices of Education Decentralization and Schooling**

<b>Panel B: Structural Estimates: Educational Outcomes 1985-1995</b>									
Dependent Variable	Average Years of Schooling in 1985-1995	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Primary education enrollment in 1985-1995	Secondary education enrollment in 1985-1995	Higher education enrollment in 1985-1995			
Democracy 1985-1995	0.04 (0.20)	0.33 (0.26)	3.92 (1.48)	4.24 (2.29)	0.05 (1.76)	0.89 (1.96)	0.12 (1.19)	1.26 (1.29)	
Decentralization of School Management	2.41 (1.15)		-3.6 (13.77)		18.65 (10.86)		16.35 (8.48)		
Decentralization of School Finance		-0.15 (0.97)		-3.52 (13.14)	4.44 (7.10)			1.29 (5.33)	
Log of Per-Capita GDP	1.16 (0.02)	1.15 (0.26)	9.29 (2.12)	9.18 (1.98)	9.05 (1.76)	8.87 (2.22)	4.15 (1.01)	4.09 (1.16)	
Over-identification test (p-value)	0.49	0.01	0.15	0.28	0.29	0.03	0.89	0.03	
Number of Observations	50	50	44	44	44	44	44	44	44

Note: This panel presents instrumental variables regressions for the cross-section of countries for the equation  $S_i = \alpha + \beta_1 SD_i + \beta_2 Dem_i + \beta_3 Y_i + X_i' \gamma + \varepsilon_i$ , where  $S_i$  is average years of schooling in country  $i$ ,  $SD_i$  is an index of school decentralization,  $Dem_i$  is democracy,  $Y_i$  is income, and  $X_i$  is a matrix of controls (including religion variables and the identity of the main colonizer). Instruments for  $Dec$ ,  $Dem$ , and  $Y$  are a group of historical variables (settler mortality, population density in 1500, and factor endowments), a dummy if the number of indigenous cultures is greater than 1, and terms of trade shocks. F-Test presents the p-value for the global significance of the second stage and the over-identification test presents the p-value for a test that the instruments are orthogonal to the second-stage residuals. White-Huber robust standard errors are shown in parentheses. Constants and religion and colonizer variables are not reported.

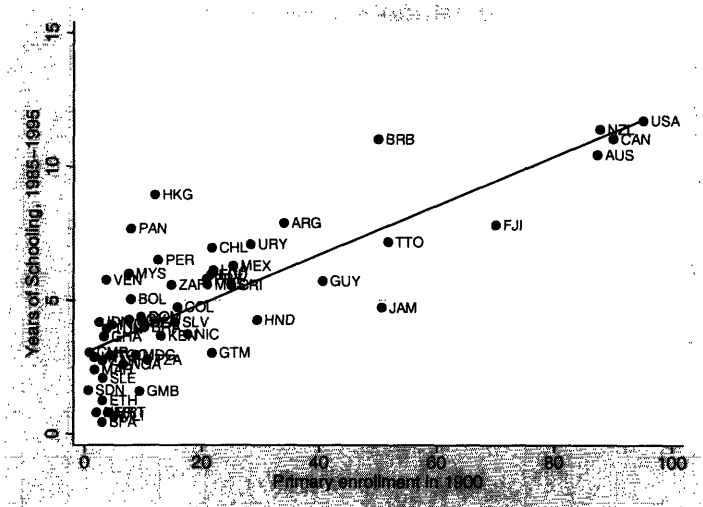


Figure 1, Panel A: Persistence of Schooling, Complete Sample

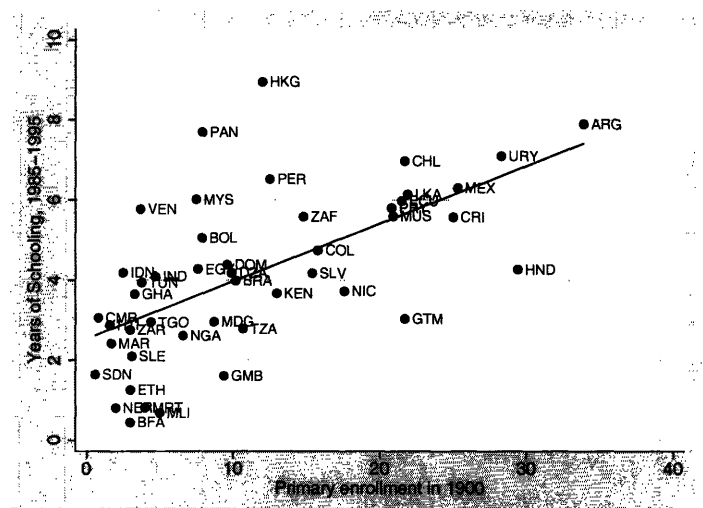


Figure 1, Panel B: Persistence of Schooling, Sample Excluding Primary Enrollment above 40%

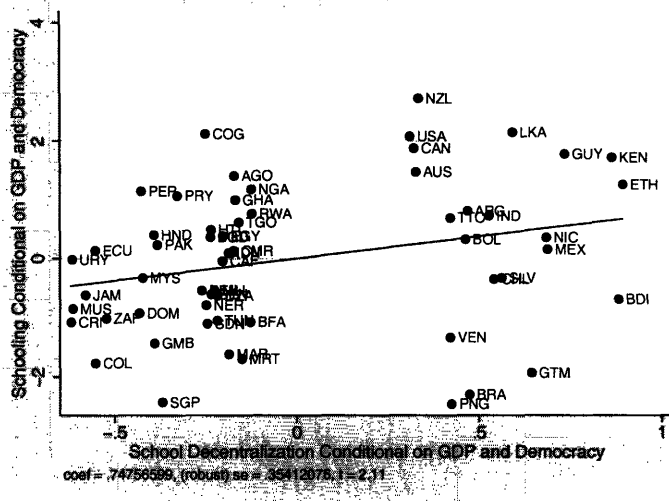


Figure 2, Panel A: Schooling and Decentralization of School Management

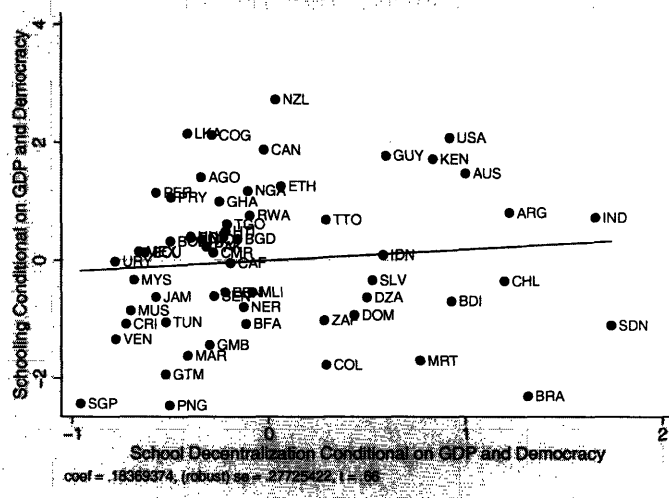


Figure 2, Panel B: Schooling and Decentralization of School Finance



## Chapter 4

# Christian Missionaries and Education in Former Colonies: An Early Example of the Economics of School Choice?<sup>1</sup>

### 4.1 Introduction

Educational attainment varies widely across countries. Average years of schooling are two years higher in the former British colonies than in non-British colonies. Within Africa, the median region in a Catholic state (defined according to Barro and McCleary, 2004) currently has a literacy rate of about 33% and an educational level of about 1.3 years of schooling. In contrast, the median region in a non-Catholic state has significantly better educational outcomes: a literacy rate of about 48% and about 3.3 years of schooling. These differences in schooling levels predate the present. In 1900, while non-Catholic countries in Africa had an average primary enrollment of 4.6%, Catholic countries had an average primary enrollment rate of

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<sup>1</sup>Joint with Robert Woodberry. We would like to thank Daron Acemoglu, David Autor, Dora Costa, and seminar participants at the Harvard University and the Catholic University of Chile for useful comments and suggestions; Norman Loayza and Koichi Kume for providing us the African data sets used in this paper; and Pamela Siska for editing help. Gallego thanks the MIT World Economy Laboratory for financial support. The usual disclaimer applies.

0.9%.

This paper analyzes how national identity, religion, and institutions explain educational outcomes in the former colonies by seeing how differences in market structure affected the provision of education by Christian missionaries in former colonies. Christian missionaries were central agents in the development of the educational systems in former colonies. In most former colonies, the first schools were founded by missionaries (as in British colonies) or were managed by priests as agents of the colonial power (as in most Belgian, Portuguese, and Spanish colonies). Interestingly, different colonial powers had very different regulations affecting missionaries. While in British and German colonies there was a relatively neutral policy allowing both Catholic and Protestant missionaries to operate under similar conditions, in Spanish, Belgian, and Portuguese colonies there were implicit or explicit policies favoring the Catholic Church. The policies ranged from those directly granting the monopoly of production of education to Catholic groups (including harsh barriers of entry to non-Catholic groups) to those providing subsidies to Catholic schools (See Woodberry, 2002, 2004 and Gill, 1998 for detailed descriptions).

Economic theory predicts that these differences in the institutional environment should affect missionaries' productivity. Parents who choose schools consider differences in school quality, missionaries want to maximize the number of children that attend their schools, and production of school quality is costly for missionaries. Thus, while the productivity of Protestant and Catholic missionaries should be similar in colonies where both groups have to compete for students, Protestant missionaries should be especially productive in areas where Catholic missionaries are protected.

This paper uses data on educational outcomes combined with detailed information on the activities of Protestant and Catholic missionaries to examine their productivity in both Catholic and non-Catholic countries. Woodberry (2002, 2004) document that Protestant missionaries were much more active in schooling than Catholic missionaries when country regulations benefited the Catholic Church. Anecdotal evidence (Bassey, 1999; Kalinga, 1985; Fairweather-Tall, 2002; Kitaev, 1999; and, Woodberry and Shah, 2004) suggests that both Catholic and Protestant missionaries competed by followers by expanding and improving their educational institutions in former British colonies, where both groups received the same treatment. This



paper examines missionary activity in both Catholic and non-Catholic countries.

Studies of the relative importance of national identity, religion, and institutions have a long tradition in economic history. Weber (1958) argued that Protestant (in particular Calvinist) beliefs were related to the onset of capitalism and the subsequent development of areas with bigger Protestant populations. In contrast, by emphasizing the importance of competition as opposed to religious and national identity, our results are closely related to the literature that emphasizes the effects of competition and institutions versus national identity or religion on long-term development (e.g., Acemoglu et al., 2001, 2002; Landes, 1998; La Porta et al., 1998, 1999; North, 1990; North et al., 2000).<sup>2</sup> This paper draws on the insights of two literatures. One line of research studies the effect of historic factors on the development of institutions and cross-country differences in educational outcomes (e.g., Engerman et al., 1997, Gallego, 2006; Lindert, 1999), concluding that political institutions established in the past have long-lasting effects on educational outcomes. The second line of research examines how the incentives faced by providers of education affect the provision of education at the micro level (e.g., Hoxby, 2003).

This paper is organized as follows. Section 4.2 presents a review of the non-economic literature and some historical background. Section 4.3 presents an economic interpretation that produces testable empirical implications: Catholic and Protestant missionaries should be similarly productive in areas with non-Catholic states and Protestant missionaries should be more productive in Catholic states. Section 4.4 describes the empirical strategy to contrast the theoretical predictions against the data. Sections 4.5 and 4.6 present the results of testing the empirical predictions of the model using a cross-country sample of former colonies and a sample of African regions, respectively. Finally, Section 4.7 briefly concludes.

## 4.2 Non-Economic Literature and Historical Background

The link between education and religious activity is very old. There is almost no civilization with a developed religion in which instruction was not related or directly provided by the

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<sup>2</sup>However, it is worth noting that, when discussing educational differences, Landes (1998) stresses a *Weberian* argument by stating that Protestants were more interested in instruction and literacy than Catholics because “good Protestants were expected to read the holy scriptures by themselves. (By way of contrast, Catholics were catechized but did not have to read, and they were explicitly discouraged from reading the Bible)” (Landes, 1998, pp. 178).

main religious institutions (e.g., consider the cases of Egypt, the Ottoman Empire, and some early Chinese and Indian dynasties). The same is true for most Christian denominations. In the times of the Roman Empire, the Church started to have significant responsibilities in providing education. However, it was not until the Reformation and Counter-Reformation that the Catholic and Protestant Churches began to develop a mass-education approach. Since then Catholic orders and Protestant denominations have developed a strong involvement in the provision of education.<sup>3</sup> The motivation for providing education has ranged from altruistic objectives related to improving the quality of life of children to instrumental objectives related to gaining more followers.

Before colonization, religious groups had accumulated an abundance of know-how and experience in instruction. Thus, when colonization started, the colonial powers allowed missionaries to establish schools. The degree of missionaries' responsibility in running schools varied across colonial powers. In British and Dutch colonies, the *laissez-faire* ideology that was predominant in the motherland until the end of the 19th century translated to colonial policies. This implied that there was a relatively neutral approach to missionaries and in most cases the colonial offices even gave similar economic support to Catholic and Protestant missionaries. Unlike British and Dutch colonies, Spanish, Portuguese, and Belgian colonies had a more explicit bias towards the Catholic Church's involvement in education. This bias took the form of a number of regulations favoring the Church and limiting the influence and actions of Protestant missionaries in general and, in particular, in education.

Various reasons motivated missionaries to provide education. Missionaries came to the colonies with a high degree of experience in working in schools in their homelands. At the same time, there were very low costs of entry in education (especially in comparison with other activities such as health care). Some historians stress that education was *the* Western feature that was especially notorious and new for native people, in comparison to other elements such as health care and even the idea of the existence of one God (Basse, 1999 and Berman, 1974). Moreover, schooling was a particularly useful way of converting people—a missionary working in Nigeria put it this way: “*We knew the best way to make conversions in pagan countries was*

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<sup>3</sup>For instance, among Catholic groups, the Jesuits and a number of Catholic orders started actively working in educational institutions during the Counter-Reformation. Among Protestant groups, the Lutheran Church in Germany and the Scottish Presbyterians developed a mass-education system during the Reformation.

*to open schools. Practically all pagan boys asked to be baptized. So, when the district (...) was opened (in 1916) we started schools even before there was any church or mission house.*" (Quoted in Basse, 1999).

Sociologists have noted the relationship between religious variables and education. The main conclusion of the sociological studies is that former British colonies tend to have more schooling. This pattern has been explained by the claim that Protestants put more emphases on formal instruction (Landes, 1998 Meyer, et al., 1992; Ramirez and Boli, 1987).<sup>4</sup> More recently, Woodberry (2002, 2004) show that when controlling for Protestant missionary activity, colonizer identity is irrelevant. Woodberry collected data on Protestant missionary activity in former colonies and presents an analysis linking missionary activity and schooling. His main empirical result is that the often-reported positive effect on schooling of being a former British colony disappears when controlling for missionary activity. Conceptually, he argues that Protestant missionaries had a significant effect on schooling for at least two reasons. First, using a Weberian argument similar to Landes (1998), Protestant missionaries were more interested in instruction because "...[they] wanted people to read the Scriptures in their own language (p.27)". In contrast, Woodberry (2002, 2004) argues that Catholic missionaries, in those times, did not put emphasis on whether people were able to read the Bible. Thus, Protestant missionaries were much more interested in having literate believers and, therefore, they initiated mass education. Second, Protestant missionaries acted more independently of the homeland and, therefore, were able to implement the educational practices they wanted, even if the colonial officials were not interested in (or even were opposed to) providing good education.<sup>5</sup> From a more institutional perspective, as previously discussed, British colonies had a more open approach to Protestant missionaries and, therefore, they had more missionary activity. Thus, Protestant missionaries's keener interest in providing education and their great ability to do so, combined with institutional features favoring more entry of Protestant missionaries in British colonies would explain the difference in educational outcomes. In all this literature, however, the implicit assumption is that Catholic and Protestant missionaries provided education of different qualities.

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<sup>4</sup>Some recent economics papers also find support for the idea that religious affiliation and economic and social outcomes (e.g., Gruber, 2005).

<sup>5</sup>This claim is supported by the historical record for Latin America, where some Catholic clergymen were interested in providing education but did not pursue this aim (or even were expelled from the country as the Jesuits in Paraguay) because opposition from colonial officials and settlers (Deeds, 2004).

Analyses based on the role of missionaries in British colonies in Africa, however, cast doubt on the idea that Catholic missionaries were not as interested in providing good education as Protestant missionaries were. Bassey (1999) describes Catholic missionaries competing with Protestant groups and even seeming to be the more innovative group in schools. Bassey's book provides numerous examples of how different missionaries innovated in order to get more students. For instance, he documents that "Catholics taught the English language in their schools from the early grades while the Church Missionary Society (CMS, a Protestant group) frowned upon the teaching of English in their schools. The teaching of English was of particular attention to students and parents alike. . . Perceiving the threat posed by the Roman Catholics curriculum to the CMS missionary field, . . . the CMS started teaching English in their schools. . ." (pp.72-73). Something similar happened regarding the establishment of high schools by Catholics in Onitsha in 1901.

Fairweather-Tall (2002) presents a similar account for the case of Malawi. In the early 1920s, there was discussion between colonial officials and Protestant ministers about whether to establish or not secondary schools. In the mean time, the newly arrived French White Fathers established "illegal" secondary schools. This act immediately created incentives for Protestant groups to open secondary schools when parents started sending their children to the Catholic schools. These examples show that in countries where Catholic missionaries were forced to compete with other denominations, they were innovative in gaining students. Similar descriptions are presented by Kitaev (1999) for some regions of Kenya and Uganda, Kalinga (1985) for Malawi, Ilife (1979) for Tanzania, and Lomawaima (1994) for competition among missionaries for educating the Chilocco in North America.

The historical record provides interesting evidence suggesting that consumers (i.e., parents) cared about quality of education. Bassey (1999) and Berman (1974) present anecdotal evidence supporting the view that consumers did consider the quality of missionary schools when deciding where to send their children. In addition, Bassey (1999) presents some detailed examples of how local chiefs in Nigeria decided which missionary group had the right to operate schools based on the quality of the offers they received. This evidence supports the notion that consumers considered the quality of education when choosing among different education providers.

Other papers suggest that missionaries made "rational" decisions in the sense that market

conditions affected their behaviors.<sup>6</sup> For instance, Catholic missionaries offered very different styles of education in Catholic vs. non-Catholic colonies. In Catholic states, Catholic missionaries were not as innovative and active as in non-Catholic states, where they implemented more advanced policies such as secondary education and the teaching of English. But, in areas where Catholic missionaries faced direct competition from other missionaries and had to compete for students, Catholic missionaries were very innovative and pushed for the very same aspects that were absent in their work in Catholic countries.<sup>7</sup>

Overall, the anecdotal evidence discussed in this section suggests that (i) missionaries were important agents in the development of educational systems in former colonies, (ii) regulations affecting missionary work varied in Catholic and non-Catholic colonies, (iii) Protestant missionaries seem to have been more productive than their Catholic counterparts in countries with protections in favor of Catholic missionaries, and (iv) Catholic missionaries were at least as active and innovative as their Protestant counterparts regarding education in places where they did not have state protection and support. The next section develops an economic interpretation of the last two results.

### 4.3 An Economic Interpretation

In this section, we present a simple economic interpretation of the main stylized facts derived in the previous section. The key element in this interpretation is that different missionaries operated under dissimilar institutional/market structures in different areas. British colonies had a highly competitive environment in which missionaries from different denominations had to compete for students. Dutch and German colonies are located closer to British colonies in terms that they did not establish protections in favor of the Catholic Church. In contrast, Belgian, Portuguese, and Spanish former colonies (Catholic states hereafter) had a clear bias towards Catholic missionaries, which had a sort of monopolistic position there.<sup>8</sup> Thus, Protes-

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<sup>6</sup>In addition, research on the economics of religion and on the effects of religious market structure on churches' decisions shows that these institutions do strongly react to competitive incentives in a variety of ways (e.g., Iannaccone, 1998).

<sup>7</sup>For instance, in 1901 the Mill-Hill Fathers offered English, Math, Geography, and even Music in their mission schools in British Africa (Beck, 1966).

<sup>8</sup>Classifying the French among these two groups is not clear-cut. While over the initial period of colonization France certainly favored the Catholic Church, the French colonies saw a neutral treatment of missionaries over

tant missionaries had to be particularly efficient to overcome the Catholic advantages. But in British, Dutch, and German colonies (non-Catholic states hereafter), the religious affiliation of missionaries was not relevant because they operated under competitive rules and, therefore, if missionaries were inefficient, they would lose students (and potential followers).

Formally, assume that there are two groups competing for a certain number of students. Parents value quality and are in the same location. Each group can decide how much education to provide given its resources. Assume that missionaries can use their resources in objectives other than producing instruction (for instance, evangelizing or just consuming resources that are valuable for the missionaries themselves and not for students).

We first present the case in which both missionary groups are treated equally. Assume, moreover, that the market can be modeled as Bertrand competition in quality of schooling. Assume that both missionary groups have the same level of resources and that if both groups offer the same quality, half of the students go to schools of each denomination. In this simple set up, the optimal response is that both groups produce the same level of education given their resources, and that half of the students goes to each school.

The existence of another group of providers with potentially similar characteristics and the threat of losing students create incentives to provide a level of education such as missionaries do not earn rents. Also, in this scenario, missionary identity does not matter because parents choose the school that offers the highest quality. We may expect that each missionary that is operating in the market should provide the same level of quality given her resources. Thus, the main empirical implication is that in Bertrand-like markets identity does not matter and both groups should have the same effect on schooling. We expect this theoretical result to be relevant in countries having non-Catholic states in 1900.

The situation in countries having Catholic states is different. There were barriers to entry and subsidies favoring Catholic missionaries. Thus, the implicit logic of Bertrand competition does not apply to these markets. There are many ways of modeling the situation: we present two simple cases motivated by the historical record:

- Protestant missionaries could only establish schools if they were located a certain distance

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the period analyzed in this paper (from the early XX century).

from Catholic missionaries. For instance, Woodberry (2002, 2004) mention that the Portuguese allowed Protestants to enter Angola and Mozambique, but banned Protestant mission stations from being located near Catholic missions (generally about 20 miles). In this case, the only way that Protestant missionaries could have positive enrollment is by offering a school quality level that was strictly *above* the quality offered by Catholic missionaries.<sup>9</sup>

- Catholic missionaries received a certain share of the student population irrespective of the level of education they provided. This could be an equilibrium result of the limited supply of Protestant missionaries –and, therefore, Protestant schools—in Catholic colonies. For instance, Woodberry (2002, 2004) document that some Catholic colonial powers, as Italy, banned the entry of missionaries to some of their colonies. Other regulations limited the entry in a more indirect way. For instance, most Catholic colonizers required all education to be in the colonial language. As most Protestant missionaries were primarily English speakers, they needed to spend some years to gain the required linguistic fluency before going to the colonies.

Therefore, in many cases Catholic missionaries had a captive population given by the absence of competitors. This situation allowed them to keep students without offering a high level of school quality. Protestant missionaries did not receive these protections, so they had to be especially productive if they were going to have students. Assuming that missionaries have to provide the same education for all students that attend their schools and assuming the typical properties of the benefits and costs functions (concave benefit functions and convex cost functions), we get the result that Protestant missionaries should have offered, in most cases, a quality level above that offered by Catholic missionaries.

Therefore, these two simple cases generate the same prediction: Protestant missionaries should have been more productive in areas in which Catholic missionaries received preferential

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<sup>9</sup>Formally, assume a Hotelling (1929)-like model. Parents  $i$  maximize a utility function of the form  $U_{ij} = q_j - t(l_j - l_i)^2$ , where  $q_j$  is quality in school  $j$ ,  $l_j$  is the location of school  $j$ ,  $l_i$  is the location of parents  $i$ , and  $t$  is a transportation cost. Assume the location of all parents is the same:  $l_i = 0$ . The Catholic school is also located at  $l_C = 0$  (where  $C$  refers to the Catholic school). Assume the Protestant school can only be located at  $l_P = d > 0$  ( $P$  refers to the Protestant school). In this case, if  $t > 0$  and the Protestant schools exists (i.e. has a positive enrollment level),  $q_P > q_C$ . In other words, Protestant missionaries have to offer a school quality above that offered by Catholic missionaries in order to have students.

treatment. We expect this theoretical prediction to be relevant in Catholic states.

Our interpretation is that these historical institutional differences persist to the present because educational outcomes and institutions present a high degree of inertia. There are several reasons why persistence is plausible in the case of education (Gallego, 2006). Firstly, setting up institutions is costly and there are irreversible complementary investments. Secondly, intergenerational inertia creates persistence in educational levels among members of several cohorts. Thirdly, the accumulation of human capital is endogenous. Increases in the supply of education increase the profitability of investing in human capital-related technologies, which, in turn, encourages schooling (Acemoglu, 2002). Finally, peer effects can explain low levels of education over several generations even though there are policies aiming to expand schooling. Consistent with this hypothesis, Gallego (2006) presents evidence that cross-country differences in schooling are highly persistent. Therefore, we expect the differences in the institutional setting to have an impact on educational outcomes both in the past and in the present.

In summary, the theoretical rationale presented in this section predicts that, while the education productivity of Catholic and Protestant missionaries should have been the same in non-Catholic states, Protestant missionaries should have been more productive in Catholic states. Since education presents a high degree of inertia, we expect that these historical differences also affect current educational outcomes. The next section presents the empirical framework we develop to test these predictions.

## 4.4 Empirical Framework

Using the theoretical and historical background described above, we study whether the productivity of missionary educational activity depends on government regulation of religion by comparing countries having Catholic states with other former colonies. The main estimating equation is:

$$S_i = \beta_P PM_i^{1900} + \beta_C CM_i^{1900} + \gamma_P PM_i^{1900} \times CS_i^{1900} + \gamma_C CM_i^{1900} \times CS_i^{1900} + \delta CS_i^{1900} + \mathbf{X}_i' \beta + e_i, \quad (4.1)$$



where  $S$  is schooling in area  $i$ ,  $PM$  is a proxy for Protestant missionary activity in area  $i$ ,  $CM$  is Catholic missionary activity,  $CS$  is a dummy taking a value of 1 if the area  $i$  has a Catholic state,  $\mathbf{X}$  is a vector of controls in area  $i$ , and  $e$  is an error term.

We interpret  $\beta_P$  and  $\beta_C$  as the education productivity of Protestant and Catholic missionaries in non-Catholic states, and  $\gamma_P$  and  $\gamma_C$  as the productivity differential of each group of missionaries in Catholic states. The empirical counterparts of our two theoretical predictions are:

$$\begin{aligned}\beta_P &= \beta_C, \text{ and} \\ \gamma_P &> \gamma_C.\end{aligned}\tag{4.2}$$

The first prediction states that Catholic and Protestant missionaries should be equally productive in areas with non-Catholic states. The second prediction states that Protestant missionaries are more productive than Catholic missionaries in Catholic states.<sup>10</sup>

To test these predictions, we need information about (i) the presence of Catholic and Protestant missionaries in different areas, and, (ii) the regulations affecting those missionaries. We use data for around 1900 because missionary activity increases considerably after the foundation of a number of Protestant missionary societies in the first half of the 1800s and the London Conference (Johnson, 1997). At the same time, Catholic missions were revived after the 1750-1815 period when missionary interest diminished, the empires disintegrated, and the Society of Jesus (i.e. the Jesuits) was suppressed. Subsequently, new missionary orders were founded and native clergy and bishops were ordained to serve new churches in Asia, Africa, and throughout the world. Consistent with this, we use information on the existence of Catholic states during the same period.

We use data on Protestant missionaries from Woodberry (2002, 2004). We use two indicators of Protestant activity: (i) the number of Protestant missionaries per capita working in a particular area in the early 1900s and (ii) a dummy that takes a value of one if Protestant missionaries worked in a particular region in the early 1900s. Woodberry (2002, 2004) collected

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<sup>10</sup>Strictly speaking, the model also predicts that  $\gamma_C < 0$ . However, this prediction is difficult to test empirically with our available data because Catholic missionaries in areas with a Catholic state may have more resources for education than in non-Catholic areas, which may imply  $\gamma_C > 0$ .

data using information on the location of mission stations and linked that information with modern borders of countries. In addition, for the cross-region analysis developed in this paper, we linked this information with modern borders of regions within a country for 17 African countries. The definition of missionary in Woodberry (2002, 2004) corresponds to “one who is doing missionary work away from his own national home and among the people of another race”.

Data on Catholic missionaries come from linking two sources: (i) the *Catholic Encyclopedia* (1907), which presents information on the number of religious personnel per diocese in the early 1900s; and (ii) “Catholic Hierarchy” (<http://www.catholic-hierarchy.org>), which collects information about current and past Catholic dioceses, allowing us to match historical dioceses (in the early 1900s) with current regions and countries. The basic measure of Catholic missionaries is the total number of priests in a particular diocese—there is also information for other related variables, such as the number of schools and the number of pupils attending Catholic schools for a sub-sample of countries. This variable incorporates both native and foreign priests that are ministering to the total population of a country (diocese). Therefore, when constructing the ratio of Catholic missionaries priests per capita, we use the total population as the denominator. This method contrasts with the variable measuring Protestant missionaries in Woodberry (2002, 2004). His variable considers only foreign priests ministering to non-European population for all countries (except Latin American countries where he considers missionaries ministering to the total population). So, to make both per-capita missionary ratios comparable, in the case of Protestant missionaries, we use total population in the denominator for Latin American countries and non-European population for the other countries.

We complement the information from the *Catholic Encyclopedia* with a number of country-specific sources to construct proxies for the presence of Catholic missionaries across African regions. Appendix Table 1 presents a description of the sources to construct the proxies for Catholic missionary activity in each country.

In order to identify which countries had regulations favoring Catholic missionaries, we use two different indicators. In the cross-country analysis, we use the state religion classification from Barro and McCleary (2004), who present the countries having an official religion in 1900 (by Catholic states we mean countries with Catholic as the official state religion). In particular,

they classify a country as having a state religion when the government explicitly favors a particular denomination. We will use the variable for 1900 as a proxy for the existence of a number of regulations favoring the Catholic Church. This variable is important because we have data for a period when a number of former colonies were already independent (i.e., most former Spanish colonies located in Latin America). Most Spanish colonies kept the colonial tendency towards giving a preferential treatment to the Catholic Church, but four of them did not have a Catholic state in 1900 (Ecuador, Mexico, Nicaragua, and Uruguay). These countries are not particularly different from the other former Spanish colonies in a number of dimensions (such as per-capita income, democracy, primary enrollment, and income distribution in 1900).

In the cross-region regressions for Africa, we classify regions having regulations favoring Catholic missionaries as those located in areas controlled by the Belgian and the Portuguese. These two colonial powers had explicit regulations favoring the Catholic Church. In contrast, French colonies *during this period* did not have regulations favoring Catholic missionaries.

In the next two sections we estimate equation (4.1) using two different samples: a cross-country sample and an African cross-region sample.

## 4.5 Cross-Country Evidence

In this section we apply the empirical framework described in the previous section in a cross-country context. We study whether the productivity of missionaries changes depending on the market structure they face. We estimate regressions for schooling levels in the present and the past, given the evidence that schooling levels present a high degree of inertia (Gallego, 2006). Since we study the effect of missionary activity in the past on current levels of schooling, our estimates are also informative as to the historical roots of educational outcomes.

Our measures of schooling are average years of schooling of the adult population in 1985-1995 and primary enrollment rates in 1900. Data on current levels of schooling come from Barro and Lee (2001) and Cohen and Soto (2001). Data on primary enrollment in 1900 come from Benavot and Riddle (1988), who present enrollment rates in the 1870-1940 period (Gallego, 2006 presents a detailed description of this dataset). In all specifications we control for general conditions faced by colonizers—measured using settler mortality from Acemoglu et al. (2001 and 2002). This is an

important control to distinguishing the theory we are proposing in this paper from alternative theories emphasizing the effect of the conditions faced by the colonizers on educational outcomes (Gallego, 2006). Since countries having a Catholic state in 1900 became independent before other countries, we also control for years since independence in some specifications.

Before estimating equation (4.1), we discuss the main characteristics of our missionary activity data. Table 1 presents the basic descriptive statistics for our measures of missionary activity. Missionaries were present in most countries in our sample. The average number of Protestant and Catholic missionaries per 1,000 people is roughly similar in the complete sample. When we split the sample between Catholic and non-Catholic states, differences are substantial. While in Catholic states Catholic missionaries outnumbered Protestant missionaries, the median number of Protestant and Catholic missionaries is roughly the same in non-Catholic states. This result is not unexpected because Protestant missionaries were not allowed to enter some Catholic states. The results in Table 2 confirm the evidence in Table 1. Simple and partial correlations between Catholic and Protestant missionaries are positive and statistically significant only for non-Catholic states. Among Catholic states, correlations are smaller and not statistically significant. These results present indirect evidence that competition among missionaries was more intense in countries with a Catholic state.

Figure 1 studies the relationship between missionary activity and schools. This figure presents the relationship between Catholic schools per-capita and Catholic missionaries per-capita in a sub-sample of 44 countries for which we have information (we do not have information about Protestant schools). The data suggest that Catholic missionary activity was associated with the founding of schools. The estimates imply that a one-percent increase in the number of missionaries in a country was associated with a one-percent increase in the number of schools.

Our theoretical discussion and the above-mentioned anecdotal evidence suggest that there are heterogeneous effects of missionaries in different areas, depending on the market structure. Table 3 presents estimates of equation (4.1). This evidence supports our theoretical discussion. First, using educational data for 1900 and 1985-1995, Protestant and Catholic missionary activity has the same effects in non-Catholic countries (i.e.,  $\beta_C = \beta_P$ ). Second, Protestant missionaries are significantly more productive than Catholic missionaries in non-Catholic countries

(i.e.,  $\gamma_C < \gamma_P$ ). These results are robust to including years since independence and interactions of missionaries with years of independence, as shown in columns (2) and (4). Interestingly, we find evidence in favor of our theory both in 1900 and the 1990s, suggesting that institutions established in the past have long-lasting effects on educational outcomes.

The effects reported in Table 3 are economically relevant. Using the estimates from column (2), our results imply that increasing the number of Protestant missionaries by one standard deviation (roughly 0.25 missionaries per 1,000 people) in Catholic states produces roughly 7 additional percentage points of primary enrollment in 1930 in comparison to a proportional increase in the number of Catholic missionaries. This effect is significant and is equivalent to about a 50% of the average primary enrollment rate in 1930 in our sample, which is 14.11%. Using estimates in column (4), a one standard-deviation increase in Protestant missionaries in 1990 produces about one additional year of schooling in Catholic versus non-Catholic states (equivalent to about 25% of the average years of schooling in our sample).

Overall, these results strongly support our two main theoretical predictions. Now, we extend our initial analysis and address a potential concerns about our results. We present a falsification exercise of our previous results. We present estimates of equation (4.1) using primary enrollment rate in 1870 as our left-hand side variable for a sub-sample of countries where Protestant missionaries arrived *after* 1870 (Table 4). A significant interaction effect in this sample implies that omitted variables and/or other mechanisms should explain our results because Protestant missionaries *were not working* in those countries in 1870.<sup>11</sup> The results suggest that the interaction of Protestant missionaries and Catholic states is negative in 1870, which is the opposite of what we find in Table 3. More importantly, the interaction effect is *positive* and significant when we use primary enrollment in 1930 as the left-hand side variable, confirming our previous results. Putting it differently, the positive differential effect of Protestant mis-

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<sup>11</sup>We have also run other robustness exercises that we do not report here in interest of saving space. First, we run regressions including a measure of democracy as our left-hand side variable. Our theory and the historical background do not provide clear reasons to expect the interaction effect between Protestant missionaries and Catholic to be significant. Second, we control for potential differences in the human capital of missionaries going to different states. Since missionaries from different colonial powers and denominations had different levels of human capital, these differences may explain the significance of our interaction effects. Third, we have put in higher order terms in Catholic and Protestant missionaries per capita to test whether our main regressions are picking up diminishing marginal returns to missionaries. Fourth, we have run regressions excluding outliers. In all these cases, our main results are robust to these checks. Results available upon request.

sionaries in Catholic states is not present in the data *before* Protestant missionaries arrived to these countries and is *positive* and statistically significant after they arrived. Therefore, these results confirm our previous results and lend additional support to the theoretical mechanism we propose to explain these results.

Overall, the results in this section document the argument that while Protestant and Catholic missionaries were similarly productive in countries with a competitive educational market, Protestant missionaries were significantly more productive than Catholic missionaries in markets in which the former were protected by regulations and government support. The next section analyzes the same issue using a regional data set include about 180 regions of 17 African countries.

## 4.6 African Cross-Region Evidence

In this section, we test the theoretical predictions presented in (4.2) using cross-region data for 17 African countries. This cross-region sample presents some important advantages. First, the allocation of different regions to different colonial powers follows a more or less arbitrary process. In particular, the actual shape of many African countries was determined in a rather arbitrary form after a number of struggles among several colonial powers in the late 1800s (notice the number of straight lines in the map of Africa). For instance, between May 1884 and February 1885, Germany announced its claims to territory in South West Africa (now South West Africa/Namibia), Togoland, Cameroon, and part of the East African coast opposite Zanzibar. Even smaller nations such as Belgium, Italy, Portugal and Spain also became active in bidding for African territory. The problem was that France and England already had a number of claims in the continent. The settlements resulting from these struggles completed the European partition of Africa. The partition started in 1884 with the West African Conference. The conference recognized the Congo Free State (the modern Democratic Republic of Congo) ruled by Belgium that subsequently took over the Katanga region in 1908. Germany consolidated its possessions of Togo and Cameroon, while England and France pushed northward and eastward from their bases: England concentrated on the Niger region, while France aimed at joining its possessions at Lake Chad. The boundaries determined by conquest and agreement between the

conquerors gave France French West Africa and French Equatorial Africa, while Britain carved out its Nigerian colony (Encyclopædia Britannica, 2004). Therefore, the allocation of areas to different colonial powers is arguably "more exogenous" than the allocation in a cross-country setting.

Second, educational sectors in the countries in this sample started to be developed around 1900, with Christian missionaries playing a central role. Thus, this sample provides a "cleaner" test of the effects of institutional features affecting missionaries on the development of educational systems. Third, most central African regions/countries started with relatively similar levels of development circa 1900 (as documented in Madison, 2003) and many ethnic groups ended up divided between countries with different colonizers. Thus, we can use the entry of missionaries and the arbitrary definition of boundaries between colonial powers as a source of exogenous variation in the number of missionaries and colonial policies regarding them.

Our sample includes about 180 regions/provinces that belong to 17 African countries located in two African areas:

- Central-West Africa: Benin, Burkina Faso, Cameroon, Central African Republic, Cote d'Ivoire, Gambia, Ghana, Guinea, Nigeria, and Togo.
- Central and South-East Africa: Angola, Burundi, Kenya, Malawi, Rwanda, Tanzania, and Zambia.

We use two measures of educational outcomes in the present: average years of schooling of the adult population and literacy rates at the provincial level. Table Appendix 1 presents the sources of data for each country. The choice of countries was basically related to the availability of data about educational outcomes.

Table 5 presents descriptive statistics for educational outcomes and missionary activity. As expected, educational outcomes are low. Average attainment is below three years of schooling and literacy rates are below 50% in average. At the same time, the variability of both dimensions is high: average schooling varies from roughly no schooling to an average schooling of above seven years.

Table 5 also presents descriptive statistics of the presence of Catholic and Protestant missionaries at the province level in the early 1900s. Missionaries were working in about 60% of the

provinces. Provinces within a Catholic state tended to have fewer areas with missionary activity than areas outside Catholic states. The number of missionaries per 1000 people was roughly the same in regions with and without a Catholic state, but the composition of the missionaries changed significantly. While in Catholic states there were about 1.2 Catholic missionaries per Protestant missionary, in the other areas there were about two Protestant missionaries per Catholic missionary. The data also suggest that Protestant missionaries only entered some areas in Catholic states. Interestingly, these results confirm the basic pattern we observe in the cross-country data, as presented in Table 1.

Table 6 complements this evidence. We present simple and partial correlations of our measures of missionary activity in different areas. The results in Panel A of Table 6 using the dummies for the presence of missionaries give a pattern similar to that observed in the cross-country data (Table 3). While in Catholic states the correlation of Protestant and Catholic missionary activity is negative or insignificant, in “neutral” states the correlation is positive and significant. The results using a partial correlation index present a similar pattern.<sup>12</sup> The results using our measures of missionaries per person in Panel B of Table 6 suggest a similar pattern, but the correlations are not precisely estimated. Overall, the results in this table suggest that the degree of competition between Protestant and Catholic missionaries was higher in non-Catholic states.

Next, we estimate equation (4.1) using regional data. Table 7 presents the results. Panel A presents results without including controls at the region level. The results show a pattern similar to our cross-country evidence. The two basic theoretical predictions are supported by the data: (i) Protestant and Catholic missionaries have a similar effect on educational outcomes in areas where they have to compete among them and (ii) Protestant missionaries are significantly more productive in areas with a Catholic state. In Panel B, we introduce controls for region characteristics and the results are roughly similar. The second implication is not supported only in two of the eight alternative specifications presented in Table 7 (p-values of about 0.15).<sup>13</sup> Therefore, our results are robust to using two alternative measures of schooling

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<sup>12</sup>When computing partial correlations, we control for population density, distance to the sea, dummies for the presence of rivers, lakes, and access to the sea, a dummy that takes a value of one if capital city of the country is located in the region, and broad-region dummies (i.e., if the province is located in Central-West Africa or Central and South-East Africa).

<sup>13</sup>Finally, if we impose the restriction that  $\beta_P = \beta_C$ , the results are similar and more precisely estimated. In



(years of schooling and literacy) and two alternative proxies for missionary activity (a dummy for presence of any missionary activity and a measure of missionaries per person).<sup>14</sup>

Overall, the results using a sample of African regions confirm our theoretical predictions and confirm the results using cross-country evidence. Since educational systems in these African regions started to develop in the early 1900s and missionaries played a significant role in the development of these systems, these results are relevant because provide a cleaner test of the effects of institutional regulations in terms of the effect of missionaries on educational outcomes.

## 4.7 Concluding Comments

We started this paper documenting the big differences in educational attainment existing between Catholic and non-Catholic states in our African cross-region sample and we asked whether these differences were driven by national identity, religious affiliation, or institutional features. Our estimated effects suggest that institutions play an economically relevant role to explain differences in educational attainment. For instance, our estimates for Africa suggest that the same number of Catholic missionaries per 1,000 people would have implied 5 additional percentage points of literacy rates and about 0.5 additional years of schooling had missionaries been as productive as Catholic missionaries in non-Catholic states. Therefore, only differences in productivity of Catholic missionaries in different Catholic and non-Catholic states explain between one-third and one-quarter of the differences in educational outcomes between both groups of African provinces.

We interpret these differences as rational reactions to regulations: while in non-Catholic colonies there was a relatively neutral policy allowing most missionaries to work under equal conditions, in Catholic colonies there were implicit or explicit policies favoring the Catholic Church. This institutional feature created differences in the competitive pressures faced by Catholic and Protestant missionaries in different places. We support our theoretical predictions using three different sources of information. First, we present a number of examples taken from the historical record. Second, we use cross-country data about educational outcomes in 1900

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all the cases, we reject the null hypothesis that  $\gamma_P > \gamma_C$ . Results available upon request.

<sup>14</sup>Regressions present standard errors clustered at the country level. If we include country fixed effects, all coefficients become statistically insignificant because standard errors increase. This result suggests that most of the variation we are identifying is related to between-country differences, as expected.

and 1990 for a sample of former colonies. In this context, we present a falsification exercise that suggests that our results are robust to alternative explanations. Third, we use African cross-region data about educational outcomes in the 1990s for a sample of 17 countries.

Our results lend additional evidence to the ongoing debate on the optimal structure of provision of education. A key element in this debate has to do with the interaction of the incentives to providers, and the way consumers respond to the existence of different schools. This paper presents evidence supporting the basic predictions of models implying a positive effect of inter-school competition on educational outcomes.

More broadly speaking, our results also confirm the role that institutions established in the past play in current educational outcomes. We show that regulations that affected educational systems and actors in the past have long-lasting effects on educational outcomes. Finally, this paper also shows how historical analyses can help shed light (in a similar vein as Karpoff, 2002) on contemporary policy questions.

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## 4.8 Tables and Figures

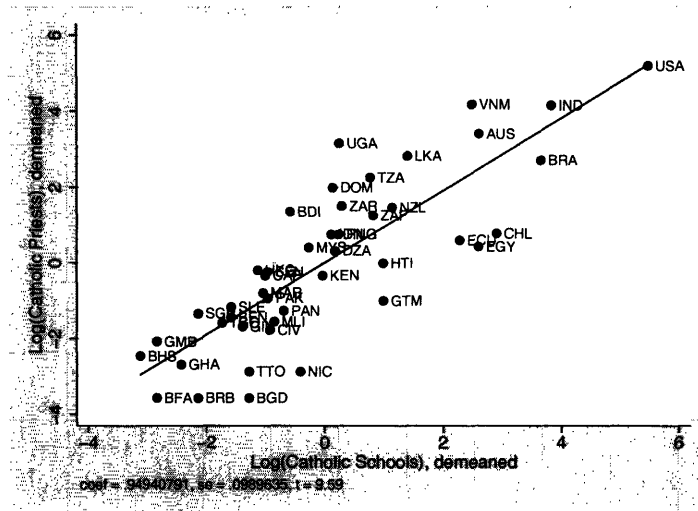


Figure 1: Catholic Schools and Catholic Missionaries

**Table 1**  
**Cross-Country Missionary Activity. Descriptive Statistics, c. 1900**

<b>Panel A: Complete Sample</b>		
	Protestant Missionaries per 1,000 people	Catholic Priests Per 1,000 people
Average	0.14 (Hong Kong)	0.11 (Belize-Haiti)
Median	0.04 (Guatemala)	0.06 (Gambia)
Standard Deviation	0.25	0.13
Maximum	0.99 (U.S.)	0.63 (Canada)
Minimum	0.00 (Burundi, Ivory Coast, Mauritania, Niger)	0 (Chad, Mauritania, Niger)
Number of Countries	75	75
<b>Panel B: Catholic States</b>		
	Protestant Missionaries per 1,000 people	Catholic Priests Per 1,000 people
Average	0.04 (Costa Rica)	0.23 (El Salvador)
Median	0.04 (Costa Rica)	0.17 (Panama)
Standard Deviation	0.03	0.14
Maximum	0.12 (Panama)	0.47 (Bolivia)
Minimum	0.01 (Colombia)	0.01 (Zaire)
Number of Countries	17	58
<b>Panel C: Non-Catholic States</b>		
	Protestant Missionaries per 1,000 people	Catholic Priests Per 1,000 people
Average	0.16 (Hong Kong-Singapore)	0.08 (Congo)
Median	0.03 (Ghana-Malaysia)	0.03 (Senegal-Singapore)
Standard Deviation	0.28	0.11
Maximum	0.99 (U.S.)	0.63 (Canada)
Minimum	0 (Burundi, Ivory Coast, Mauritania, Niger)	0 (Chad, Mauritania, Niger)
Number of Countries	17	58



**Table 2**  
**Protestant and Catholic Missionaries: Cross-Country Correlations c. 1900**

Simple correlation	
All countries	0.3423 (0.004)
Catholic State in 1900	-0.2874 (0.252)
Non-Catholic State in 1900	0.6162 (0.000)
Partial correlation controlling for settler mortality	
All countries	0.1561 (0.197)
Catholic State in 1900	0.1469 (0.601)
Non-Catholic State in 1900	0.4840 (0.000)

Notes: p-values are presented in parentheses.

**Table 3**  
**Missionary Activity and Schooling: Interaction Effects**

	Dependent Variable			
	Primary Enrollment in 1930	Average years of Schooling in 1985-1995	Average years of Schooling in 1985-1995	Average years of Schooling in 1985-1995
Protestant missionaries	71.04 (7.94)	87.59 (13.75)	5.21 (1.07)	7.14 (3.50)
Catholic missionaries	34.97 (18.54)	-2.18 (57.12)	5.06 (2.52)	0.91 (7.09)
Log(Settler Mortality)	-3.07 (1.49)	-3.32 (1.61)	-.62 (0.16)	-0.60 (0.17)
Protestant missionaries	211.76 (50.16)	230.43 (49.88)	31.30 (4.38)	32.08 (4.52)
*Catholic State	30.75 (33.51)	22.29 (29.24)	0.53 (3.45)	-0.24 (4.11)
Catholic missionaries	-10.50 (7.09)	-17.35 (5.82)	-1.08 (0.72)	-1.29 (1.12)
*Catholic State	-	-0.16 (0.09)	-	-0.01 (0.02)
Protestant Missionaries	-	0.20 (0.40)	-	0.03 (0.05)
*Years since Independence	-	7.18 (4.59)	-	0.23 (0.72)
Catholic Missionaries				
* Years since Independence				
Years since Independence/100				
F-Test (p-value): $\beta_p = \beta_c$	0.1589	0.1502	0.9624	0.5865
F-Test (p-value):	0.0002	0.0001	0.0000	0.0000
Ho: $\gamma_p = \gamma_c$ H1: $\gamma_p > \gamma_c$				
R <sup>2</sup>	0.7625	0.7753	0.7366	0.7549
Number of Observations	71	71	66	66

Notes: Constant not reported. White-Huber robust standard errors reported in parentheses.

**Table 4**  
**Falsification Exercise III: Interaction Effects *before* the Entry of Protestant Missionaries**

	Dependent Variable	
	Primary Enrollment in 1870	Primary Enrollment in 1930
Protestant missionaries	81.38 (3.17)	70.74 (3.63)
Catholic missionaries	38.06 (4.74)	57.31 (5.07)
Log(Settler Mortality)	-2.12 (1.35)	-3.30 (1.62)
Protestant missionaries	-97.81	262.88
*Catholic State	(39.50)	(56.86)
Catholic missionaries	-25.01	-14.68
*Catholic State	(22.92)	(36.36)
Catholic State	10.39 (7.68)	-6.45 (8.50)
R <sup>2</sup>	0.833	0.909
Number of Observations	25	25

Notes: Constant not reported. White-Huber robust standard errors reported in parentheses.

**Table 5**  
**African Cross-Region Data: Summary Statistics**

<b>Panel A: Complete Sample</b>						
Variable	N	Mean	Median	S.D.	Min	Max
Dummy: Catholic missionaries	189	.407	0	.493	0	1
Dummy: Protestant missionaries	189	.423	0	.495	0	1
Dummy: Missionaries	189	.577	1	.495	0	1
Cath. missionaries per 1000 people	189	.018	0	.038	0	.299
Prot. missionaries per 1000 people	189	.033	0	.077	0	.460
Missionaries per 1000 people	189	.051	.022	.087	0	.460
Literacy rate	189	.426	.455	.254	.024	.956
Average years of schooling	179	2.886	2.963	2.060	.006	7.140

**Panel B: Regions in areas with and without protection of the Catholic Church**

Variable	Catholic State	"Neutral" State
	Mean	
Dummy: Catholic missionaries	.455	.401
Dummy: Protestant missionaries	.227	.449
Dummy: Missionaries	.500	.587
Cath. missionaries per 1000 people	.028	.016
Prot. missionaries per 1000 people	.024	.034
Missionaries per 1000 people	.052	.051

**Table 6**  
**Protestant and Catholic Missionaries: African Cross-Region Correlations c. 1900**

<b>Panel A: Measure of Missionary Activity: Dummy for Presence</b>		
Simple correlation		
All regions	0.34	(0.01)
Catholic State in 1900	0.38	(0.08)
Non-Catholic State in 1900	0.34	(0.00)
Partial correlation controlling for region characteristics		
All regions	0.19	(0.01)
Catholic State in 1900	0.01	(0.98)
Non-Catholic State in 1900	0.22	(0.01)
<b>Panel B: Measure of Missionary Activity: Missionaries per Person</b>		
Simple correlation		
All regions	0.03	(0.67)
Catholic State in 1900	-0.15	(0.53)
Non-Catholic State in 1900	0.07	(0.34)
Partial correlation controlling for region characteristics		
All regions	0.01	(0.89)
Catholic State in 1900	-0.31	(0.26)
Non-Catholic State in 1900	0.05	(0.53)

Notes: Region characteristics are population density, distance to the sea, dummies for the presence of rivers, lakes, and access to the sea, a dummy that takes a value of one if the capital city of the country is located in the region, and broad-region dummies (i.e. if the province is located in Central-West Africa or Central and South-East Africa). P-values are presented in parentheses.

**Table 7**  
**Cross-Region Regressions: Educational Outcomes**  
**Panel A: Without Including Region Controls**

Proxy for Missionaries Dependent Variable	Dummy for Presence		Missionaries per 1000 people	
	Literacy (1)	Schooling (2)	Literacy (3)	Schooling (4)
Independent Variable				
Protestant missionaries	.13 (.07)	1.47 (.62)	.77 (.27)	6.16 (2.47)
Catholic missionaries	.11 (.04)	.96 (.33)	1.09 (.43)	6.87 (4.13)
Protestant missionaries *Catholic State	.37 (.21)	1.94 (1.83)	.39 (.50)	4.57 (3.54)
Catholic missionaries *Catholic State	-.00 (.05)	.00 (.69)	-1.23 (.72)	-6.75 (6.31)
Catholic State	-.19 (.10)	-0.92 (.86)	-.12 (.17)	-0.98 (1.20)
Controls	No	No	No	No
Area Effects	Yes	Yes	Yes	Yes
F-Test (p-value): $\beta_p = \beta_c$	0.79	0.51	0.47	0.85
F-Test (p-value): Ho: $\gamma_p = \gamma_c$ H1: $\gamma_p > \gamma_c$	0.05	0.16	0.00	0.02
R <sup>2</sup>	0.60	0.43	0.48	0.25
Number of Observations	189	179	189	179

**Panel B: Including Region Controls**

Proxy for Missionaries Dependent Variable	Dummy for Presence		Missionaries per 1000 people	
	Literacy (1)	Schooling (2)	Literacy (3)	Schooling (4)
Independent Variable				
Protestant missionaries	.11 (.07)	1.24 (.54)	.72 (.20)	5.64 (1.93)
Catholic missionaries	.06 (.04)	.48 (.32)	.42 (.34)	.80 (3.44)
Protestant missionaries *Catholic State	.41 (.22)	2.24 (1.81)	.49 (.34)	5.58 (2.87)
Catholic missionaries *Catholic State	-.02 (.05)	-.01 (.53)	-.84 (.53)	-2.86 (4.20)
Catholic State	-.21 (.08)	-1.22 (.69)	-.15 (.13)	-1.25 (.92)
Controls	Yes	Yes	Yes	Yes
Area Effects	Yes	Yes	Yes	Yes
F-Test (p-value): $\beta_p = \beta_c$	0.56	0.31	0.48	0.56
F-Test (p-value): Ho: $\gamma_p = \gamma_c$ H1: $\gamma_p > \gamma_c$	0.04	0.13	0.01	0.04
R <sup>2</sup>	0.66	0.50	0.57	0.41
Number of Observations	189	179	189	179

Notes: Constant not reported. Controls are population density, distance to the sea, dummies for the presence of rivers, lakes, and access to the sea, a dummy that takes a value of one if the capital city of the country is located in the region. Area effects are broad-region dummies (i.e. if the province is located in Central-West Africa or Central and South-East Africa). Clustered standard errors at the country level reported in parentheses.

**Table Appendix 1**  
**African Cross-Region Data Sources**

Human capital	
Country	Survey
Angola	Inquerito Prioritario Sobre as Condições de Vida dos Domicílios, 1995
Benin	Enquête Démographique et de Santé, 1996
Burkina-Faso	Enquête prioritaire, 1998
Burundi	Enquête prioritaire 1998 - Etude nationale sur les conditions de vie des populations
CAR	Enquête Démographique et de Santé 1994/95
Cameroon	Enquête Camerounaise auprès des Ménages, 1996
Cote d'Ivoire	Enquête à Indicateurs Multiples, 1995
Gambia	Household Education and Health Survey, 1993
Ghana	Demographic and Health Survey 1998/99
Guinea	Enquête démographique et de santé en Guinée 1999
Kenya	Demographic and Health Survey 1998
Malawi	Integrated Household Survey 1997
Nigeria	Demographic and Health Survey, 1993
Rwanda	Enquête Démographique et de Santé 1992
Tanzania	Human Resources and Development Survey 1993
Togo	Enquête Démographique et de Santé 1988
Zambia	Demographic and Health Survey 1996
Catholic Missionaries	
Country	Reference
Angola	Catholic Encyclopedia (1907) L. W. Henderson (1979) Angola : five centuries of conflict C. P. Groves (1975) The planting of Christianity in Africa B. de Vaulx, (1961) A History of Missions.
Benin	Catholic Encyclopedia (1907) Patrick Manning (1982) Slavery, colonialism, and economic growth in Dahomey, 1640-1960.
Burkina-Faso	World Christian Encyclopedia P. Englebert (1996). Burkina Faso : unsteady statehood in West Africa.
Burundi	World Christian Encyclopedia J.P. Chrétien (2003). The great lakes of Africa : two thousand years of history.
CAR	Catholic Encyclopedia (1907) World Christian Encyclopedia B. de Vaulx, (1961) A History of Missions.
Cameroon	Catholic Encyclopedia (1907)
Cote d'Ivoire	Catholic Encyclopedia (1907) World Christian Encyclopedia B. de Vaulx, (1961) A History of Missions.
Gambia	Catholic Encyclopedia (1907) World Christian Encyclopedia B. de Vaulx, (1961) A History of Missions.
Ghana	Catholic Encyclopedia (1907) World Christian Encyclopedia C. P. Groves (1975) The planting of Christianity in Africa W. Ward, (1963) A history of Ghana.
Guinea	World Christian Encyclopedia C. P. Groves (1975) The planting of Christianity in Africa
Kenya	Harold D. Nelson et al. (1975) Area handbook for Guinea. Catholic Encyclopedia (1907)

- World Christian Encyclopedia  
 C. P. Groves (1975) *The planting of Christianity in Africa*  
 Robert L. Tignor (1976). *The colonial transformation of C. Kenya : the Kamba, Kikuyu, and Maasai from 1900 to 1939*  
 C. Eliot (1976) *The East Africa Protectorate*
- Malawi  
 Catholic Encyclopedia (1907)  
 World Christian Encyclopedia
- Nigeria  
 Catholic Encyclopedia (1907)  
 World Christian Encyclopedia  
 E. A. Ayandele (1976). *Nigerian historical studies*
- Rwanda  
 Catholic Encyclopedia (1907)  
 World Christian Encyclopedia  
 C. P. Groves (1975) *The planting of Christianity in Africa*  
 R. Nyrop, et al. (1969) *Area handbook for Rwanda.*  
 J.P. Chrétien (2003). *The great lakes of Africa : two thousand years of history.*
- Tanzania  
 Catholic Encyclopedia (1907)  
 World Christian Encyclopedia  
 C. P. Groves (1975) *The planting of Christianity in Africa*  
 J.P. Chrétien (2003). *The great lakes of Africa : two thousand years of history*  
 John Iliffe (1979) *A modern history of Tanganyika.*  
 R. Bennett (1963). *Studies in East African history.*  
 J.P. Moffett (1958) *Handbook of Tanganyika*
- Togo  
 Catholic Encyclopedia (1907)  
 World Christian Encyclopedia  
 W. Ward, (1963) *A history of Ghana.*  
 Arthur J. Knoll (1978) *Togo under Imperial Germany, 1884-1914 : a case study in colonial rule.*
- Zambia  
 Catholic Encyclopedia (1907)  
 World Christian Encyclopedia  
 Robert I. Rotberg (1965). *The rise of nationalism in Central Africa; the making of Malawi and Zambia, 1873-1964.*  
 L. Gann (1964) *A history of Northern Rhodesia, early days to 1953.*  
 A.J. Wills (1985) *An introduction to the history of central Africa : Zambia, Malawi, and Zimbabwe.*
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## Chapter 5

# Skill Premium in Chile: Studying the Skill Bias Technical Change Hypothesis in the South<sup>1</sup>

### 5.1 Introduction

The evolution of the skill premium (i.e., the wage differential between skilled and unskilled workers) in an economy has interest from at least two perspectives. First, the skill premium is a rough measure of inequality among workers of different qualifications. Second, the evolution of the skill premium provides information on the characteristics of the development process of the economy.

A large body of the literature has analyzed the evolution of the skill premium in developed and developing economies. In the case of developed economies, the literature tends to emphasize the role of skill-biased technical (SBTC) change as a driving force of the evolution of the skill premium (e.g. see Acemoglu, 2002a). In the case of developing economies, the emphasis is

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<sup>1</sup>I would like to thank Daron Acemoglu, David Autor, José Tessada, and Andrea Tokman for comments, the Central Bank of Chile for financial support, Pamela Siska and Steven Strang for editing help, Dante Contreras and Javiera Vasquez for providing me the data of the employment survey of the University of Chile, Comité de Inversiones Extranjeras for providing sectoral data on FDI in Chile, and Andrés Hernando for sharing his data set on manufacturing firms. The usual disclaimer applies.

more related to the effect of reforms such as trade openness on wage differentials, albeit the results are not uncontroversial (e.g., see Attanasio et al., 2004). Some papers have tried to relate both literatures. Theoretically, in a context where only developed countries produce new technologies, Acemoglu (2003a) shows that the skill premium in developing economies—which adopt new technologies created in developed countries—should be correlated with the skill premium in developed economies, controlling for the relative supply of skilled and unskilled workers in developing countries. Interestingly, Berman et al. (1998) and Berman and Machin (2000) report positive correlations between measures of skill upgrading in high and middle income countries for the manufacturing sector in the 1970s and 1980s.<sup>2</sup>

In this paper, I extend this line of research in three dimensions: (i) I explicitly study the correlation between the wage premium and skill upgrading in a developed country (the US) and a developing country (Chile) using macro time series, (ii) I extend the analysis to include sectors outside manufacturing and data from 1960 to 2000, and to use a unique panel data set which allows me to control for time and sector specific effects, and (iii) I study empirically the implication of the Acemoglu (2003a) model that trade openness in the US should affect skill upgrading both in the US and in Chile.

Chile is a particularly interesting case of study because it corresponds to a small open economy that has undergone a significant change in its economic structure over the last 40 years. Starting in the mid 1970s, a process of economic liberalization has been implemented. At the same time, I estimate in this paper that the skill premium has increased significantly from about 82 log points in the 1960s to an average of 120 and 123 log points in the 1980s and 1990s, respectively. In turn, the relative supply of skilled workers has increased significantly over the last forty years. The ratio of college graduate equivalents to high-school graduate equivalents (my basic measure of the relative supply of skilled workers) has increased from 0.14 in the 1960s to 0.21 and 0.31 over the 1980s and the 1990s, respectively. This suggests that the relative demand for skilled workers has increased significantly in the latter period.

The finding that changes in the relative demand for skilled labor are important leaves open the question of what factors explain the recent evolution of the skill premium in the

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<sup>2</sup>While most correlations in Berman and Machin (2000) are positive the correlations are statistically significant only for about 10% of the countries.

Chilean economy. In this paper, I provide macro and sectoral evidence of a close relationship between patterns of skill upgrading in the US and Chile. As predicted by a simple model of skill upgrading along the lines of Acemoglu (2003a), macro time-series regressions imply that a proxy for the relative demand for skilled labor in Chile is significantly correlated with skill premium and trade openness in the US, after controlling for the traditional determinants presented in the literature. In turn, the sectoral evidence presents the same conclusion: skill upgrading in Chile is correlated with skill upgrading in the US, after controlling for sector and time effects. The sectoral evidence also suggests that this effect is relatively stronger in the tradable sectors especially in the period of economic liberalization (post 1975). The data I use do not provide a clear answer of what component of liberalization explains this correlation: including proxies for trade openness and FDI penetration does not capture the change in the correlation in the period after 1975. Further research using more detailed data and more countries should address this point.

The related empirical literature includes several studies for Chile and other developing countries. For the case of Chile,<sup>3</sup> Robbins (1994a) argues that the increase in the relative demand for skilled workers is related to trade openness and, in particular, to technology transfers from abroad, which is also emphasized by Pavcnik (2000) and Sánchez-Páramo and Schady (2002). The idea being that a more open economy creates incentives for firms to adapt new technologies, which are skill-biased. The basic finding of this literature is a correlation between variables such as imports of capital goods or the FDI stock and skill upgrading (typically measured as the share of the wage bill that goes to skilled labor) at the micro level.

Some evidence, however, contradicts these explanations. First, Robbins (1994a) focuses the analysis on the 1975-1990 period, but the big increase in the relative demand for skilled workers takes place only since the mid 1980s, while trade openness increases significantly in the 1970s. Second, the evidence on the role of technology transfer has no clear causal interpretation. It may well be the case that some sectors have a higher demand for skilled workers and for equipment capital because of a third (omitted) variable. Recent evidence in Fuentes and Gilchrist (2004) and Pavcnik (2003) shows that the correlation between skill upgrading and proxies for

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<sup>3</sup>Recent papers for other Latin American countries include Bustos (2005) and Galiani and Sanguinetti (2003) for Argentina, Attanasio et al. (2004) for Colombia, and Pavcnik et al. (2004) for Brazil.

technology transfers disappears after controlling for plant fixed effects. Putting it differently, *within-firm* variation does not support the claim that measures of technology adoption from abroad are per se correlated with changes in the relative demand for skilled workers.

An alternative hypothesis is that the relative bias of technology adopted from abroad is what determines the relative demand for skilled labor in Chile.<sup>4</sup> I study this hypothesis in this paper. In particular, I study the correlation of measures of skill upgrading in the US and Chile. I find suggestive support for the idea that skill upgrading in Chile is correlated with skill upgrading in the US. Since I also show that openness *in the US* is correlated with the wage premium in Chile, I interpret this result as supportive evidence of a simplified version of the Acemoglu (2003a) model. A more general interpretation of my results is the existence of *pervasive* skill biased technical change *à la* Berman et al. (1998)—i.e., the fact that there is skill biased technical change in all the countries at the same time. However, the theories of pervasive SBTC have the limitation that they take SBTC as exogenous, while the model in Acemoglu (2003a) explains *why* there may be pervasive SBTC. Finally, even though a literal interpretation of my results is about correlation between skill upgrading in the US and Chile, I interpret my results as a correlation between skill upgrading in developed countries and Chile. The basic evidence supporting this idea is three-fold: (i) a high correlation between skill upgrading at the sectoral level in all high income countries, as documented in Berman et al. (1998), (ii) a high share of the domestic supply of non-transportation machinery and equipment comes from developed countries—I document that about 85% of the supply of non-transportation machinery and equipment in Chile is imported (using data from the Chilean output-input matrix for 1996), and (iii) most imports of non-transportation machinery and equipment (and data-processing machines) come from the US (the most important exporter country to Chile in each year and category) and OECD countries (using data from Feenstra et al., 2005). In other words, Chile seems to be using technologies that mostly come from a group of developed countries that are producing skill-biased technologies.

The paper is organized as follows. Section 2 presents a group of stylized facts related to the evolution of the skill premium in Chile. Section 3 presents a simplified version of the

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<sup>4</sup>Technical changes do not have to be skill-biased: Goldin and Katz (1998) and James and Skinner (1985) present some evidence that technical change was skill-replacing during the nineteenth century.

theoretical model in Acemoglu (2003a) to motivate the main empirical tests of this paper. Section 4 presents macro time series evidence. Section 5 presents sectoral evidence from 1960 to 2000. Section 6 documents that non-transportation machinery and equipment in Chile tend to be imported from the US and the OECD and Section 7 briefly concludes.

## 5.2 Stylized Facts

### 5.2.1 Time-Series Evidence: A CES Framework (Katz and Murphy, 1992 and Krusell et al., 2000)

To organize the discussion on the determinants of the skill premium in Chile I present a simple framework that allows me to compose the skill premium between its demand and supply components (this approach was popularized by Katz and Murphy, 1992). I start from a nested CES production function that includes three inputs: skilled and unskilled labor and physical capital.

The production function of the aggregate economy is:

$$Y = K^\alpha \left[ \pi (A_h H)^{\frac{\sigma-1}{\sigma}} + (1-\pi) (A_l L)^{\frac{\sigma-1}{\sigma}} \right]^{(1-\alpha)\frac{\sigma}{\sigma-1}}, \quad (5.1)$$

where  $Y$  is aggregate output,  $K$  is physical capital,  $A_h$  is skilled labor augmenting technological change,  $H$  is skilled labor,  $A_l$  is unskilled labor augmenting technological change,  $L$  is unskilled labor,  $\pi$  is a technology parameter that can be interpreted as the share of work activities allocated to skilled labor, and  $\sigma$  is the elasticity of substitution between skilled and unskilled workers.<sup>5</sup>

Assuming that markets are competitive, then the wage of each factor is:

$$\begin{aligned} w_h &= \frac{\partial Y}{\partial H} = (1-\alpha) \pi K^\alpha A_h^{\frac{\sigma-1}{\sigma}} \left( \pi (A_h H)^{\frac{\sigma-1}{\sigma}} + (1-\pi) (A_l L)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1-\alpha\sigma}{\sigma-1}} H^{\frac{-1}{\sigma}}, \\ w_l &= \frac{\partial Y}{\partial L} = (1-\alpha) (1-\pi) K^\alpha A_l^{\frac{\sigma-1}{\sigma}} \left( \pi (A_h H)^{\frac{\sigma-1}{\sigma}} + (1-\pi) (A_l L)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1-\alpha\sigma}{\sigma-1}} L^{\frac{-1}{\sigma}}. \end{aligned}$$

The skill premium ( $\varpi$ ) is defined as the relative price of skilled labor in terms of unskilled

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<sup>5</sup>A microfoundation for this aggregate production function is presented in Section 5.3.

labor and is given by:

$$\varpi = \frac{w_h}{w_l} = \frac{\pi}{(1-\pi)} \left( \frac{A_h}{A_l} \right)^{\frac{\sigma-1}{\sigma}} \left( \frac{H}{L} \right)^{-\frac{1}{\sigma}}. \quad (5.2)$$

Finally, I take logs to (5.2):

$$\ln \varpi = \ln \frac{\pi}{(1-\pi)} + \left( \frac{\sigma-1}{\sigma} \right) \ln \frac{A_h}{A_l} - \frac{1}{\sigma} \ln \frac{H}{L}. \quad (5.3)$$

The three most important results of (5.3) are:

- An increase in the relative supply obviously produces a decrease in the skill premium, provided that skilled and unskilled workers are not perfect substitutes.
- A rise in  $\frac{A_h}{A_l}$  has ambiguous effects depending on the value of  $\sigma$ . The skill premium increases provided that  $\sigma > 1$ .<sup>6</sup>
- Physical capital has no effect on the skill premium because the capital increases the marginal productivity of skilled and unskilled labor in the same proportion.

I take expression (5.3) to the data. Data on the skill premium come from the Employment Survey of the University of Chile that spans the period from 1957 to 2002.<sup>7</sup> This survey collects a representative sample of the Santiago Metropolitan Area (which represents about 39% of the Chilean population and 48% of the Chilean GDP). The University of Chile survey is the only source of microdata that covers a long period of time and has been widely used in studies of wage inequality in Chile (e.g. Robbins, 1994a and 1994b, Sánchez-Páramo and Schady, 2002) and has the additional advantage of providing reasonably comparable data on monthly earnings, hours worked, economic sectors, and educational categories. Robbins (1994b) argues that this sample is a good representation of the labor market in Chile, except for the agriculture and mining sectors.

I focus on the monthly earnings of full-time (working at least 35 hours) wage and salary workers aged 16 to 64 years. To compute an estimate of the skill premium I apply the method-

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<sup>6</sup>A Leontieff technology (i.e.  $\sigma = 0, \alpha = 0$ ) is useful to understand the intuition of this result. In this case, an increase in  $\frac{A_h}{A_l}$  "liberates" some skilled workers and, therefore, the skill premium decreases. Given that most empirical results suggest that  $\sigma > 1$ , improvements in  $\frac{A_h}{A_l}$  in general increase the skill premium.

<sup>7</sup>Data on educational variables are missing for 1959, and 1963-1964.

ology of Autor et al. (2005) to decompose the wage premium between predicted and residual wage inequality.<sup>8</sup> I focus on male workers and run a regression of (log) earnings on dummies for eight education groups (no education, primary-school drop-out, primary-school graduate, high-school drop-out, high-school graduate, college drop-out, college graduate, and other education), and a cubic on experience for each education category for each year. It is worth noting that the estimated regressions are not meant to identify causal effects of the observables on wages—instead, the regressions are meant to be the best linear predictions of wages on observables, i.e. these regressions are meant to be used to *predict* wages on observables. Using the estimated regression I predict the wage for each observation for each year and define the log skill premium as the difference between the average log wage for the group of college graduates and high-school graduates using fixed-weighted averages of the 32 education  $\times$  experience sub-group means (using the average share of total hours worked for each sub-group from 1957 to 2002 as weights) to adjust for compositional changes within each group.<sup>9</sup>

I use the difference between college and high-school graduates as my main proxy for the difference between skilled and unskilled workers. There are some alternative measures of skilled and unskilled workers: college graduate equivalents and primary school graduate equivalents (used in Beyer et al, 1999), non-production and production workers (used in Berman et al., 1998 and Berman and Machin, 2000), for instance. My choice to use college graduate and high-school graduate equivalents to measure skilled and unskilled workers over these two alternative classifications is motivated by two facts:

1. The Chilean data suggest that the big increase in wages occurs for workers having more than 12 years of formal schooling (this result is also reported in Contreras, 2002). Putting it differently, this evidence implies that the correlation between the college-secondary wage premium and college-primary wage premium should be high. Indeed, the correlation between the college-secondary and the college-primary wage premium is 0.73 (0.83) in

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<sup>8</sup>The basic motivation for this disaggregation is to study whether the increase in the demand for skilled labor is correlated with the evolution in the premium for (unobserved) abilities which are orthogonal to education, especially in the context of the US. In the case of Chile, the correlation between predicted and total (i.e., including residual wage premium) wage premium is 0.99 and residual inequality does not have a clear pattern. This basically implies that the behavior of wages can be explained using the observables described in the main text.

<sup>9</sup>The four experience categories are 0-9, 10-19, 20-29, and 30+ years..

levels (first-differences) using data from 1957 to 2002.

2. The use of production and non-production workers as a proxy for skilled and unskilled workers in many papers is motivated by the lack of educational categories in most datasets more than by a direct preference for this classification of workers. The available evidence suggests that while using production and non-production workers identifies similar *trends* as using education categories (e.g. Feenstra and Hanson, 2001), the wage premium of non-production to production workers only corresponds to a small increase in the inequality between skilled and unskilled workers (e.g., Katz and Autor, 1999 for the US and Bustos, 2005 for Argentina). Therefore, I prefer a more direct proxy for skilled and unskilled workers.

The relative supply of skilled labor is defined as the ratio of hours worked by college graduate equivalents to high-school graduate equivalents. The supply of college graduate equivalents is the sum of hours worked by college graduates plus half the sum of hours worked by college drop-outs. The supply of high-school graduate equivalent workers is the sum of hours worked by high-school graduates, plus half the sum of hours worked by college and high-school drop-outs, plus 25% the sum of hours worked by primary-school graduates and by workers with other education, plus 12.5% the sum of hours worked by primary-school drop-outs. These weights roughly correspond to the average differences in returns to each group obtained in the above mentioned regressions.

Figure 1 shows the evolution of the skill premium in Chile from 1957 to 2000 (the skill premium is defined as the log difference between average wages of college graduates and high-school graduates). The skill premium presents a relatively volatile behavior before 1985. Initially, there is an increase in the skill premium in the mid 1960s, followed by a marked decrease at the same time of the first oil crisis and the collapse of the political and economic situation in Chile in the mid 1970s. Next, the skill premium returns to its previous level of the mid 1960s and starts a slow increase that seems to stabilize around the mid 1980s. My estimates of the evolution of the wage premium are roughly comparable to the estimates of the wage premium reported by Beyer et al. (1999) for 1960-1996 (see their Figure 1) and the estimates in Contreras (2002) for



1958-1996.<sup>10</sup>

The high level of the skill premium in Chile is a second factor that clearly emerges from Figure 1. The skill premium in Chile is about 110 log points on average over the 1965-2000 period, while the same variable for the US is about 50 log points over the same period. OECD (2004) reports skill premia of an average of 41 log points for a group of countries in the 1997-2002 period, with a maximum of 82 log points in the case of Hungary. IADB (2004) reports that the skill premium in Chile is high even in comparison to other Latin American countries. To compare the wage premium in Chile with that of a sample of countries, in Table 1 I present estimates of the wage premium in 79 countries, taken from Acemoglu (2003b), Banerjee and Duflo (2005), and Caselli and Coleman (2006). Chile is located in the percentile 87th (85th) [71th] of the distribution of the wage premium if I consider the complete sample of countries (I exclude Sub-Saharan countries) [I include only Latin American countries]. All in all, these results show that the wage premium is significantly high in Chile, even in comparison to the highly unequal Latin American countries.<sup>11</sup>

Figure 2 presents the evolution of the relative supply of skilled to unskilled labor during the same period. The relative supply increases slowly until around the early 1990s and takes off afterwards, after the big expansion of the higher education sector in the mid 1980s and the long period of high and positive economic growth.<sup>12</sup>

Regarding the level of the relative supply of skilled workers, differences with the US are evident. While the relative supply was about 0.30 in the case of Chile in the 1990s, the same variable reached a value of about 1.10 for the US. Certainly, this low relative supply could

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<sup>10</sup>The correlation between my indicator of the wage premium and the estimate of the same variable implicit in Contreras (2002) is 0.91. I construct the log of the wage difference between a college graduate and a high-school graduate as  $5\beta_t$ , where  $\beta_t$  is the estimate of the return of an additional year of education for college students for year  $t$  in a Mincerian regression, as reported in Contreras (2002).

<sup>11</sup>In order to make estimates comparable with other countries in Table 1, I use the average return to attending school –and not the marginal return of attending college– in Contreras (2002) to compute the wage premium for Chile. If I used the marginal return, the wage premium would be 1.07 for Chile.

<sup>12</sup>A valid concern to the construction of the relative supply is that a big share of the increase in the relative supply during the 1990s is related to the creation of the so-called private universities. If graduates from these universities did not receive an education comparable to the education provided by the old universities, my estimates of the relative supply may be biased. To address this concern, I study whether cohort effects vary significantly for workers of the cohorts that enter the market after 1985, using a framework similar to Card and Lemieux (2001)–i.e. including year, cohort, and age effects. Results, available upon request, suggest that cohort effects are not significantly different for the youngest cohorts. Robbins (1994b) present similar results using a different methodology. In addition, results in Rappoport et al. (2004) suggest that differences in wages among traditional and private universities are not clearly significant, depending on the career and the geographic area.

explain the above mentioned differences in skill premium. Using the series on skill premium and relative supply in Chile and the US (from Autor et al. 2005), and equation (5.3), I construct an estimate of the share of the difference in skill premium between both countries that is explained by differences in their relative supplies. This is given by:  $\frac{-\frac{1}{\sigma}(\ln \frac{H}{L} - \ln \frac{H}{L}_{US})}{\ln \varpi - \ln \varpi_{US}}$ .

To implement this exercise, I need an estimate of  $\sigma$ . Most papers in the literature report estimates in the interval between 1 and 2 (see Ciccone and Peri, 2005 for a review of estimates for the US and other countries and Robbins (1996) for estimates for a group of small open economies). My estimates for Chile using cointegration techniques produce estimates of  $\sigma$  in the interval from 1.39 to 1.67.<sup>13</sup> Given these results and the similarity to results in other papers, I choose  $\sigma = 1.50$ , which is around the mean value of the available estimates and the preferred estimate in Ciccone and Peri (2005).

Results suggest that differences in the relative supply explain 113 and 117% of the differences in skill premium between Chile and the US in the 1965-2000 period and in the 1990s, respectively. In other words, only differences in the relative supply of skilled labor can explain completely the differences between Chile and the US in terms of skill premia. This is a very important result for the theory I present in this paper to explain the behavior of technology in Chile. My claim is that a model where technology is developed in the US and used in Chile explains the behavior of the relative bias of technology in Chile. In this model, the relative bias of the technology in Chile should be the same as in the US. This piece of evidence supports that claim.

Using data on skill premia, the relative supply of skilled labor, and equation (5.3) is possible to construct an estimate of the relative demand for skilled labor as:

$$D\left(\frac{H}{L}\right) \equiv \ln \varpi + \frac{1}{\sigma} \ln \frac{H}{L}. \quad (5.4)$$

Figure 3 presents the evolution of the estimated demand in Chile from 1957 to 2000. Results confirm the presumption that the relative demand increased significantly in the 1980s and 1990s

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<sup>13</sup>I estimate (5.3) using cointegration techniques because unit root tests suggest that the skill premium and the relative supply have a unit root. Estimates are obtained from a system of the skill premium and the relative supply as endogenous variables, dummies for 1972 and 1973 as exogenous variables, and assuming a linear trend in the data. The system is estimated using a vector error correction model including one lag. In this case the estimate of  $\sigma$  is 1.39 (with a t-test of 4.07) If I include the real minimum wage and unemployment in the equation, my estimated  $\sigma$  increases to 1.67 (with a t-test of 5.10). Detailed estimates are available upon request.

to explain a flat skill premium in the presence of a rising relative supply. There is also an increase in the mid 1970s and a subsequent slow increase of demand until the mid 1980s. A noteworthy aspect of the figure is that the big increase in relative demand observed in Chile seems to be more significant in the period starting in the mid-1980s. The liberalization period that starts in 1975 is accompanied by only a mild increase in the relative demand. Section 5.4 presents a detailed discussion of the factors behind the increase in demand using a time series approach.

Next, I extend the production function (5.1) to include both equipment capital ( $K_e$ ) and capital structures ( $K_s$ ) in the production function (closely following the derivations in Goldin and Katz, 1998 and Krusell et al. 2000).

$$Y = K_s^\alpha \left[ \mu \left( \lambda (A_h H)^{\frac{\rho-1}{\rho}} + (1-\lambda) K_e^{\frac{\rho-1}{\rho}} \right)^{\left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\rho}{\rho-1}\right)} + (1-\mu) (A_l L)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma(1-\alpha)}{\sigma-1}}.$$

This extension is important because the Chilean economy has experienced a process of capital deepening in the last years. Several papers suggest that equipment capital is more complementary to skilled labor than to unskilled labor (e.g., Krusell et al. 2000). In this setup, the elasticity of substitution between unskilled and skilled labor is  $\sigma$ , which is the same value as the elasticity of substitution between equipment capital and unskilled labor. In turn, the elasticity of substitution between skilled labor and capital is  $\rho$ . To see the point more explicitly, following Krusell et al., 2000, after some algebraic manipulations, the skill premium is:

$$\varpi = \frac{w_h}{w_l} = \frac{\mu\lambda}{1-\mu} \left[ (1-\lambda) \left( \frac{K_e}{A_h H} \right)^{\frac{\rho-1}{\rho}} + \lambda \right]^{\frac{\sigma-\rho}{\sigma(\rho-1)}} \left( \frac{A_h}{A_l} \right)^{\frac{\sigma-1}{\sigma}} \left( \frac{H}{L} \right)^{-\frac{1}{\sigma}}.$$

This expression implies that skill-capital complementarity requires  $\sigma > \rho$ . Log-linearizing this expression, as in Krusell et al. (2000), yields:

$$\ln \varpi \cong \frac{w_h}{w_l} = (1-\lambda) \frac{\sigma-\rho}{\sigma(\rho-1)} \left( \frac{K_e}{A_h H} \right)^{\frac{\rho-1}{\rho}} + \frac{\sigma-1}{\sigma} \ln \left( \frac{A_h}{A_l} \right) - \frac{1}{\sigma} \ln \left( \frac{H}{L} \right).$$

Therefore, in this case the relative demand for skilled labor is given by:

$$D \left( \frac{H}{L} \right) \equiv \ln \varpi + \frac{1}{\sigma} \ln \frac{H}{L} - (1-\lambda) \frac{\sigma-\rho}{\sigma(\rho-1)} \left( \frac{K_e}{A_h H} \right)^{\frac{\rho-1}{\rho}}. \quad (5.5)$$

This expression suggests two important points. The first point is that equipment capital deepening increases the skill premium as long as  $\left(\frac{K_e}{A_h H}\right)$  increases. An empirical problem is having a good measure of the quality of equipment capital. Chumacero and Fuentes (2002) argue that available measures of the price of equipment capital in Chile are not good measures of its quality. To overcome this problem, I use two assumptions regarding the evolution of the quality of equipment capital: (i) the evolution of the quality of equipment capital in Chile is similar to the evolution of the same variable in the US and (ii) the evolution of the quality of equipment capital is similar to the evolution of  $A_h$ .

Figure 4 presents the evolution of  $\left(\frac{K_e}{A_h H}\right)$  from 1957 to 2000. Strikingly, results suggest that the level of this variable is *not significantly higher* in the post-liberalization period and only starts increasing significantly over the 1990s. Putting it differently, in spite of the big increase in equipment capital, the supply of skilled labor also increased significantly, and, therefore, the ratio of both variables does not increase.<sup>14</sup>

The second point that is derived from (5.5) is that the effect of capital deepening on the skill premium is likely to be small. To see this, following Krusel et al. (2000), I take the time derivative of (5.5) and, after some algebraic manipulations, the growth rate of the relative demand is:

$$g_D \equiv \left(\frac{\sigma - 1}{\sigma}\right) (g_{A_h} - g_{A_l}) = g_{\omega} + \frac{1}{\sigma} (g_H - g_L) - \theta (g_{K_e} - g_H - g_{A_h}). \quad (5.6)$$

where  $g$  denotes growth rate, and  $\theta = (1 - \lambda) \frac{\sigma - \rho}{\sigma \rho} \left(\frac{K_e}{A_h H}\right)^{\frac{\rho - 1}{\rho}}$ . Using results in Krusel et al. (2000), estimates from Figure 4, and a value for the capital share of 1/3, I get that  $\theta = 0.20$ . Therefore, the relative contribution of equipment capital deepening to explain any increase in the demand is probably small, even if the figures in Figure 4 are underestimated.<sup>15</sup>

Figure 5 presents the evolution of the growth rate of the skill premium using (5.6) to disentangle the contributions of relative supply, equipment capital deepening, and relative demand. The results suggest that the two major contributors are relative supply and demand. Capital

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<sup>14</sup>Braun and Braun (1999) make a related point. They argue, contrary to the conventional wisdom, that the ratio of physical to human capital is relatively low in Chile.

<sup>15</sup>The result that equipment capital does not have a first order importance to explain the skill premium is also reported by Berman et al. (1994) and Acemoglu (2002).

deepening has a minor impact on the evolution of the skill premium. The big increase in the skill premium during the 1980s was an outcome of the combination of a strong demand with a relative slowdown in the growth rate of the relative supply. By contrast, the small increase in the 1990s was a consequence of an important expansion in the relative supply, which almost fully compensates for a strong demand.

In summary, the simple accounting framework presented in this section suggests that, from a macro perspective, both supply and demand play a significant role in explaining the evolution of the skill premium in Chile. The remainder of the paper focuses on explaining the evolution of the relative demand for skilled labor. An analysis of the evolution of the relative supply in Chile will be the focus of future research, probably using detailed microdata.

### 5.2.2 Sectoral Evidence: Between and Within Sector Decomposition

The sectoral composition of the demand for skilled labor adds another important stylized fact to understand the evolution of the skill premium in Chile. Subsection 5.2.1 suggests changes in the relative demand for skilled workers are significant especially in the 1980s and 1990s. It remains to be analyzed whether the increase in demand is a between or a within sector shift. This decomposition is particularly useful to disentangle several theories. For instance, an increase in the relative demand that is a consequence of inter-sectoral reallocation of workers would support theories that emphasize the reallocation of skilled labor toward sectors more intensive in skilled labor as suggested by Matsuyama (2005). By contrast, a within-sector increase in the relative demand would be consistent with theories that emphasize skill bias technical change.

To implement this decomposition, I focus on the evolution of the skilled labor share of the wage bill as a proxy for skill upgrading at the sectoral level.<sup>16</sup> I decompose both components of skill upgrading according to Berman et al. 1994 and Autor et al. 1998:

$$\Delta(S_{jt}) = \sum_k (\Delta S_{kt} \gamma_{jk}) + \sum_k (\Delta \gamma_{jkt} S_k), \quad (5.7)$$

where  $S_{jt}$  is the group  $j$  (i.e., skilled and unskilled labor) share of the wage bill in year  $t$ ,  $S_{jkt}$  is the group  $j$  share of the wage bill of sector  $k$  in year  $t$ ,  $S_{kt} = \sum_j S_{jkt}$  is the sector  $k$

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<sup>16</sup>This proxy is equal to the relative demand if  $\sigma = 1$ . See Autor et al. (1998) for a detailed discussion.

share of the wage bill in year  $t$ ,  $\gamma_{jkt} = \frac{S_{jkt}}{S_{kt}}$  is the group  $j$  share of the wage bill of sector  $k$  in year  $t$ ,  $\gamma_{jk} = \frac{\gamma_{jkt} + \gamma_{jkt-1}}{2}$ , and  $S_k = \frac{S_{kt} + S_{kt-1}}{2}$ . Thus, the first term in the right-hand side of the equation captures the change in the skilled labor share of the wage bill related to reallocation of the demand for workers between sectors, and the second term reflects within-sector changes.

I implement this decomposition using data on 21 two-digit ISIC sectors from the Employment Survey of the University of Chile for 1960, 1970, 1980, 1990, and 2000. Appendix 1 describes the construction of the sectors and Table 2 presents annual changes in the skilled labor share of the wage bill.

The results confirm the macro evidence in that while skill upgrading in the 1960s and 1970s is roughly constant, this variable seems to increase significantly during the 1980s and the 1990s. More importantly, the within component of skill upgrading explains between 75 and 93% of skill upgrading for the economy. Results for the tradable sector suggest sizeable skill upgrading in the 1980s jointly with a small increase in the 1990s. In the tradable sectors, the within sector component also explains more than 90% of skill upgrading.<sup>17 18</sup>

All these results suggest that within sector skill upgrading explains the major part of the increase in the relative demand observed in Chile during the 1980s and 1990s, while between sector changes are small.

### 5.3 Motivating Theory: A Simple Model of Skill Upgrading

I present a simplified version of the main results of the model in Acemoglu (2003a).<sup>19</sup> The model basically analyses the balanced growth path (BGP) conditions of the evolution of a world where a developed country (the US) develops technologies and developing countries (like Chile) adopt technologies. The basic empirical implication of the model for this paper is that the bias of

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<sup>17</sup>A valid concern about this decomposition is that I use only 2-digit sectors, so a lot of reallocation could be between 3- and 4-digit industries. I do not have more disaggregated sectors in the University of Chile dataset. If I use the ENIA survey that includes a 4-digit disaggregation of economic sectors (but only includes manufacturing plants from 1979 to 2001 and a rough proxy of skilled workers—e.g., non-production workers), I find that within sector reallocation explains 93 and 96% of skill upgrading in the 1980s and the 1990s, respectively. Still, the recent paper by Schott (2004) suggests that using very detailed information on reallocation between firms producing the same goods gives a more important role for the between-firm component.

<sup>18</sup>Wacziarg and Wallack (2004) and Caballero (2005) present evidence that inter-sectoral reallocation does not significantly increase after trade and other reforms that liberalize markets.

<sup>19</sup>I closely follow Acemoglu (2003a)'s notation and exposition.

technology in the US affects the bias of technology in a country like Chile. In addition, the model also predicts that trade openness in the US increases the skill premium in Chile.

I use three important assumptions in the model. First, I assume that inventors in the US do not receive payments for technologies that are adopted in developing countries. In Acemoglu's model this assumption is related to the absence of intellectual property rights in developing countries, which make it unprofitable for inventors to develop technologies that are "appropriate" for developing countries. In the case of Chile, this assumption may appear as extreme because institutions in Chile are more developed than in most emerging countries. A (likely complementary) alternative assumption is that foreign inventors have to pay a fixed cost in order to start developing technologies abroad. In this case, small countries, like Chile, may not have enough size to make it profitable for frontier inventors to develop new technologies. In this case, only an improvement in intellectual property rights implemented by a (big) group of developing countries creates an incentive to invent technologies that are appropriated for developing countries.

The second assumption is that I solve the model considering the extreme case of a closed economy in the goods market. I do so basically to simplify the analysis. This assumption does not change the main implications of model (i.e., a correlation between skill premia in the US and Chile and the effect of openness in the US on the skill premium in Chile). The main implication of assuming a closed economy is that I allow the domestic relative supply of skilled labor to have a negative effect on the skill premium. The alternative polar case, complete trade openness, generates the prediction that the domestic relative supply of skilled labor has no impact on the skill premium (as long as the country is small, and technology adoption does not depend on the domestic relative supply of skilled labor). As previously stated, the significance of the domestic supply to understand the evolution of the skill premia in open economies is supported by the data. Robbins (1996) presents evidence that domestic relative supply has a negative and significant effect for a group of middle-income open economies. Moreover, the estimates for Chile I present in section 5.2.1 are not significantly different from other estimates of the elasticity of substitution between skilled and unskilled labor. Desjourneres et al. (1999) present simple generalizations of the basic open economy model that allow domestic supply to have an impact on the skill premium.

Finally, I assume, as do most papers in this literature, that domestic relative supply is exogenously given. Acemoglu (2003a, Appendix C) shows that the major conclusions of the model are robust to adding this factor. The main additional implication for the case of Chile is that an increase in the relative supply of skilled labor in the US, through its effect on technology and the skill premium, encourages the accumulation of skills in Chile.

### 5.3.1 Environment

Consider an economy with  $J + 1$  countries ( $J$  developing countries and the US).<sup>20</sup> As previously defined,  $H$  and  $L$  are skilled and unskilled labor, respectively.

All consumers in all countries have identical linear preferences:

$$U(t) \equiv \int_t^{\infty} \exp(-r(\tau - t)) C(\tau) d\tau,$$

where  $C(\tau)$  is consumption at time  $\tau$  and  $r$  is the discount rate. Consumption is defined over a CES aggregate of skilled and unskilled intensive goods,  $C_h$  and  $C_l$ , respectively:

$$C^j = \left[ \gamma \left( C_l^j \right)^{\frac{\epsilon-1}{\epsilon}} + (1-\gamma) \left( C_h^j \right)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}, \quad (5.8)$$

where  $\epsilon$  is the elasticity of substitution between the two goods. Assuming the goods market is competitive, the relative price of both goods is:

$$p^j \equiv \frac{p_h^j}{p_l^j} = \frac{1-\gamma}{\gamma} \left( \frac{C_h^j}{C_l^j} \right)^{-\frac{1}{\epsilon}}.$$

Assuming a closed economy, we have that  $C_s^j = Y_s^j$ , for  $s = h, l$ , where  $Y_s$  is the production of the  $s$ -intensive good. Then,

$$p^j = \frac{1-\gamma}{\gamma} \left( \frac{Y_h^j}{Y_l^j} \right)^{-\frac{1}{\epsilon}}. \quad (5.9)$$

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<sup>20</sup> An alternative motivation is that there are  $J$  developing countries and a group of developed countries that use the same technology.



The production functions of each good in country  $j$  are:

$$Y_l^j = \int_0^1 \tilde{q}_l^j(i)^\beta x_l^j(i)^{1-\beta} (L^j)^\beta di, \text{ and } Y_h^j = \int_0^1 \tilde{q}_h^j(i)^\beta x_h^j(i)^{1-\beta} (H^j)^\beta di \quad (5.10)$$

where  $x_s^j(i)$  and  $\tilde{q}_h^j(i)$  are the quantity and the quality (productivity) of machine  $i$  used with workers  $s$  in country  $j$ , respectively. These production functions assume a continuum of different types of machines or intermediates used by unskilled labor and a different group of machines used by skilled labor and present constant returns to scale at the firm level. In contrast, the aggregate production possibilities set presents increasing returns to scale because the quality of technologies is determined endogenously.

Therefore, the demand for machines is:

$$x_s^j(\tilde{q}_s^j(i)) = \left[ \frac{(1-\beta)p_s^j}{\chi_s^j(\tilde{q}_s^j(i))} \right]^\beta \tilde{q}_s^j(i) S^j, \text{ with } s = h, l; \text{ and } S = H, L. \quad (5.11)$$

$\chi_s^j(\tilde{q}_s^j(i))$  is the rental price of machine  $i$  of quality  $\tilde{q}_s^j(i)$  for skill type  $s$  in country  $j$ .

Firms in all countries can use domestic or foreign technologies, accordingly to the following rule:

$$\tilde{q}_h^j(i) = \begin{cases} q_h^j(i) \\ \theta^j q_h^{j'}(i) \text{ if } j \neq j' \end{cases}, \text{ with } \theta^j \leq 1,$$

where  $q_h^j$  is the most advanced technology developed in country  $j$ . This expression implies that countries can use domestic technologies or adopt foreign technologies. The important point is that foreign technologies may not be "appropriate" for the firms in country  $j$  (in the sense of Basu and Weil, 1998; Acemoglu and Zilibotti, 2001; and, Caselli and Coleman, 2006), and, therefore, the productivity of machines produced in country  $j'$  may be lower when used abroad.<sup>21</sup>

Technical progress is related to R&D activities (Aghion and Howitt, 1998). Innovating over

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<sup>21</sup>Various papers have presented evidence that developing countries tend to suffer from using inappropriate technologies (given their endowments)—e.g., Acemoglu and Zilibotti, 2001; Berman, 2000; Caselli and Coleman, 2006). For instance, Caselli and Coleman (2006) present estimates that the degree of inappropriateness of using US technologies decreases per-capita income (e.g. Chile would lose 20% of its GDP by using US technologies).

a machine of quality  $q$  creates a new vintage with quality  $\lambda q$  ( $\lambda > 1$ ). One unit of R&D spending (in terms of the final good) produces a flow rate of innovation  $z\phi(z)$ . R&D cost (also in terms of the final good) of innovating  $z$  over a machine of quality  $q$  is  $Bqz$  ( $B = \beta(1 - \beta)\lambda$ ), with  $\phi'(z) < 0$  and  $\phi(z)z$  is increasing in  $z$ .

The inventor of a new machine in the US becomes the monopolist of this technology. Given the demand functions in (5.11), the monopolist price is a constant markup over the marginal cost.<sup>22</sup> To simplify the analysis, Acemoglu (2003a) assumes that machines fully depreciate after a year and the marginal cost of producing each machine is constant and equal to  $(1 - \beta)^2$ . This implies that  $\chi^U = (1 - \beta)$ . There is a monopolist in the developing country that can copy US technologies at a small cost  $\xi$ .

### 5.3.2 Skill premium

Assuming that  $(1 - \beta)\theta^j q_s^U(i) > q_s^j(i)$  for all  $s = h, l$  and  $j$  and  $i$ , firms in developing countries will use US technologies.<sup>23</sup> This result implies that (1)  $\tilde{q}^j(i) = \theta^j q_s^U(i)$ , (2) the domestic monopolist will set  $\chi^U$  (the monopolist price), and (3) there will be no R&D in developing countries in the future, so the developing country will always adopt US technologies.

Substituting  $\chi^U$  in (5.11) and the demands in the production function, I get:

$$Y_s^j = (p_s^j)^{\frac{(1-\beta)}{\beta}} \tilde{Q}_s^j S^j, \text{ for } s = h, l; \text{ and } S = H, L; \quad (5.12)$$

where  $\tilde{Q}_s^j = \int_0^1 \tilde{q}_s^j(i) di$ , for  $s = h, l$ . Notice that (5.12) is equivalent to a linear technology,

where the productivity of each unit of labor is proportional to the state of technology ( $\tilde{Q}_s^j$ ) and to product prices.<sup>24</sup>

Computing the marginal productivity of labor, using the fact that  $\tilde{q}^j(i) = \theta^j q_s^U(i)$ , the skill premium in this economy is:

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<sup>22</sup>Formally, this result requires that  $\lambda > (1 - \beta)^{\frac{(1-\beta)}{\beta}}$ .

<sup>23</sup>This assumption implies that it is more efficient to use US technologies even if the US monopolist sells the machine at the monopolist price and the domestic monopolist sells the machine at the marginal cost.

<sup>24</sup>Expression (5.12) is equivalent to the aggregate production function (5.1), if  $A_s^j = (p_s^j)^{\frac{(1-\beta)}{\beta}} \tilde{Q}_s^j$  and  $\alpha = 0$ .

$$\omega^j = (p^j)^{\frac{1}{\beta}} \frac{Q_h^U}{Q_l^U}.$$

Using (5.9), (5.10), and (5.12) implies that the relative price is:

$$p^j = \left[ \left( \frac{1-\gamma}{\gamma} \right)^{-\varepsilon} \frac{Q_h^U H^j}{Q_l^U L^j} \right]^{-\frac{\beta}{1+\beta(\varepsilon-1)}}. \quad (5.13)$$

Therefore, the skill premium is:

$$\omega^j = \left[ \left( \frac{1-\gamma}{\gamma} \right)^{-\varepsilon} \frac{H^j}{L^j} \right]^{-\frac{1}{1+\beta(\varepsilon-1)}} \left( \frac{Q_h^U}{Q_l^U} \right)^{\frac{\beta}{1+\beta(\varepsilon-1)}}. \quad (5.14)$$

This expression highlights the positive relationship between technological bias in the US and the skill premium in developing countries and the negative effect of the domestic relative supply on the skill premium.

### 5.3.3 Equilibrium Skill Bias

I determine the equilibrium skill bias of technology in the US to find a closed-form for the skill premium in the US. I will not present all the derivations to save space, but I use the following two results from Acemoglu (2003a):

$$(p^U)^{\frac{1}{\beta}} \frac{H^U}{L^U} = \Theta \left( \frac{z_h}{z_l} \right), \text{ with } \Theta' \left( \frac{z_h}{z_l} \right) > 0. \quad (5.15)$$

$$\frac{Q_h^U}{Q_l^U} = \left( \frac{1-\gamma}{\gamma} \right)^{\varepsilon} \left( \frac{H^U}{L^U} \right)^{\beta(\varepsilon-1)}. \quad (5.16)$$

The first result is the basic prediction of the theory of induced technical change of Acemoglu (2002b). Relative research effort toward skilled labor increases if the relative price increases (the price effect) or the relative supply of skilled labor increases (the market size effect). Given that there is a relationship between both forces as highlighted by (5.13), the second expression presents the reduced-form relationship between the relative supply of labor in the US and the relative bias of technology. Notice that in this model the relative bias of technology in all the countries is completely determined in the US.

These expressions, jointly with the previous structure described in the model, lead to proposition 1 in Acemoglu (2003a):

$$\omega^U = \left(\frac{1-\gamma}{\gamma}\right)^\varepsilon \left(\frac{H^U}{L^U}\right)^{\beta(\varepsilon-1)-1}, \text{ and} \quad (5.17)$$

$$\omega^j = \left(\frac{1-\gamma}{\gamma}\right)^\varepsilon \left(\frac{H^U}{L^U}\right)^{\frac{(\beta(\varepsilon-1))^2}{\beta(\varepsilon-1)+1}} \left(\frac{H^j}{L^j}\right)^{-\frac{1}{\beta(\varepsilon-1)+1}}. \quad (5.18)$$

Finally, substituting (5.17) in (5.18) and taking logs I get:

$$\ln \omega^j = a \ln \left(\frac{1-\gamma}{\gamma}\right) + b \ln (\omega^U) + c \ln \left(\frac{H^j}{L^j}\right), \quad (5.19)$$

where  $a = \frac{\beta(\varepsilon-1)-2}{\beta(\varepsilon-1)-1}$ ,  $b = \frac{(\beta(\varepsilon-1))^2}{(\beta(\varepsilon-1))^2-1}$ , and  $c = -\frac{1}{\beta(\varepsilon-1)+1}$ .

Equation (5.1) is the basic specification for the empirical analysis in the next section, using macro time series. Two basic results can be derived from (5.19):

- A positive relationship between the skill premium in the US and in countries that use technologies developed in the US. Moreover,  $b$  is expected to be greater than 1.
- A negative impact of the domestic relative supply on the skill premium.<sup>25</sup>

### 5.3.4 Trade Openness in the US

This theory also presents the additional implication that periods of trade openness in the US create additional incentives to produce skill-biased technologies. The basic intuition of this result comes from expression (5.15). If  $\frac{H^U}{L^U} > \frac{H^j}{L^j}$  for all countries  $j$ , then periods of trade openness in the US increase the relative price of skilled-intensive goods in the US on impact. This creates an incentive to increase the relative effort in developing new machines to be used in the production of skilled-intensive goods. Thus, in the new steady-state equilibrium, there

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<sup>25</sup>Equation (5.18) suggests the alternative empirical implication that the relative supply in the US should be positively correlated with the wage premium in Chile. Unfortunately, the relative supply of skilled labor in the US is empirically hard to distinguish from a deterministic trend, so time series exercises using this variable are hard to interpret.

is an increase in the degree of bias of the new technologies.<sup>26</sup>

The main implication for the analysis of the skill premium in Chile is a predicted correlation between skill premium in Chile and trade openness in the US.

## 5.4 Time Series Evidence

This section takes a macro time-series approach to study the determinants of changes in the relative demand for skilled labor documented in section 5.2, using the main theoretical predictions of equation (5.19): a positive correlation between the skill premium in Chile and the US. In addition, I also test whether an increase in trade openness in the US should increase the skill premium in Chile, which is a more demanding test of the model in Acemoglu (2003a).

The model outlined in section 5.3 is highly stylized. Therefore, I extend the model to include other (potentially competing) determinants of the relative demand for skilled labor in the empirical analysis. I include a group of determinants that have been studied in other papers in the main estimating equations of this section. The other variables are:

- A proxy for the relative price of goods intensive in unskilled labor to capture potential Stolper-Samuelson effects. In particular, I use a wholesale price index of textile goods in Chile as a proxy for the relative price of unskilled-labor intensive goods (Beyer et al., 1999).<sup>27</sup>
- Proxies for policy reforms (Behrman et al., 1997). Namely, I use a structural reform index and the subindices of trade and financial liberalization constructed by Morley et al. (1999) and Lora (2001).<sup>28</sup>
- The evolution of (the log of) real minimum wage to control for labor market regulations (Autor et al., 2005). I use and extend data from Bravo and Contreras (1999).

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<sup>26</sup>This theory also predicts that along the BGP the relative price of skill-intensive goods remains constant in the US. This result is supported by the empirical literature. See Acemoglu (2003a) for more details.

<sup>27</sup>Notice that the model of section 5.3 suggests that including the relative price of skill-intensive goods and the relative labor supply is redundant. In a more general model, however, both variables could be included.

<sup>28</sup>My procedure to construct a structural reform index that covers the complete period in my sample is as follows. First, I extend the Morley et al. (1999) index to cover the 1996-1999 period using the Lora (2001) index. Second, I extend the combined index to cover the 1960-1969 and 2000-2002 periods. To do that, I run a regression of the combined index on trade openness and financial depth. I use the predicted coefficients and observed variables to extend the index. Data on trade openness and financial depth come from Diaz et al. (2005).

- Finally, the output gap to capture the potential effect of short-run fluctuations on the skill premium (Autor et al., 2005). I use the Hodrik-Prescott filter to construct my measure of output gap.<sup>29</sup>

I focus on analyzing the relative demand for skilled labor. I use the estimated demand from equation (5.4), i.e., without including equipment capital, because of the problems related with equipment capital measurement. I choose  $\sigma = 1.5$  (results using other estimates of  $\sigma$  in the interval between 1 and 2 produce similar results).

My basic estimating equation is:

$$D_t = \alpha_1 + \alpha_2 t + \alpha_3 cycle_t + \alpha_4 \log(w_{\min t}) + \alpha_5 SR_t + \alpha_6 \log(p_t) + \alpha_7 \log(\varpi_t^{US}) + \varrho_t, \quad (5.20)$$

where  $D$  is the relative demand obtained from (5.4) at time  $t$ ,  $cycle$  is the output gap,  $w_{\min}$  is the real minimum wage,  $SR$  is an index of structural reforms,  $p$  is an index of the relative price of unskilled goods,  $\varpi^{US}$  is the skill premium in the US (I use the estimates reported in Autor et al., 2005), and  $\varrho$  is an error term.

I estimate equation (5.20) using both levels and first differences because of the known limitations of unit root tests.<sup>30</sup> In this case, for instance, Phillips-Perron tests are inconclusive because they suggest that  $D$  has either a unit root or is stationary around a deterministic trend.

The results of estimating equation (5.20) are presented in column (1) of tables 3 and 4. All the estimated coefficients are in line with the previous literature, but the only coefficient that is statistically significant at the conventional levels is the skill premium in the US.<sup>31</sup> Notice that the fact that both level and first-difference equations report very similar results suggesting that spurious correlation between the skill premium in the US and the relative demand in Chile is not driving the results. An additional way of testing whether results could be driven by spurious correlation is using Granger-causality tests. I can not reject the hypothesis that the relative demand in Chile does not Granger-cause the relative skill premium in the US (p-value=0.47),

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<sup>29</sup>Using the unemployment rate instead of output gap produces similar results.

<sup>30</sup>In the case of first-difference equations I include an  $MA(1)$  to control for potential over-differentiation of the series if the true process is  $I(0)$ .

<sup>31</sup>Results do not change significantly if I replace the structural reforms index by indices of trade and financial liberalization.

but I reject the hypothesis that the skill premium in the US does not Granger-cause the relative demand in Chile (p-value=0.03).

The estimated coefficient of the skill premium in the US is positive and significant and implies that a 1% increase in the skill premium in the US increases the relative demand in Chile by between 2.1 and 2.4%. This is consistent with the prediction of equation (5.19) that this elasticity should be bigger than one. More importantly, I cannot reject that the magnitude is equal to the value predicted by equation (5.19) (with p-values of 0.17 and 0.14 for first-difference and level estimates, respectively), given the available estimates of  $\beta(\varepsilon - 1) - 1$  for the US. The coefficient  $\beta(\varepsilon - 1) - 1$  captures the long-run relationship between the relative supply and the skill premium in the US (see equation 5.17). I find an estimate for this variable of 0.15 for the US (Acemoglu, 2003a reports an estimate of 0.13).

I test the second implication of the model in section 5.3: the level of trade openness in the US should positively affect the relative demand for skilled labor in Chile. In columns (3) of Tables 3 and 4, I replace the skill premium by a proxy of trade openness in the US—the ratio of the sum of real exports and imports to GDP. Results support this theoretical prediction: an increase in trade openness in the US increases the skill premium in Chile. As discussed in section 5.3, the intuition of this result is that in periods of trade opening in the US, the price of skill intensive goods increases, which creates an incentive to produce technologies that are biased towards skilled labor.

Finally, for completeness I present estimates including both the wage premium in the US and trade openness in the US in columns (3) of Tables 3 and 4—notice that in the model, the wage premium in the US is determined by trade openness in the US so these estimates have no clear theoretical interpretation. Both variables are positive and (marginally) significant.<sup>32</sup>

The time series evidence suggests that the relative demand for skilled workers in Chile responds to the behavior of skill upgrading in the US. These effects are not only statistically significant, but also economically relevant. The skill premium in the US increased about 25 log

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<sup>32</sup>Other (non-reported) exercises include substituting total wages for predicted wages, including equipment imports, including dummies for 1972-1973, including measures of strikes, including alternative indices of institutions (such as democracy), and including interactions of the skill premium in the US and the supply of skills in Chile. Results were not significant. The last exercise is interesting because a model where technology adoption depends on skill intensity in Chile would suggest a higher correlation of demand and supply for skills as the economy becomes more skill intensive. The evidence does not support this view.

points between 1980 and 2000. The estimated elasticity implies an effect of between 50 and 60 log points on the relative demand in Chile, which increased about 80 log points over the same period. Similarly, trade openness in the US increased about 80 log points over the last 20 years, and the estimated effect on the relative demand in Chile is above 100 log points.<sup>33</sup>

The timing of the evolution of the relative demand for skilled labor in Chile also supports the empirical results in this section. As Figure 6 shows, the big increase in the relative demand in the mid 1980s occurs at the same time as the increase in the relative wage in the US and the period of major trade openness in the US. As previously discussed, the 1980s was the period when skill upgrading was stronger in Chile. The next section analyzes in more detail this set of results by using sectoral data from 1960 to 2000 to analyze whether skill upgrading in Chile is related to skill upgrading in the US at the sectoral level.

## 5.5 Sectoral Evidence

The model in section 5.3 predicts a positive correlation between skill upgrading in the US and skill upgrading in Chile because the relative bias of technologies is determined in the US, where machines are produced. I test this prediction using sectoral data on the share of the wage bill of skilled labor in Chile and the US from 1960 to 2000, as a proxy for skill upgrading. I use 20 two-digit sectors that are consistent across time and across countries. The University of Chile Employment Survey provides the sectoral classification in Chile at the two-digit level. I follow Robbins (1994b) in the definition of sectors and in the exclusion of public employees and the agriculture and mining sectors. For the US, I use the 1% Census Public Use Micro Samples of the decennial censuses of 1960, 1970, 1980, 1990, and 2000 provided by the Integrated Public Use Microdata Series (IPUMS) of the University of Minnesota to construct wage bill shares for each sector. I follow Autor et al. (1998) and extend their methodology to the 2000 census, using information from the Census Bureau. This methodology produces 142 four-digit sectors in the US that are consistent from 1960 to 2000. Next, I aggregate these US four-digit sectors to have two-digit sectors that are consistent with the Chilean data.

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<sup>33</sup>As a comparison, if I use the point estimates in Tables 3 and 4 for the other variables, the improvement in the structural reform index and the drop in the relative price labor-intensive goods from 1980 to 2000 explain an increase in the relative demand of about 5 and 30 log points, respectively. Obviously, the confidence intervals around these values are huge, given that the point estimates are not statistically significant.



In addition, I use a second proxy for skill upgrading in the US: an index of computer use at the sectoral level, from Autor et al., 1998. Several papers use this as a proxy for technological changes that increase the demand for skilled workers (e.g., Autor et al., 1998, Berman and Machin, 2000). In this sense, computer use can be thought of as a more primitive determinant of changes in the relative demand for skilled workers in the US. Therefore, I can test the theoretical prediction that skill upgrading in the US is correlated with skill upgrading in Chile using a more direct measure of a skill-biased technology at the sectoral level. The data on computer use are not available for 1960 and 1970.<sup>34</sup>

The basic estimating equation is:

$$S_{jt} = \beta_1 + \beta_2 S_{jt}^{US} + D_j + D_t + v_{jt}, \quad (5.21)$$

where  $S_{jt}^{US}$  is skilled labor share in the US (recall that  $S_{jt}$  is the skilled labor share in Chile),  $D_j$  are sector fixed effects,  $D_t$  are year dummies, and  $v_{jt}$  is an error term. This regression allows me to identify the effect of skill upgrading in the US from *within-sector* variation and after controlling for time effects. This is important because not including these time and sector fixed effects may generate spurious estimates if there are sectoral differences in skill intensity or time effects that are common to both countries. As previously discussed, in some regressions I substitute a proxy for computer use at the sector level in the US for  $S_{jt}^{US}$ .

The first column of Table 5 presents results of these estimates. The proxy for skill upgrading in the US is significantly correlated with skill upgrading in Chile, after controlling for sector and year dummies. This result gives additional support to the main prediction of the model: patterns of skill upgrading in the US are correlated with patterns of skill upgrading in Chile at the sectoral level. In addition, the effects are economically relevant. The implicit elasticity is about 0.83 (evaluated at the average values of the shares in the US and Chile). This elasticity predicts an increase of about 150% in the skilled-labor share of the wage bill in Chile, which is equal to 170% from 1960 to 2000. Putting it differently, the estimated elasticities imply that the evolution of skill upgrading in the US explains about 90% of the skill upgrading in Chile from 1960 to 2000.

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<sup>34</sup>A natural assumption is that computer use was 0 in 1960 and 1970. Most results in this paper are qualitatively similar if I use that assumption.

The next column of Table 5 presents results of studying whether the patterns of skill upgrading vary before and after the liberalization of the mid 1970s. I use a dummy that takes a value of one after 1975 and interact this dummy with skill upgrading in the US. Results suggest that the correlation does not change after the liberalization period if I include in my sample all the two-digit sectors. The next four columns of Table 5 present results of studying whether the effects are different for tradable and non-tradable sectors. The correlation between patterns of skill upgrading in the US and Chile is stronger in the tradable sector. This result may be explained in a model where firms operating in the tradable sector face stronger competitive pressures and the most efficient technologies are skill-biased, as suggested by the model in section 5.3.<sup>35</sup> Evidence regarding changes in the correlation over the post-liberalization period confirms this conjecture because, albeit not very precisely estimated, results suggest that skill upgrading in the tradable sectors is more important in the post-liberalization period.<sup>36</sup>

The elasticities implicit in the estimates for the tradable and nontradable sectors imply that skill upgrading in the US explains about 103% and 60% of skill upgrading in Chile in the tradable and nontradable sector, respectively. This result is particularly remarkable because skill upgrading has been significantly higher in the tradable sector in the last 40 years, as reported in Table 2.

Table 6 presents the basic estimates of equation (5.21), but using computer use in the US at the sectoral level instead of the skilled labor share as a proxy for skill upgrading. In this case I cannot study the differential effects of computer use after and before the liberalization period because I do not have data for computer use in the US in 1960 and 1970. Results are mostly similar to results in Table 5, albeit more precisely estimated: skill upgrading in the US has a positive association with skill upgrading in Chile and the results seem to be more significant and more relevant for the tradable sector. For completeness, Table 7 presents the estimates including both the skilled labor share and computer use in the same regression—again, these regressions are not straightforward to interpret from a theoretical point of view. Results suggest that computer use in the US tends to be more correlated with skill upgrading than the

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<sup>35</sup>Data suggest that skill upgrading in the US in the tradable and nontradable sectors is roughly similar from 1960 to 2000.

<sup>36</sup>Attanasio et al. (2004) report a related result for Colombia. They find that skill-biased technical change is more significant in the tradable sector after the Colombian liberalization of the early 1990s.

wage bill.

It remains to be studied if some particular component of the liberalization process drives these results for the tradable sector. I focus on trade liberalization and FDI at the sectoral level, measuring trade liberalization using an index of implicit taxes at the sectoral level (from Hachette, 1998) and measuring FDI at the sectoral level as (the log of) the stock of real FDI divided by employment in each sector.<sup>37</sup> Tables 8 and 9 present the results of these exercises. The interactions are not statistically significant. These results suggest that these two components of the liberalization process are not driving the differential results in the post 1975 period. Future research should analyze this phenomenon in more detail.

In summary, results in this section confirm time series results of section 5.4 and the predictions of the model of section 5.3. Patterns of skill upgrading in Chile are related to patterns of skill upgrading in the US at the sectoral level.<sup>38</sup>

## 5.6 Technology Imports to Chile

One of the main implications of the model developed in Section 5.3, which is implicit in the macro and sectoral analyses presented in the previous two sections, is that most technologies used in Chile come from developed countries, in particular from the US. In this section, I present descriptive evidence of (i) the share of the supply of non-transportation machinery and equipment that is imported and (ii) the main importers of machinery and equipment.

The input-output tables of Chile allow me to estimate the share of the domestic supply of machinery and equipment that is imported. Using the 1996 version of the tables (Banco Central of Chile, 2001), I estimate that about 85% of the non-transportation machinery and equipment is imported. In addition, using data on the exporter of non-transportation machinery and equipment imports to Chile from Feenstra et al., 2005, I estimate the share of imports of machinery and equipment that comes from the US and OECD (as a proxy for developed

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<sup>37</sup>My procedure to construct the stock of real FDI is as follows. I use annual flows of FDI, deflate the flows using the investment deflator, and use an annual depreciation rate of 10%. I have sectoral data on FDI only from 1974. To extend the series backwards I use total FDI flows from Diaz et al. (2005) and the sectoral shares observed in 1974-1975 to allocate the total flows to each sector.

<sup>38</sup>Other (non-reported) exercises suggest that skill intensity of the sector does not explain differences. This result confirms the results using time series data.

countries). I also present estimates for data-processing equipment, probably a more direct proxy of skill-biased technologies. Results in Table 10 confirm the basic assumption that most machinery and equipment come from developed countries. The US alone sends more than 50% of the non-transportation machinery and equipment imported to Chile, and OECD countries account for at least two-thirds of import share of machinery and equipment and data-processing machines.

As previously discussed, even though a literal interpretation of my results is about correlation between skill upgrading in the US and Chile, I interpret my results as a correlation between skill upgrading in developed countries and Chile. The basic evidence supporting this idea come from the findings in Berman et al. (1998) of the existence of pervasive SBTC among developed countries, the evidence presented in this section, and the results in the previous sections.

## 5.7 Conclusions

This paper studies the evolution of the skill premium in Chile over the last 40 years. I use macro and sectoral evidence to analyze the behavior of the skill premium and to test implications of the skill-biased technical change hypothesis in a country that uses technologies developed abroad.

Macro evidence suggests that, after some fluctuations in the 1960s and 1970s, the skill premium increased in the 1980s and has remained roughly constant since then. Specifically, the skill premium has increased significantly from about 82 log points in the 1960s to an average of 120 and 123 log points in the 1980s and 1990s, respectively. I use a CES aggregate production function a la Katz and Murphy (1992) and Krusel et al. (2000) to decompose the evolution of skill premium into supply and demand factors. The relative supply of skilled workers has increased from 0.14 in the 1960s to 0.21 and 0.31 in the 1980s and the 1990s, respectively. Therefore, the relative demand for skilled workers increased significantly in the latter period.

Results using the CES framework also suggest that differences in the relative supply can completely explain the differences between Chile and the US in the level of the skill premium. This is a first piece of suggestive evidence supporting the theory I present to explain the technological bias in Chile. In my model, the relative bias of the technology in Chile should be the same as in the US (as representative of developed countries technologies). This piece of

evidence supports that claim.

Next, I present sectoral evidence that supports the view that most of the skill upgrading in Chile over the last 40 years has taken place in all the sectors of the economy (i.e., within-sector skill upgrading). This result supports theories stressing skill-biased technical change to explain the evolution of the relative demand for skilled-labor and does not support theories explaining skill upgrading as a consequence of reallocation of labor demand between sectors.

I provide macro and sectoral evidence of a close relationship between patterns of skill upgrading in the US and Chile. As predicted by my model, macro time-series regressions imply that a proxy for the relative demand for skilled labor in Chile is significantly correlated with skill premium and trade openness in the US, after controlling for the traditional determinants presented in the literature. Namely, my time series estimates imply that the evolution of the skill premium in the US can explain between 60 and 75% of the increase in relative demand in Chile from 1980 to 2000.

Results using sectoral data, in turn, present the same conclusion: skill upgrading in Chile is correlated with skill upgrading in the US, after controlling for sector and time effects. The sectoral evidence also suggests that this effect is relatively stronger in the tradable sectors, especially in the period of economic liberalization (post 1975). Namely, my estimates imply that skill upgrading in the US explains about 103% and 60% of skill upgrading in Chile in the tradable and nontradable sector, respectively. The data I use do not provide a clear answer of what component of liberalization explains this correlation: including proxies for trade openness and FDI penetration does not capture the change in the correlation in the period after 1975. Further research using more detailed data should address this point.

## **5.8 Appendix: Construction of Economic Sectors using the University of Chile Employment Survey**

The University of Chile survey allows me to construct 21 2-digit ISIC sectors that are comparable over the complete period. The detailed definitions of the sectors come from DECON(undated). Using this information, I follow Robbins (1994b) and exclude from my sample the agriculture, mining, and public administration and military sectors. Table A.1 presents the

sectors included in the analysis.

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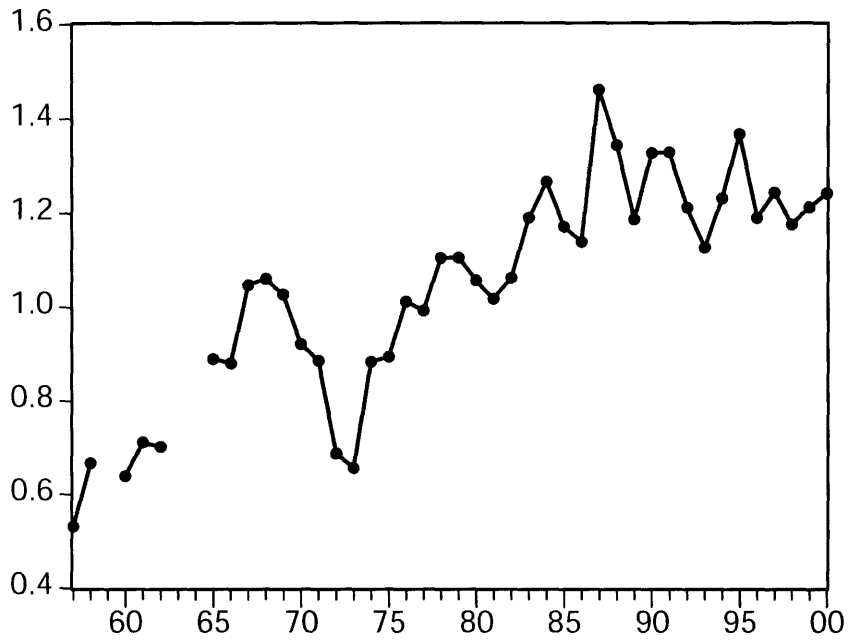


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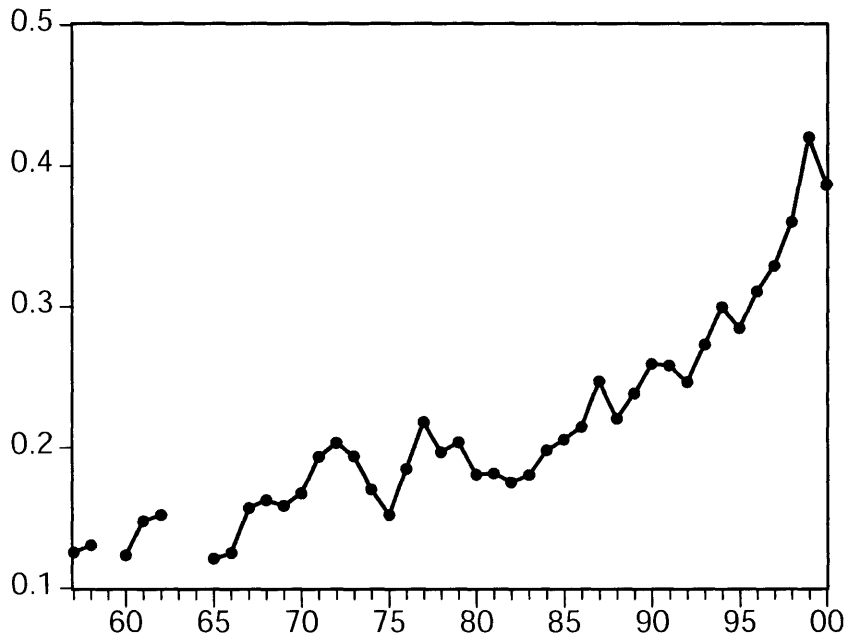
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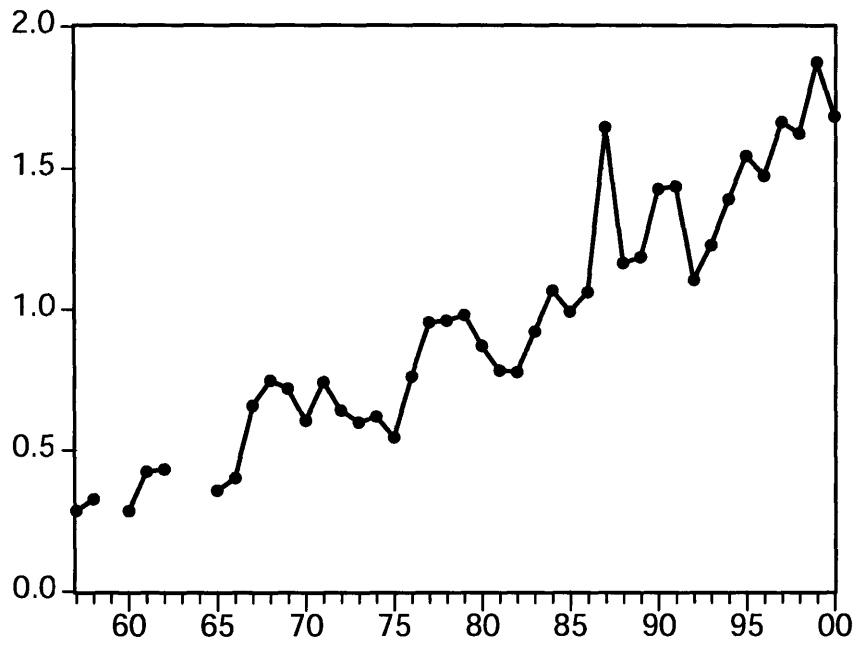
**Figure 1: The Wage Premium in Chile**



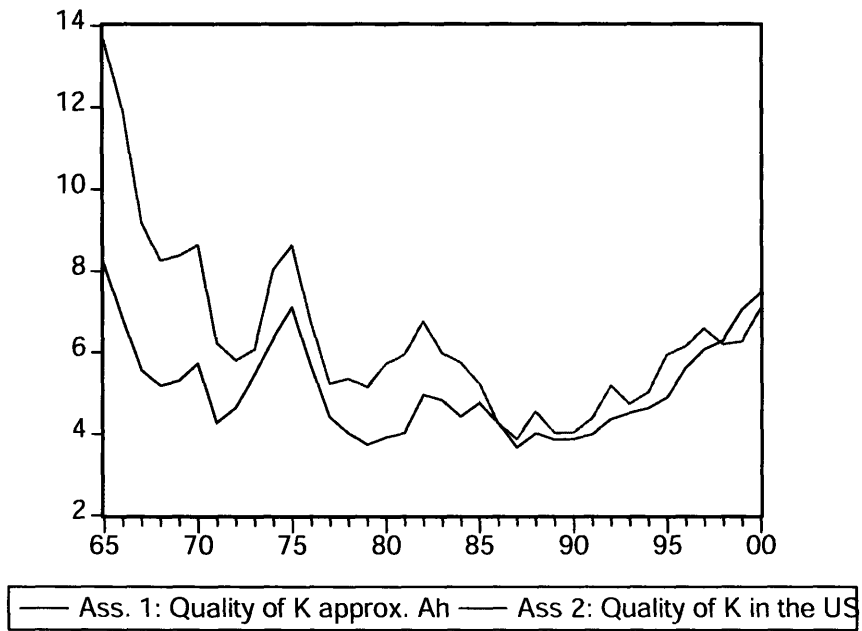
**Figure 2: Relative Supply in Chile**



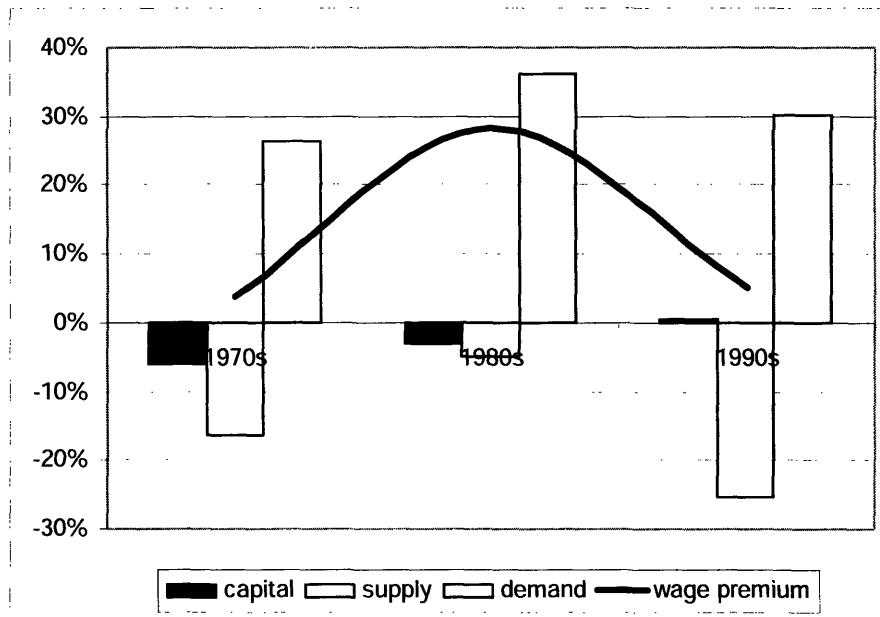
**Figure 3: Relative Demand in Chile**



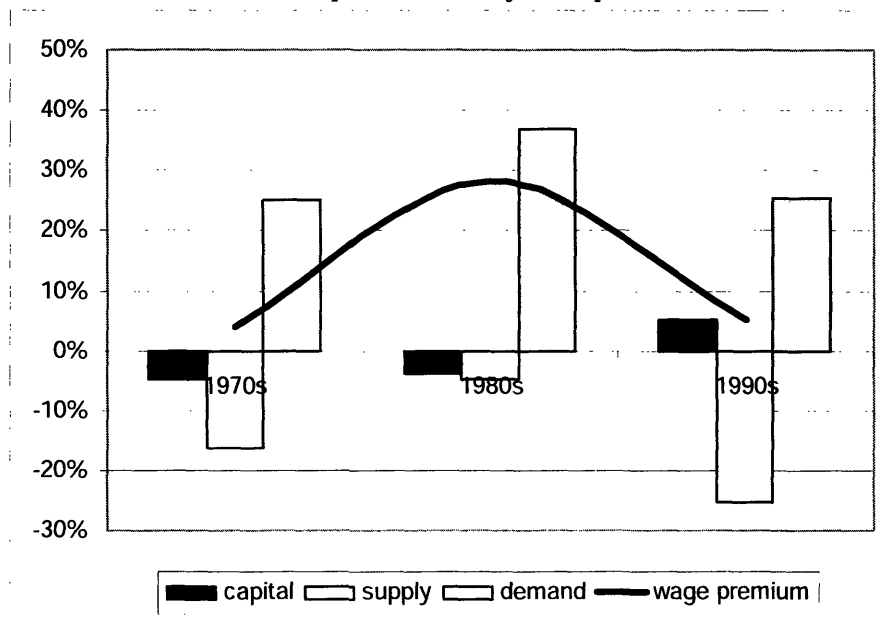
**Figure 4: Equipment Capital per Skilled Labor**



**Figure 5: Decomposing Wage Premium Growth, by Decade**  
 Panel A: Assumption 1: Quality of Capital equal to  $A_h$



Panel B: Assumption 2: Quality of Capital in the US



**Figure 6: Skill Premium in Chile and the US**

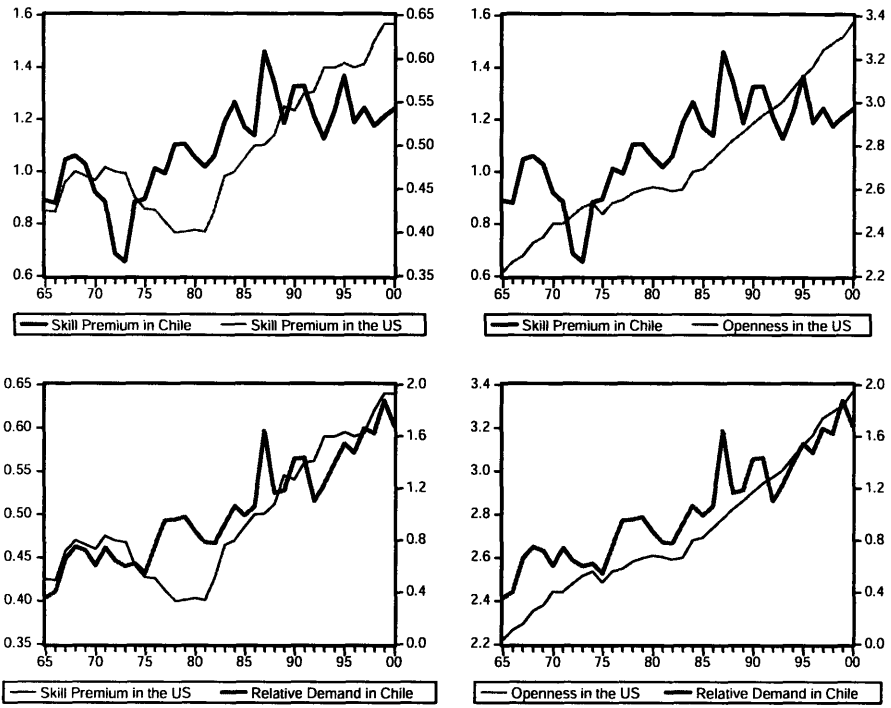


Table 1: College/High School Wage Premium (in log points)

	Middle East and North Africa		East Asia and Pacific		Developing Europe and Central Asia		Latin America and the Caribbean		High Income	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Kuwait	0.23	0.48	0.24	0.53	0.22	0.29	0.41	0.62	0.14	0.37
Egypt	0.39	0.48	0.31	0.52	0.24	0.27	0.43	0.59	0.20	0.36
Tunisia	0.40	0.48	0.35	0.52	0.27	0.27	0.47	0.59	0.26	0.26
Iran	0.58	0.48	0.35	0.53	0.35	0.29	0.47	0.62	0.27	0.27
Morocco	0.79	0.48	0.47	0.53	0.36	0.29	0.47	0.62	0.28	0.28
<b>Sub-Saharan Africa</b>										
Mean	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.30	0.30
Median	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.30	0.30
Ethiopia	0.16	0.48	0.63	0.63	0.63	0.63	0.63	0.63	0.30	0.30
Zimbabwe	0.28	0.48	0.66	0.66	0.66	0.66	0.66	0.66	0.30	0.30
Uganda	0.30	0.48	0.68	0.68	0.68	0.68	0.68	0.68	0.30	0.30
Cameroon	0.30	0.48	0.95	0.95	0.95	0.95	0.95	0.95	0.30	0.30
Ghana	0.44	0.48							0.36	0.36
Sudan	0.47	0.48							0.36	0.36
Burkina Faso	0.48	0.48							0.37	0.37
South Africa	0.51	0.48							0.38	0.38
Zambia	0.53	0.48							0.38	0.38
Kenya	0.57	0.48							0.38	0.38
Cote d'Ivoire	0.66	0.48							0.38	0.38
Tanzania	0.69	0.48							0.38	0.38
Botswana	0.96	0.48							0.38	0.38
<b>South Asia</b>									0.38	0.38
Mean	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.38	0.38
Median	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.38	0.38
Sri Lanka	0.35	0.51	0.35	0.51	0.35	0.51	0.35	0.51	0.38	0.38
Nepal	0.49	0.51	0.49	0.51	0.49	0.51	0.49	0.51	0.38	0.38
India	0.53	0.51	0.53	0.51	0.53	0.51	0.53	0.51	0.38	0.38
Pakistan	0.77	0.51	0.77	0.51	0.77	0.51	0.77	0.51	0.38	0.38
<b>Central Asia</b>									0.38	0.38
Mean	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.38	0.38
Median	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.38	0.38
Hungary	0.22	0.27	0.22	0.27	0.22	0.27	0.22	0.27	0.38	0.38
Yugoslavia	0.24	0.27	0.24	0.27	0.24	0.27	0.24	0.27	0.38	0.38
Estonia	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.38	0.38
Poland	0.35	0.27	0.35	0.27	0.35	0.27	0.35	0.27	0.38	0.38
Russian Fed.	0.36	0.27	0.36	0.27	0.36	0.27	0.36	0.27	0.38	0.38
<b>Latin America and the Caribbean</b>									0.38	0.38
Mean	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.38	0.38
Median	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.38	0.38
Peru	0.41	0.59	0.41	0.59	0.41	0.59	0.41	0.59	0.38	0.38
Costa Rica	0.43	0.59	0.43	0.59	0.43	0.59	0.43	0.59	0.38	0.38
Honduras	0.47	0.59	0.47	0.59	0.47	0.59	0.47	0.59	0.38	0.38
Dominican R.	0.47	0.59	0.47	0.59	0.47	0.59	0.47	0.59	0.38	0.38
Venezuela	0.47	0.59	0.47	0.59	0.47	0.59	0.47	0.59	0.38	0.38
Uruguay	0.49	0.59	0.49	0.59	0.49	0.59	0.49	0.59	0.38	0.38
Argentina	0.52	0.59	0.52	0.59	0.52	0.59	0.52	0.59	0.38	0.38
Bolivia	0.54	0.59	0.54	0.59	0.54	0.59	0.54	0.59	0.38	0.38
Paraguay	0.58	0.59	0.58	0.59	0.58	0.59	0.58	0.59	0.38	0.38
Ecuador	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.38	0.38
Nicaragua	0.61	0.59	0.61	0.59	0.61	0.59	0.61	0.59	0.38	0.38
Brazil	0.61	0.59	0.61	0.59	0.61	0.59	0.61	0.59	0.38	0.38
Panama	0.69	0.59	0.69	0.59	0.69	0.59	0.69	0.59	0.38	0.38
Chile	0.69	0.59	0.69	0.59	0.69	0.59	0.69	0.59	0.38	0.38
Colombia	0.70	0.59	0.70	0.59	0.70	0.59	0.70	0.59	0.38	0.38
El Salvador	0.70	0.59	0.70	0.59	0.70	0.59	0.70	0.59	0.38	0.38
Mexico	0.70	0.59	0.70	0.59	0.70	0.59	0.70	0.59	0.38	0.38
Guatemala	0.75	0.59	0.75	0.59	0.75	0.59	0.75	0.59	0.38	0.38
Jamaica	1.44	0.59	1.44	0.59	1.44	0.59	1.44	0.59	0.38	0.38
USA	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.38	0.38
Cyprus	0.61	0.50	0.61	0.50	0.61	0.50	0.61	0.50	0.38	0.38
Japan	0.66	0.50	0.66	0.50	0.66	0.50	0.66	0.50	0.38	0.38

Source: Author's calculations using data from Contreras (2002) for Chile; Autor et al. (2005) for the US; and Acemoglu (2003b), Banerjee and Duflo (2005), and Caselli and Coleman (2006) for other countries.



**Table 2: Skill Upgrading in Chile, Sectoral Evidence**

<b>Panel A: All Sectors</b>				
	Total (1)	Between (2)	Within (3)	Within Share (3)/(1)
1970-1961	0.58%	0.15%	0.44%	75.90%
1980-1970	0.65%	0.07%	0.58%	89.30%
1990-1980	1.34%	0.18%	1.17%	87.61%
2000-1990	0.84%	0.07%	0.77%	92.04%

<b>Panel B: Tradable Sectors</b>				
	Total (1)	Between (2)	Within (3)	Within Share (3)/(1)
1970-1961	0.13%	-0.01%	0.14%	108.85%
1980-1970	0.64%	0.06%	0.59%	91.81%
1990-1980	1.98%	0.11%	1.89%	95.50%
2000-1990	0.36%	0.00%	0.35%	99.56%

<b>Panel C: Non-Tradable Sectors</b>				
	Total (1)	Between (2)	Within (3)	Within Share (3)/(1)
1970-1961	0.75%	0.21%	0.56%	73.85%
1980-1970	0.56%	-0.02%	0.58%	103.68%
1990-1980	1.15%	0.24%	0.93%	81.00%
2000-1990	0.88%	-0.01%	0.89%	100.91%

**Table 3: Times-Series Evidence: Estimation in Levels**

Dependent Variable: Relative Demand			
Variable	(1)	(2)	(3)
Wage Premium in the US	2.0807 (0.8284)		1.8739 (0.7501)
Openness in the US		1.3312 (0.4210)	1.3527 (0.5696)
Output gap	0.6743 (0.4584)	0.4540 (0.5533)	0.5625 (0.4646)
Real Minimum Wage	-0.2943 (0.1994)	-0.3455 (0.1977)	-0.4986 (0.2203)
Structural Reforms	0.3712 (0.4646)	0.2432 (0.3304)	0.9408 (0.4005)
Price of unskilled goods	-0.2752 (0.1862)	-0.2542 (0.1462)	-0.3286 (0.1784)
Trend	0.0005 (0.0117)	0.0186 (0.8761)	-0.0510 (0.0227)
N	38	40	38
R <sup>2</sup>	0.8534	0.8761	0.883
ADF-test	-4.6285	-4.6038	-5.6767

Notes: Newey-West HAC standard errors

**Table 4: Times-Series Evidence: Estimation in First Differences**

Dependent Variable: Relative Demand			
Variable	(1)	(2)	(3)
Wage Premium in the US	2.3966 (0.8769)		2.1424 (0.0620)
Openness in the US		1.5966 (0.4472)	1.3810 (0.5892)
Output gap	0.7211 (0.5601)	0.4383 (0.5496)	0.5383 (0.4427)
Real Minimum Wage	-0.3445 (0.2495)	-0.3884 (0.2130)	-0.5311 (0.2330)
Structural Reforms	0.4775 (0.3701)	0.3901 (0.3384)	1.0363 (0.4048)
Price of unskilled goods	-0.3172 (0.2070)	-0.2454 (0.2190)	-0.3649 (0.1788)
Trend	-0.0064 (0.0134)	-0.0336 (0.0165)	-0.0583 (0.0239)
N	38	40	37
R <sup>2</sup>	0.2515	0.2931	0.4816

Notes: Newey-West HAC standard errors

**Table 5: Sectoral Evidence, including the Wage Bill in the US**

Dependent Variable: Skilled Labor Share of Wage Bill in Chile						
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Skilled Labor Share of Wage Bill in the US	1.5836 (0.7384)		2.1000 (1.9250)		1.2724 (0.7242)	
Skilled Labor Share of Wage Bill in the US*Pre-Liberalization		1.1189 (0.5007)		0.3243 (1.9248)		1.0100 (0.5288)
Skilled Labor Share of Wage Bill in the US*Liberalization		1.1285 (0.5270)		0.9849 (1.5635)		0.9606 (0.5489)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	0.7796	0.7756	0.5776	0.5652	0.84600	0.8467
R <sup>2</sup>	100	100	45	45	55	55
Sample	All sectors	All sectors	Tradable	Tradable	Non-Tradable	Non-Tradable

Robust standard errors clustered at the sector level.

**Table 6: Sectoral Evidence, including Computer Use in the US**

Dependent Variable: Skilled Labor Share of Wage Bill in Chile			
Variable	(1)	(2)	(3)
Computer Use in the US	1.3479 (0.6539)	2.0099 (0.8047)	0.9835 (0.8826)
Sector dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
N	0.8193	0.751	0.8578
R <sup>2</sup>	60	27	33
Sample	All sectors	Tradable	Non-Tradable

Robust standard errors clustered at the sector level.

**Table 7: Sectoral Evidence, including the Wage Bill and Computer Use in the US**

Dependent Variable: Skilled Labor Share of Wage Bill in Chile			
Variable	(1)	(2)	(3)
Skilled Labor Share of Wage Bill in the US	0.2495 (1.1208)	-0.7107 (2.8712)	0.3097 (1.2187)
Computer Use in the US	1.3043 (0.7415)	2.1115 (0.8654)	0.9275 (0.9880)
Sector dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
N	0.8796	0.7534	0.8583
R <sup>2</sup>	60	27	33
Sample	All sectors	Tradable	Non-Tradable

Robust standard errors clustered at the sector level.

**Table 8: Sectoral Evidence: FDI and Tariffs, using the Wage Bill in the US**

Dependent Variable: Skilled Labor Share of Wage Bill in Chile		
Variable	(1)	(2)
Skilled Labor Share of Wage Bill in the US	4.0523 (3.3289)	2.6613 (1.8817)
FDI	0.0065 (0.0125)	
Tariffs		-0.0008 (0.0005)
Skilled Labor Share of Wage Bill in the US * FDI	-0.1381 (0.1314)	
Skilled Labor Share of Wage Bill in the US * Tariffs		0.0035 (0.0023)
Sector dummies	Yes	Yes
Year dummies	Yes	Yes
N	0.6004	0.5986
R <sup>2</sup>	45	45
Sample	Tradable	Tradable

Robust standard errors clustered at the sector level.

**Table 9: Sectoral Evidence: FDI and Tariffs, using Computer Use in the US**

Dependent Variable: Skilled Labor Share of Wage Bill in Chile		
Variable	(1)	(2)
Computer Use in the US	4.4443 (3.5583)	2.0257 (0.9706)
FDI	0.0315 (0.0597)	
Tariffs		-0.0148 (0.0615)
Computer Use in the US * FDI	-0.1657 (0.2320)	
Computer Use in the US* Tariffs		0.0078 (0.0537)
Sector dummies	Yes	Yes
Year dummies	Yes	Yes
N	0.7635	0.7544
R <sup>2</sup>	33	33
Sample	Tradable	Tradable

Robust standard errors clustered at the sector level.

**Table 10: Share of Developed Economies in Imports of Non-Transportation Machinery and Equipment**

	US	OECD
1962		
Machinery and Equipment	50.01%	98.50%
Data Processing Machines	31.23%	99.26%
1970		
Machinery and Equipment	44.68%	94.33%
Data Processing Machines	24.12%	80.21%
1980		
Machinery and Equipment	38.23%	86.29%
Data Processing Machines	45.13%	91.58%
1990		
Machinery and Equipment	25.23%	83.27%
Data Processing Machines	46.97%	77.64%
2000		
Machinery and Equipment	38.79%	74.28%
Data Processing Machines	55.91%	67.56%

Sources: Author's calculations using Feenstra et al. (2005)

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**Table A1: Two-Digit Industries**

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Manufacture of food products, beverages, and tobacco products  
Manufacture of textiles, dressing, and leather products  
Manufacture of wood and wood products  
Manufacture of paper and paper products, publishing and printing  
Manufacture of chemicals and chemical products, plastics and rubber products, petroleum products  
Manufacture of other non-metallic mineral products  
Manufacture of basic metals  
Manufacture of fabricated metal products, machinery and equipment  
Other manufacturing industries  
Construction  
Wholesale and retail trade  
Hotels and restaurants  
Financial intermediation and real estate  
Personal service activities  
Education and health services  
Sanitation services  
Other community and social services  
Transportation  
Communications  
Electricity, gas, steam and hot water supply  
Collection, purification and distribution of water

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