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Geographical Constraints to Growth in Bolivia*

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La Paz, March 2007

Abstract:
This paper seeks to test to which extent geographical constraints can be blamed for Bolivia's poor growth performance during the last three decades. Although geographical characteristics are too stable to explain the dramatic fluctuations in growth rates over time in Bolivia, there are at least four factors that contribute to changing the importance of those characteristics over time: 1) internal migration, 2) infrastructure investments, 3) change in export partners, and 4) change in export products. The results show that Bolivia is indeed adjusting in all 4 dimensions in order to reduce the importance of geographical constraints, but not nearly fast enough.

Keywords: Geography, Development, Bolivia
JEL classification: Q56, R11.

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1. Introduction

The objective of this paper is to assess whether geographical factors can be blamed for Bolivia's poor economic performance during the last three decades. One might suspect so, since the country is landlocked, located in the tropics, and extremely rich in natural resources, factors which all have been convincingly shown to reduce average growth rates in cross country regressions (e.g. Sachs & Warner, 1995; Gavin & Hausmann, 1998; Gallup & Sachs, 1998; Rodriguez & Sachs, 1999; Hall & Jones, 1999; Sachs, 2001; Sachs & Warner, 2001; Masters & McMillan, 2000, Faye *et al*, 2004).

On the other hand, Bolivia experienced consistently high growth rates during the 1960s and early 1970s, with those same geographical conditions, and, curiously, the areas of Bolivia with tropical climate (the lowlands) have been doing a lot better than those with a temperate climate (the highlands). The departments (states) with oil and gas reserves are also generally richer than the departments without fossil fuel reserves.

So it is not at all clear that the cross-country results mentioned above would carry over if analyzed at a more local level within Bolivia. Indeed, at the municipality level all available measures of income level are positively correlated with temperature, distance to the ocean, and presence of oil and forest resources, rather than the opposite (see Table 1). Thus, while Bolivia is frequently highlighted as a typical case in support of the above mentioned relationships (poor, landlocked, tropical, and natural resource-rich), it may actually contradict the findings if scrutinized more closely.

Table 1: Simple correlations between level of development and different geographical variables at the municipality level in Bolivia 2001.

Geography variable	**Human Development Index 2001 (a)**	**Average per capita consumption 2001 (a)**	**Unsatisfied Basic Needs Index 2001 (b)**
Average temperature	0.373	0.343	-0.302
Average annual rainfall	0.294	0.262	-0.117
Altitude	-0.425	-0.360	0.295
Distance to ocean	0.316	0.305	-0.343
International border dummy	0.159	0.143	-0.165
Average slope	-0.452	-0.309	0.136
Oil concession dummy	0.213	0.191	-0.185
Mining concession dummy	-0.010	0.017	-0.137
Forest concession dummy	0.268	0.192	-0.082

Sources: (a) PNUD (2004), (b) INE (National Statistical Institute).

The purpose of this paper is to investigate how geographical factors really affect development in Bolivia. Although geographical characteristics are too stable to explain the dramatic fluctuations in growth rates over time in Bolivia, there are at least four factors that contribute to changing the importance of those characteristics over time. One is migration. Bolivia is a large country with almost all conceivable climates and ecosystems, ranging from permanent glaciers to hot, humid tropical rainforest. Presumably, people could locate in the climate zone that suits them best, thus reducing the adverse effects of climate and disease, or they could seek out the economic zones which provide them with the best opportunities and services.

The second factor which might change the importance of geography over time is manmade infrastructure. For example, the construction of a pipeline to Brazil, made it possible to export enormous volumes of natural gas at marginal costs very close to zero. The limited access to international markets could change dramatically with the construction of a bi-oceanic highway crossing the country. Or new roads into the lowland forests might give access to previously inaccessible wood resources thus encouraging a wood processing industry.

The third factor is the destination for exports. Landlockedness is much less of a problem if exports go to neighboring countries instead of distant markets. Due to a strengthening of regional integration over the last few decades, there is a tendency for export distances to decrease over time.

Finally, the fourth factor is the composition of export goods. High transport costs due to difficult topography and landlockedness are not nearly as important for goods with a high value per kilo, such as gold, jewelry or coca paste, as they are for low value, perishable goods such as cereals and tropical fruits. A change in the composition of exports could thus dramatically change the degree to which geography is a constraint.

The rest of the paper is organized as follows. Section 2 reviews the literature on the impacts of geographical factors on development in Bolivia. Section 3 estimates a cross-municipal growth equation, in order to establish the general relationships between geographical factors and growth within Bolivia. Section 4 delves into the issue of internal migration, estimating a gravity-type model that tries to explain migration patterns within Bolivia in order to test the importance of different geographical factors. Section 5 analyses the impact of infrastructure investments on growth and exports. Section 6 investigates changes in the composition of export goods and export destinations. Finally, Section 7 concludes and provides policy recommendations.

2. The literature on geography and development in Bolivia

There are three existing studies dealing specifically with the relationship between geography and development in Bolivia, but all three of them were carried out before the 2001 census, and before economic data at the municipal level became available. The amount, quality, and geographical disaggregation of data available are thus considerably larger now than it was when these studies were undertaken.

The studies nevertheless provide important observations on the relationships between geography and development in Bolivia. Andersen (1999) applies the Fields' Decomposition to earnings regressions in urban Bolivia and shows that geographical factors are more important than experience, gender and ethnicity in explaining individual wage differences, while education remains the most important factor. When applying the Oaxaca decomposition to regional differences between the highlands and the lowlands, the study shows that 86% of the substantial advantage of the lowland salaries is explained simply by temperature differences, whereas individual characteristics, such as education, experience, ethnicity, gender and work sector do nothing to explain regional differences. The remaining part of the difference between highland and lowland salaries is explained by contributions from infrastructure, such as telephone density and transport investment.

Urquiola *et al* (1999) concentrates on the human geography of Bolivia, or specifically, human settlement patterns, industrial specialization, and transportation costs. The paper documents a low degree of specialization consistent with the sparse transport network and with the usual assumption that the country exhibits high transport costs. Indeed, each of the three main eco-regions (highlands, valleys, and low-lands) have developed their own dominant urban center (La Paz, Cochabamba, and Santa Cruz de la Sierra), implying a very low degree of urban primacy[1] compared to other Latin American Countries, and a degree that has been falling over time. In addition, the country displays remarkable flexibility over time in its ordering of cities by size, with five of its seven largest urban centers having changed position at least once in the 1950-1992 period.

Whatever specializations do exist is determined mainly by regional differences in natural resources. Mining activities are found in the highlands where silver and zinc deposits are abundant, while petroleum and natural gas is extracted in the lowlands from the big fields in Santa Cruz and Tarija. Modern agriculture is mainly located in the western part of Santa Cruz, where soil quality and topography favors this activity. Coca growing is restricted to

[1] Urban primacy is defined as the population of the biggest city as a share of the total urban population of the country.

the rugged valley region, one of the few places on earth where the coca plant thrives, while wine production is better suited to the natural conditions of Tarija. Wood processing is of course concentrated close to the vast forest resources in the Amazon basin.

Morales *et al* (2000) also find that geographical variables matter in the explanation of poverty levels, labor income and GDP per capita disparities among provinces, especially altitude, erosion, urbanization rate and the distance toward the main cities of the central axis of the country (La Paz, Cochabamba, Santa Cruz). The main channels for this are the effects of geographical variables on land and labor productivity.

Apart from these three studies dealing specifically with Bolivia, there are also a few studies on the impact of geography in Latin America, which include information on Bolivia. These are useful in order to compare the impact of geography in Bolivia to the impact in other countries. For example, Gallup, Gaviria & Lora (2003) shows that Bolivia is relatively free of natural disasters compared to most of the other countries in the region. Not one of the 50 major natural disasters in Latin America and the Carribbean since 1970 was located in Bolivia, since the country has little seismic activity (causing earthquakes and volcano eruptions), and is insulated from hurricanes and tsunamis due to its landlockedness. However, minor landslides and localized droughts and floods are common complaints in Bolivia.

Finally, Faye *et al* (2004) analyzes the special problems of landlocked countries, including Bolivia. The paper shows that the two land locked countries in South America (Bolivia and Paraguay) are also the two countries with the lowest level of human development. However, Bolivia seems to be less troubled by its landlockedness than many similar countries in Africa, and has even at times been able to capitalize on its position in the center of South America, for example by becoming an energy hub.

3. Cross-municipal regression models of geography and development

This section presents several different regression models designed to test the relationship between geography and development within Bolivia at the municipal level.

As a measure of development we use the Human Development Index (HDI), a multidimensional indicator of development regularly calculated by the United Nations both at the national level, for international comparisons, and at the sub-national level for within-country analysis (see PNUD, 2004). The following three dimensions are included in the index with equal weights (1/3 each):

- **Life expectancy** (to have a long and healthy life): Life expectancy at birth.
- **Education level** (to have the necessary knowledge): A combination between adult alfabetization rate (weight 2/4), net combined immatriculation rate (weight ¼) and average years of education (weight ¼).
- **Quality of life** (to have sufficient income): Consumption per capita.

In section 3.1 below, the HDI of 2001 is used as the dependent variable, while in section 3.2 we use the change in the HDI between 1992 and 2001, although the methodology for measuring the HDI has changed slightly between the two years. The main difference is that the third component use *income* per capita in 1992 (see UDAPSO-PNUD 1997) rather than *consumption* per capita. Since the change in methodology is the same for all municipalities, a municipality level regression of changes should be valid.

The HDI takes on values between 0.214 and 0.686 in 1992, and between 0.311 and 0.741 in 2001.

The explanatory variables included are listed in Table 2:

Table 2: Explanatory variables used in regressions, municipal level.

Variable	**Unit**	**Source**
Human Development Index 1992	-	(1)
Municipality area	1000 km^2	(3)
Average temperature	°C	(3)
Average annual rainfall	m/year	(3)
Altitude (of the municipal government)	Km above sea	(3)
Distance to ocean (by fastest road)	1000 km	(3)
Border dummy (1 if the municipality has an international border with a road crossing)	-	(3)
Slope (share of municipality with a slope of more than 10%	%	(3)
Oil concessions (1 if there are oil and gas concessions in the municipality	-	(3)
Mining concessions (1 if there are mining concessions in the municipality	-	(3)
Forest concessions (1 if there are forest concessions in the municipality	-	(3)
Primary road density	1000 km/km^2	(3)
Secondary road density	1000 km/km^2	(3)
Urbanization rate 2001	%	(1)
Population size 2001	10.000 persons	(2)
Population density	persons/ km^2	(2)/(3)
Education level (average years of education for working age population)	years	(1)
Public municipal spending per inhabitant	US$100/person	(4)

Sources: (1) PNUD (2004), (2) INE, Census 2001, (3) Special tabulation made by Juan Carloz Ledezma based on the GIS database at Conservation International Bolivia, (4) Office of National Accounts, Ministry of Finance.

3.1 Geography and the level of development

Table 3 shows three different sets of regression results with the level of HDI in 2001 as the dependent variable. The first model includes four traditional geographical variables: 1) temperature, 2) distance to ocean, 3) oil, and 4) a border crossing dummy that is a proxy for access to international markets. In this model temperature is highly significant with a positive coefficient suggesting that warmer municipalities have higher living standards than municipalities with a temperate climate. The border crossing dummy is also highly significant suggesting that municipalities with easy access to international markets are better off. Distance to the ocean and the presence of oil concessions were not found to be significant in this simple model.

Table 3: Municipal level regressions with HDI 2001 as the dependent variable (311 obs.)

Geography variable	**Model 1: Classical geography variables**	**Model 2: Extended geography variables**	**Model 3: Human geography included**
Constant	0.4860 ***	0.9912 ***	1.0857 ***
	(0.0109)	(0.1141)	(0.0904)
Average temperature	0.0047 ***	-0.0109 ***	-0.0147 ***
	(0.0013)	(0.0042)	(0.0034)
Distance to ocean	-0.0256	-0.0731 *	-0.1061 ***
	(0.0380)	(0.0383)	(0.0298)
Oil concession dummy	0.0124	-0.0151	-0.0169
	(0.0136)	(0.0133)	(0.0104)
International border dummy	0.0580 ***	0.0306 *	0.0032
	(0.0195)	(0.0178)	(0.0139)
Average annual rainfall		-0.0203	-0.0276 ***
		(0.0131)	(0.0101)
Altitude		-0.0891 ***	-0.1037 ***
		(0.0210)	(0.0168)
Slope		-0.0007 ***	-0.0003 ***
		(0.0001)	(0.0001)
Mining concession dummy		0.0351 ***	0.0041
		(0.0114)	(0.0092)
Forest concession dummy		-0.0150	0.0033
		(0.0142)	(0.0112)
Municipality area			-0.0005
			(0.0005)
Population size 2001			0.0003
			(0.0003)
Urbanization rate 2001			0.1521 ***
			(0.0129)
Rural population density 2001			0.0004 ***
			(0.0001)
Density of primary roads 2001			0.0600
			(0.0684)
Density of sec. roads 2001			0.0013
			(0.0014)
R^2	0.1668	0.3497	0.6271

Sources: Authors' estimation.

Notes: Standard errors in parenthesis.
* Significant at the 90% level, ** Significant at the 95% level, *** Significant at the 99% level.

Model 2 includes 5 additional geographical variables: 1) rainfall, 2) altitude, 3) slope, 4) mining concessions, and 5) forestry concessions. When these are included, the coefficient of temperature changes from significantly positive to significantly negative. This is because temperature and altitude are highly correlated ($\rho = -0.9869$), but IDH 2001 more strongly correlated with altitude ($\rho = -0.4251$) than with temperature ($\rho = 0.3726$).

The degree of ruggedness of the terrain (slope) is also found to have a significantly negative effect of the level of human development, whereas mining concessions are found to have a significantly positive effect on human development in this model.

Model 3 adds the following six variables related to human geography: 1) municipality size, 2) population size, 3) urbanization rate, 4) rural population density, 5) density of primary roads, and 6) density of secondary roads. These are all variables related to the organization of the population and the way they try to overcome geographical obstacles.

In this more complete model, temperature and distance to the ocean both become significantly negative in accordance with the international literature. Rainfall, slope, and altitude are also highly significant, with adverse effects resulting from too much rainfall, too rugged terrain and too high altitude.

The only human geography variables that turn out significant are urbanization rates and rural population density, which both indicate an advantage of higher population concentrations.

Thus, even though the simple correlations presented in Table 1 indicated that the Bolivian municipality level evidence was contradicting the international literature regarding geography and development, a more complete regression model does confirm that geographical factors are significantly correlated with human development, and all coefficients have the expected signs.

Natural resources were not found to have a significant effect on the level of human development, but that may be because rents and the adverse effects of rents are not limited to within the municipality. For example, in the cross-country literature, Dutch Disease is often considered one of the main explanations of the adverse effect of natural resources, but this effect would not necessarily operate at the local level. For example, it is easy to imagine that the appreciation of the exchange rate caused by natural resource exports from one municipality would adversely affect the competitiveness of other export products from other municipalities.

3.2 Geography and the speed of development

Having established in the previous sub-section that geographical variables are significantly related to the *level* of human development, this sub-section tests whether they also affect recent *changes* in human development. The dependent variable used is the change in the Human Development Index between 1992 and 2001. To test for convergence effects we include the level of HDI in 1992 as an explanatory variable together with all the same variables as in the previous section.

Table 4 shows that geographical variables are not as good at explaining changes in HDI as the level of HDI.

There is a very strong convergence effect as indicated by the significantly negative coefficient on HDI 1992. This shows that municipalities that initially had low levels of human development tend to improve faster than the municipalities that were better off in 1992. This is partly a consequence of the construction of the index, as several of the sub-components have natural upper limits. For example, once you have achieved 100% literacy rates, it is impossible to improve this indicator further. It is also more difficult to improve life expectancy if you start out with a level around 70 years than around 50 years.

Temperature was not found to have a significant effect on the change in HDI, and neither were oil and international border crossings. Distance to the ocean, however, did have a slightly negative effect. Rainfall and slope also both have a very significant negative effect on the change in HDI again suggesting that too much rain and too rugged a terrain are limiting the possibilities for rapid human development.

Of the human geography variables, only the urbanization rate was found to have a highly significant effect. The density of primary roads was found to have a slightly positive effect, but only with a level of confidence of 90%.

Table 4: Municipal level regressions with the change in HDI between 1992 and 2001 as the dependent variable (311 obs.)

Geography variable	**Model 1: Classical geography variables**		**Model 2: Extended geography variables**		**Model 3: Human geography included**	
Constant	0.2262	***	0.1300		0.3423	***
	(0.0126)		(0.0840)		(0.0894)	
HDI 1992	-0.1992	***	-0.2115	***	-0.3718	***
	(0.0333)		(0.0379)		(0.0461)	
Average temperature	-0.0011		0.0053	*	0.0006	
	(0.0008)		(0.0028)		(0.0029)	
Distance to ocean	0.0156		-0.0231		-0.0500	**
	(0.0224)		(0.0247)		(0.0237)	
Oil concession dummy	0.0120		0.0140		0.0072	
	(0.0080)		(0.0087)		(0.0083)	
International border dummy	-0.0049		-0.0026		-0.0105	
	(0.0118)		(0.0115)		(0.0109)	
Average annual rainfall			-0.0265	***	-0.0292	***
			(0.0084)		(0.0079)	
Altitude			0.0196		-0.0079	
			(0.0144)		(0.0149)	
Slope			-0.0003	***	-0.0002	***
			(0.0001)		(0.0001)	
Mining concession dummy			0.0098		0.0005	
			(0.0074)		(0.0072)	
Forest concession dummy			0.0106		0.0116	
			(0.0092)		(0.0088)	
Municipality area					-0.0003	
					(0.0004)	
Population size 2001					-0.0004	
					(0.0003)	
Urbanization rate 2001					0.0712	***

			(0.0118)
Rural population density 2001			0.0002
			(0.0001)
Density of primary roads 2001			0.1030 *
			(0.0538)
Density of sec. roads 2001			0.0014
			(0.0011)
R^2	0.1650	0.2289	0.3381

Sources: Authors' estimation.
Notes: Standard errors in parenthesis.
* Significant at the 90% level, ** Significant at the 95% level, *** Significant at the 99% level.

Based on the results in both Tables 3 and 4, we can conclude that high temperatures, high rainfall, high altitudes, too rugged terrain, and long distances to the ocean are natural geographical factors which negatively affects the possibilities for human development in Bolivia. On the other hand, the presence of natural resources, such as oil, minerals and wood, do not seem to encourage human development. Neither do they seem to discourage it.

Some of these natural constraints may be overcome or sharply reduced through the process of urbanization, whereas road building seems to have a minimal effect.

4. Internal migration, geography and development

Bolivia has urbanized rapidly over the last 50 years. Table 5 shows that in 1950 only 26.2% of the population lived urban areas (defined as agglomerations of more than 2000 people) whereas by 2001 this number had increased to 62.4%. This urbanization process has no doubt helped reduce the impact of geographical constraints, but the country is still lagging behind most of its neighbors in terms of urbanization. For Latin America and the Caribbean as a whole, the urbanization rate reached 76% in 2001 (World Development Indicators).

Table 5: Urban and rural populations in Bolivia, 1950, 1976, 1992 and 2001

Area	**1950**	**1976**	**1992**	**2001**
Urban	708,568	1,925,840	3,694,846	5,165,230
Rural	1,995,597	2,687,646	2,725,946	3,109,095
BOLIVIA	2,704,165	4,613,486	6,420,792	8,274,325
Urbanization rate	**26.2%**	**41.7%**	**57.5%**	**62.4%**

Source: The population censuses of 1950, 1976, 1992 and 2001 conducted by INE.

Rural-urban migration does not represent the only, or even the main migration flow, however. There are also substantial rural-rural, urban-urban and even urban-rural movements. The problem is that it is difficult to quantify the different types of migration flows by origin using census data, as many migrants do not state their location of origin with sufficient accuracy. We usually know which department and municipality they come from, but in many cases it is impossible to see in the data whether their location of origin was rural or urban.

However, according to estimations made by Tannuri-Pianto, Pianto & Arias (n.d.) based on the ENE 1997 and MECOVI 2002 household surveys, recent migration flows (during the 5 years before the survey) by heads of households can be decomposed as follows:

	1997	2002
Rural → Rural:	16.6%	8.8%
Rural → Urban:	20.0%	14.7%
Urban → Rural:	17.4%	20.0%
Urban → Urban:	46.0%	56.6%

The main flows are clearly from one urban area to another, mostly from La Paz and Cochabamba to Santa Cruz de la Sierra, and to a lesser extent from La Paz to Cochabamba.

The numbers obtained for 2002 seem inconsistent with continued urbanization, as urban-rural migration flows were more important than rural-urban flows. This suggests either that the estimated migration flows from the household surveys are not very reliable, or that households moving from rural to urban areas are larger than households moving from urban to rural areas. In any case, we have to look beyond just rural-urban migration to understand why people migrate within Bolivia.

In the remainder of this section we therefore analyze migration between municipalities. We use the 314 municipalities that existed in Bolivia at the time of the 2001 census. A complete municipality to municipality migration matrix therefore includes 314 x 313 = 98282 entries. For each entry we calculate the migration rate, m_{ij}, as:

$$m_{ij} = \frac{M_{ij}}{pob_i},$$

where M_{ij} is the number of migrants moving from municipality i to municipality j within a given time period (the five years before the 2001 Census), and pob_i is the population in municipality i at the beginning of the period.

The migration rate can be decomposed in two parts:

$$m_{ij} = \left(1 - \frac{M_{ii}}{pob_i}\right) \cdot \left(\frac{M_{ij}}{\sum_{k=1, k \neq i}^{n} M_{ik}}\right),$$

where the first part is the proportion of persons who decide to migrate from municipality i and the second part is the probability that they chose destination j given that they have decided to migrate. This specification reflects the two-step process of migration: First people decide whether to migrate or not, and then they decide where to migrate to.

Given that, there are 3 different models that can be estimated in order to analyze the determinants of migration:

Model 1 (Out-migration): $1 - \frac{M_{ij}}{pob_i} = \alpha + \beta'(X_i).$

Model 2 (Destination choice): $\frac{M_{ij}}{\sum_{k=1,k\neq i}^{n} M_{ik}} = \alpha + \beta'(d_{ij}, X_j).$

Model 3 (Migration rate): $m_{ij} = \alpha + \beta'(d_{ij}, X_i, X_j)$

Model 1 establishes the factors that cause a municipality to retain or expel its population. All the possible explanatory variables are characteristics of the municipality itself, including geographical variables as well as economic variables.

Model 2 establishes the factors that make municipalities more or less attractive as a migration destination. All the possible explanatory variables are characteristics of the receiving municipality plus the physical distance between the sending and the receiving municipality.

Finally, Model 3 establishes the determinants of migration rates from one specific municipality to another using the distance between the two municipalities (d_{ij}), characteristics of the sending region (X_i) and characteristics of the receiving region (X_j).

When estimating Models 2 and 3, we will have many observations (314 x 313 = 98.282), but most of them will be zero, as there are many municipality pairs between which there was no migration at all. For example, migrants from the municipality Pelechuco chose 32 different destination municipalities implying that the remaining 281 possible destinations received zero migrants from Pelechuco. With 98.282 migration rates calculated on the basis of only 675.588 migrants, each observation will include a lot of random variation, which implies that the explanatory power of the model is likely to be low.

In Model 1 we have summed over all receiving municipalities and are only interested in the characteristics which cause a municipality to expel its population. This model will have much fewer observations (314), but a lot of random variation has been summed out, which means that we can expect a higher explanatory power for this model.

As possible explanatory variables we include all the variables listed in Table 2 as well as the following three:

- $Distance_{ij}$: Distance between municipality *i* and *j*.
- Share in secondary or tertiary sectors: Percentage of economically active population working in secondary or tertiary sectors.
- Pressure: The ratio of population to total employment. This is an indication of the level of unemployment or lack of economic opportunities, and is thus expected to vary positively with out-migration and negatively with in-migration (Brown & Jones, 1985).

The regression results are presented in Table 6. All variables that were not significant at the 95% level were automatically deleted using the stepwise function in Stata.

Table 6: Regression results for the three migration models

Explanatory variables	**Model 1: Out-migration**	**Model 2: Destination Choice**	**Model 3: Migration rates**
Constant	102.9977 (5.72)	7.5899 (8.08)	1.0099 (9.82)
$Distance_{ij}$		-15.7015 (-49.25)	-1.8210 (-53.48)
Characteristics of sending municipality:			
Per capita $consumption_i$	0.2197 (2.44)		0.0022 (6.57)
(Per capita $consumption_i)^2$	-0.0004 (-2.16)		-0.000003 (-5.07)
Share in secondary and tertiary $sectors_i$			-0.4264 (-2.78)
(Share in secondary and tertiary $sectors_i)^2$	68.9969 (4.43)		0.6932 (4.19)
Urbanization $rate_i$			-0.2364 (-4.93)
Education $level_i$			
(Education $level_i)^2$			

Municipal spending per capita$_i$			0.0010
			(3.69)
Population density$_i$	-0.5072		-0.0020
	(-3.58)		(-3.91)
Share of municipality with steep slope$_i$	0.4251		0.0020
	(4.56)		(6.00)
Average temperature$_i$	-9.0987		-0.1070
	(-3.80)		(-12.29)
(Average temperature$_i$)^2	0.3912		0.0037
	(4.57)		(12.26)
Average rainfall$_i$	-19.4839		-0.0943
	(-2.78)		(-3.71)
Distance to Ocean$_i$			0.4914
			(6.66)
Bordercrossing$_i$			0.1782
			(5.59)
Density of secondary roads$_i$			
Oil concession$_i$			-0.0567
			(-2.64)
Forestry concession$_i$			0.0672
			(2.73)
Characteristics of receiving municipality:			
Population size$_j$		0.9811	0.0872
		(80.60)	(78.94)
Per capita consumption$_j$		-0.0255	-0.0021
		(-12.17)	(-11.61)
Education level$_j$		0.7224	0.0675
		(8.73)	(9.37)
Municipal spending per capita$_j$		0.0137	0.0018
		(4.44)	(6.25)
Share in secondary and tertiary sectors$_j$		4.2242	0.3373
		(6.19)	(5.41)
Pressure$_j$		-0.8017	-0.0719
		(-4.39)	(-4.37)
Municipality area$_j$		-0.0424	-0.0034
		(-3.54)	(-3.09)
Population density$_j$		0.1786	0.114
		(28.97)	(20.23)
Urbanization rate$_j$			
Density of primary roads$_j$		-0.0018	
		(-2.13)	
Density of secondary roads$_j$		-0.0086	-0.0007
		(-6.12)	(-5.23)
Average temperature$_j$		-0.8119	-0.1063
		(-10.27)	(-12.24)
(Average temperature$_j$)^2		0.02570	0.0036
		(9.22)	(13.07)
Average rainfall$_j$		0.8814	
		(3.30)	
Distance to Ocean$_j$		7.3220	0.7138

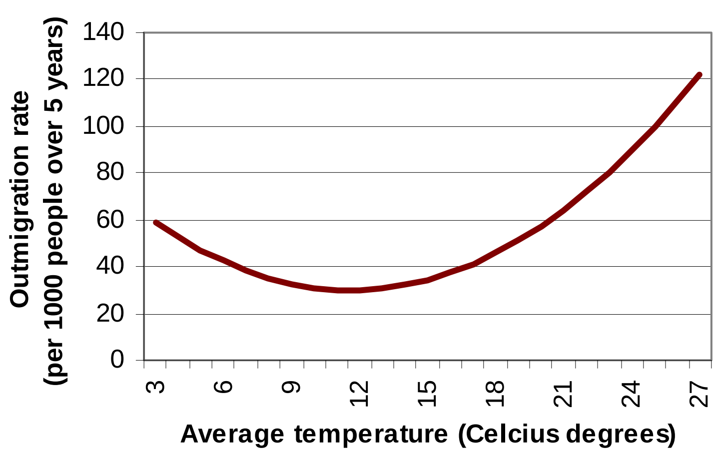
		(8.98)	(10.57)
$Bordercrossing_j$		2.0610	0.1922
		(5.55)	(5.82)
Share of municipality with steep $slope_j$			0.0009
			(2.74)
Oil $concession_j$		0.5168	
		(2.19)	
Number of Observations	314	97656	97032
R^2	0.2518	0.2186	0.1977

Source: Authors' estimation.
Notes: *t*-values in parenthesis.

Interpretation of Model 1 results

The results for Model 1 (out-migration) show that out-migration rates vary substantially with temperature, in a non-linear fashion. If all other factors were held constant, out-migration rates would be high in cold and hot municipalities, but low in municipalities with average temperatures around 10-12 degrees (see Figure 1). In Bolivia, these "preferred" temperatures correspond to an altitude of 3000-3500 meters over sea level (for example Yanacachi in the Departament of La Paz or Sacaba in the Departament of Cochabamba).

Figure 1: Temperature sensitivity of out-migration rates

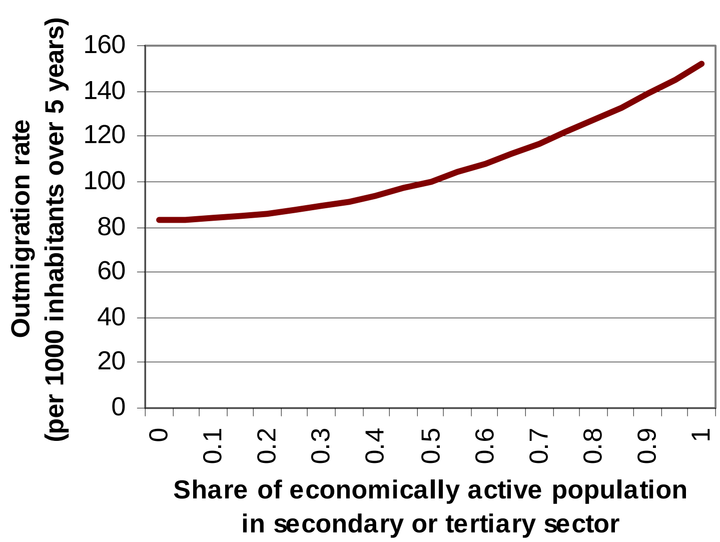


Since the average out-migration rate is 83 per 1000 inhabitants over 5 years (with a standard deviation of 37), temperature alone explains a substantial part of the variation in out-migration rates (2/3 of total explained variation, according to the Fields' decomposition). The difference in predicted out-migration rates between the least desired and most desired temperature is 92 points, corresponding to 2.5 times the standard deviation of out-migration rates.

The second most important factor in explaining out-migration rates is the share of the economically active population who are occupied in the secondary or tertiary sectors. Out-migration is low in municipalities dominated by farmers, but increases exponentially as the share in manufacturing and service sectors increase (see Figure 2). The predicted difference in out-migration rates between the lowest and highest observed share in secondary and tertiary sectors is 69 points.

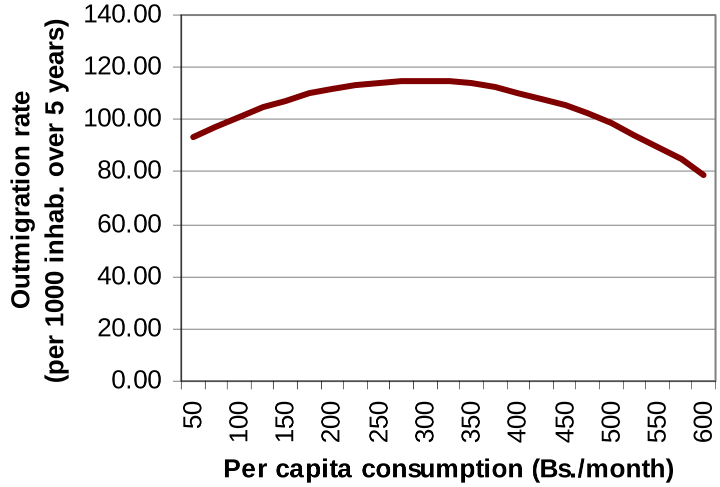
This variable was originally meant to capture the level of development of the municipality, so the results were contrary to expectations, as people are more likely to leave the most developed municipalities. However, the explanation for the result is likely that people working in manufacturing and service sectors are much more mobile than farmers, since the latter are tied to their land. This is particularly true if farmers do not have title to their land (most subsistence farmers) and thus find it difficult to sell their land at a reasonable price.

Figure 2: Sector sensitivity of out-migration rates



Out-migration rates also vary non-linearly with per capita consumption levels. They are lowest in the richest municipalities, as expected, but they are also quite low in the poorest municipalities. This is likely because these people are simply too poor to incur the costs of migrating (see Figure 3).

Figure 3: Income sensitivity of out-migration rates



Out-migration rates vary inversely with rainfall, indicating that people appreciate rain, but positively with slope, indicating that people dislike very rugged terrain. They also vary inversely with population density, suggesting that people are abandoning the most sparsely populated municipalities.

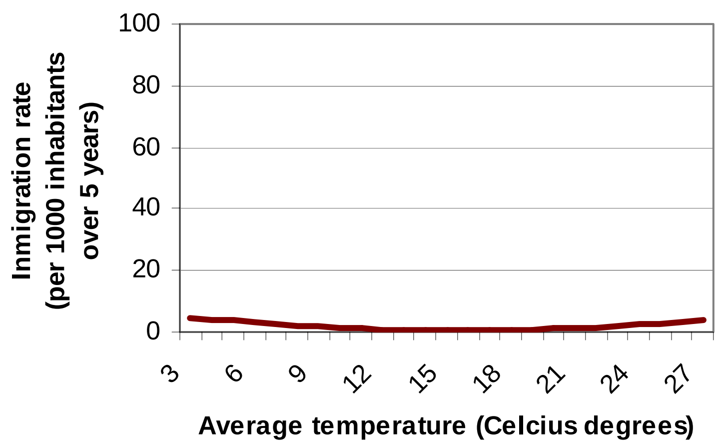
Finally, the farther away from the ocean, the lower is the out-migration rate. This finding is in contrast to the literature which suggests that people prefer to stay closer to the coast.

Interpretation of Model 2 results

Model 2 shows factors that influence the choice of location. People principally choose small municipalities with large populations and high population densities, probably because these offer more opportunities due to economies of scale. The also prefer municipalities with relatively developed secondary and tertiary sectors and with high public investment, and they avoid municipalities with few economic opportunities (as proxied by the variable "pressure"). Strangely, they avoid municipalities with high per capita consumption levels, possibly because these have higher costs of living.

With respect to geographical factors, they prefer municipalities that are not too far away from their municipality of origin, but as far away from the ocean as possible and with as much rain as possible. They also prefer municipalities which have oil concessions, whereas they don't seem to care much about mining and forestry concessions. They are ambiguous about temperature, with a slight preference for high or low temperatures instead of temperate climates, but the differences, although statistically highly significant, are very small (see Figure 4). The predicted in-migration rate only varies by 4 points between most preferred and least preferred temperature, which is low compared to the standard deviation of 24 points.

Figure 4: Temperature sensitivity of in-migration rates



Finally, in contrast to expectations, people avoid municipalities with high road densities. This is a strange result, which together with the findings from the previous section on the impact on growth, suggests that the substantial investments in road infrastructure in Bolivia may be wasteful, since it does not contribute significantly to human development and people seem to dislike both primary and secondary roads. This topic will be explored further in Section 5 on infrastructure and development.

Interpretation of Model 3 results

Model three combines factors in both sending and receiving municipalities in order to explain specific migration rates. All the estimated signs are consistent with the two previous models, and the interpretations are basically the same, only the relative importance changes.

The single most important factor explaining migration patterns (as judged by the Fields' decomposition) is the size of the population at the destination. Then follows: the population density at the destination, the migration distance, and the education level at the destination. This basically suggests that people are moving to the nearest big city the can find. All the remaining variables, while statistically highly significant, add very little (less than 0.017) to the explanatory power of the model.

This means that the human geography variables are much more important than physical geography variables in explaining migration patterns.

5. Infrastructure investments and development

Physical geographical constraints can potentially be overcome by adecuate investments in man made infrastructure. A clear example is the investment in natural gas pipelines, which have reduced the marginal transportation costs of natural gas from prohibitively high to close to zero, permitting Bolivia to become an important exporter of natural gas.

Another example of an infrastructure project which have had a substantial effect on subsequent development is the road which connected tiny Santa Cruz de la Sierra with Cochabamba and La Paz in the 1950s. This (together with complementary investments) permitted the rapid development of the lowland region, which we have witnessed in the last half century.

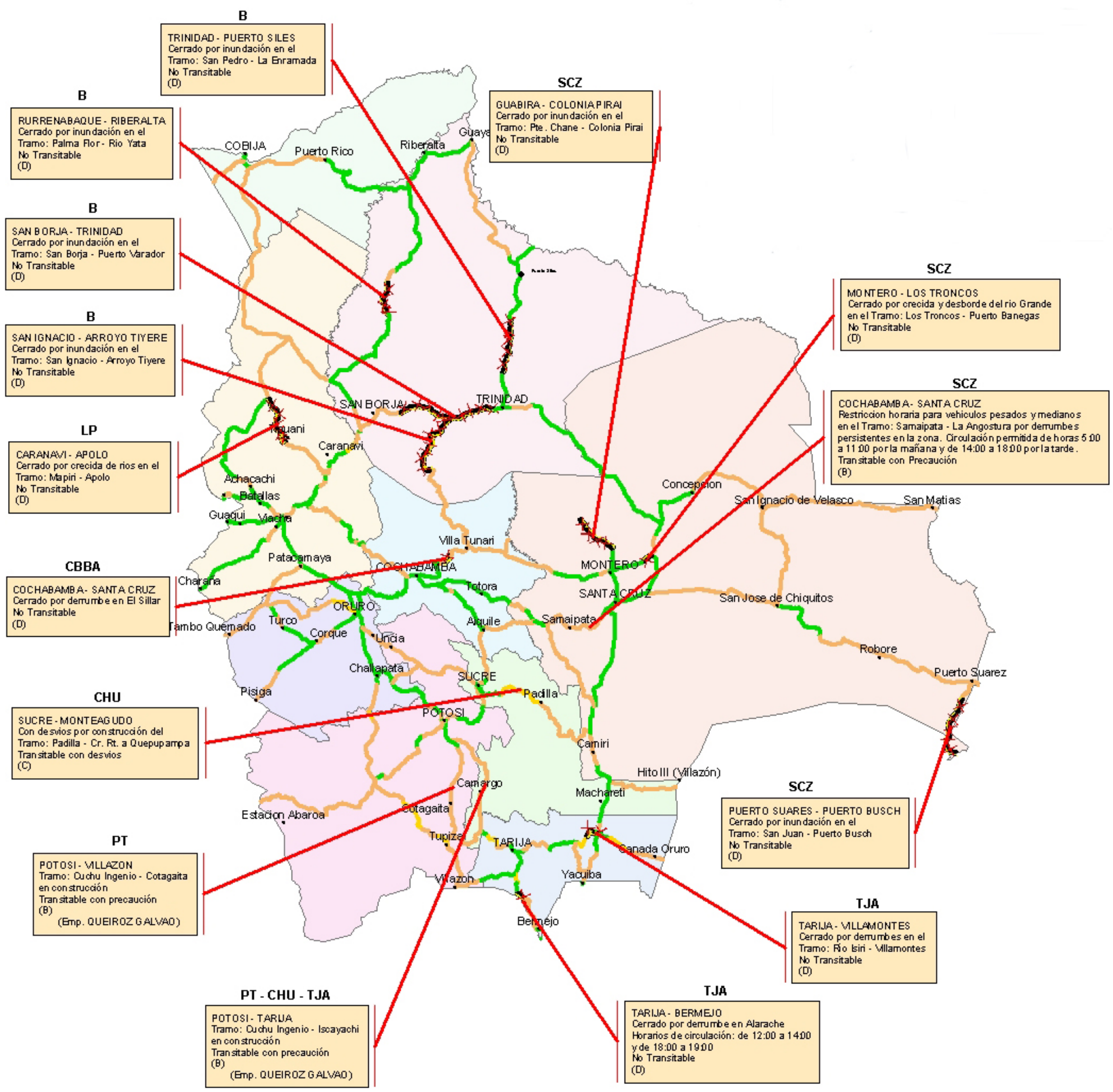
But, in general, road density does not seem to be strongly correlated with neither the level, nor the speed of human development (see Section 3), and the regression results in Section 4 indicate that migrants actively avoid municipalities with high road densities (all other things equal).

Due to the difficult geography of Bolivia, road construction and maintenance is extremely expensive. Andersen & Evia (2003) show that during the period 1997 – 2002 only 572 kilometers of primary roads were constructed at a total cost of US$159 million. This corresponds to an average cost of US$278.000 per kilometre. By July 2003, another 712 kilometers were under construction budgeted at US$ 322 million, corresponding to an average budgeted cost of about US$ 452.000 per kilometre.

These high road construction costs combined with an extremely low population density explains why there are so few roads in Bolivia. It can easily cost $10 million to construct a 50 km road that would connect some 500 families to the main road network, but given that none of these 500 families own a car, they would most likely prefer the $10 million in cash instead of a road.

In addition, despite some advances in the fundmental road network over the last 30 years, connectivity is regularly interrupted, if not by natural events then by roadblocks made by discontented population groups. At the time of writing this section, the fundamental road network was completely impassable in no less than 11 different places across the country (see Map 1) due to landslides and flooding. This means that the physical integration of the country is little better now than it was 50 years ago.

Map 1: Transitability of the main road network in Bolivia, 1 March 2007.



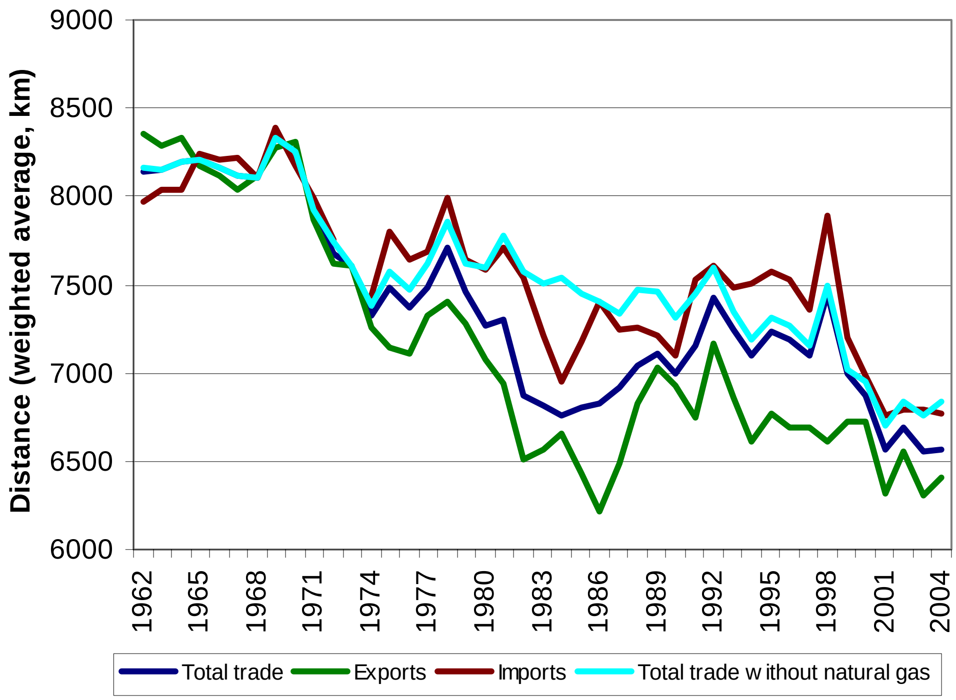
Source: Bolivian Road Administration (www.snc.gov.bo). *Note:* (D) means completely impassable.

6. The composition of exports

Even without building more or better export infrastructure, there are ways of reducing the impact of geographical constraints on international trade. One option is to trade more with neighboring countries and less with distant markets. Another is to change the composition of exports towards products with a higher value per kilo (for example jewelry or electronic documents) in which case transport costs will constitute a smaller share of final costs.

Figure 5 shows that there is a clear trend in Bolivia towards trading more with nearby markets and less with distant markets. During the 1960s the average distance for both imports and exports were around 8200 km (which roughly corresponds to the distance between Bolivia and Spain). By now the average distance is only around 6600 km, and the distance for exports even lower, due to the strong influence of natural gas exports to Argentina and Brazil.

Figure 5: Average distance to international trade partners, 1962-2004



Source: Authors' elaboration based on data from the Comtrade data base.

While distances are expected to continue shrinking due to regional integration (Nina & Andersen, 2004), they are still very high.

In order to test whether distance has changed its importance over time, we have estimated a series of gravity models of international trade. For each product group, the estimated equation is the following:

$$\ln\left(T_{i,j,t}\right) = \beta_0 + \beta_1 \ln\left(Y_{i,t}\right) + \beta_2 \ln\left(Y_{j,t}\right) + \beta_{3,t} \ln\left(D_{i,j}\right) + \beta_4 D_{B,i,j} + \beta_5 D_{L,i,j} + \varepsilon_t$$

where $T_{i,j,t}$ is the bilateral trade between countries *i* and *j* in period *t*, $Y_{i,t}\,(Y_{j,t})$ is the income level of country *i*(*j*) in period *t*, $D_{i,j}$ is the distance between *i* and *j*, $D_{B,i,j}$ and $D_{L,i,j}$ are dummy variables indicating common frontier and common language, respectively, between countries *i* and *j*.

Notice that the parameter $\beta_{3,t}$ depends on time. Here we assume a second order polynomial function:

$$\beta_{3,t} \ln\left(D_{i,j}\right) = \left(\alpha_0 + \alpha_1 \cdot t + \alpha_2 \cdot t^2\right) \ln\left(D_{i,j}\right)$$

which is equivalent to:

$$\beta_{3,t} \ln\left(D_{i,j}\right) = \alpha_0 \ln\left(D_{i,j}\right) + \alpha_1\left(t \cdot \ln\left(D_{i,j}\right)\right) + \alpha_2\left(t^2 \cdot \ln\left(D_{i,j}\right)\right)$$

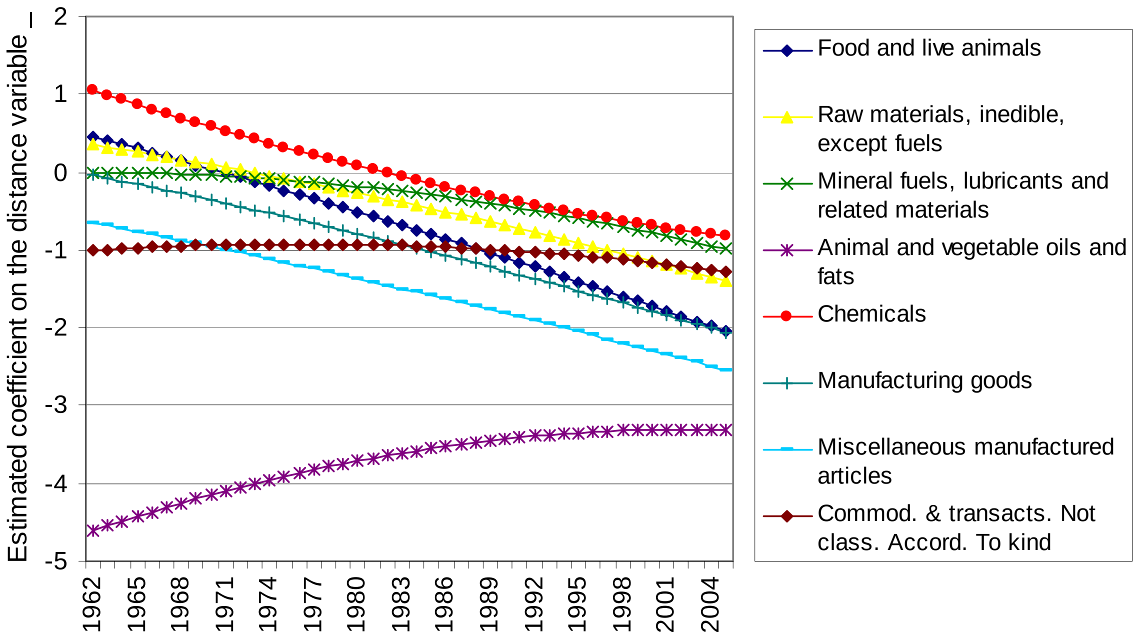
By creating two new variables: $t \cdot \ln\left(D_{i,j}\right)$ and $t^2 \cdot \ln\left(D_{i,j}\right)$, it is possible to estimate the total model as a standard linear model. Subsequently it is possible to calculate the value $\beta_{3,t} = \alpha_0 + \alpha_1 \cdot t + \alpha_2 \cdot t^2$ for each year.

$\beta_{3,t}$ is expected to be negative, and the more negative it is the more sensitive trade is to distance.

The estimated distance sensitivity of Bolivian exports over the 1962-2004 period is presented in Figure 6. The results suggest that exports are getting more sensitive to distance over time for almost all product groups (with the exception of "Animal and vegetable oils and fats").

According to the estimated results, some product groups started out with positive distance elasticities in the 1960s, for example "Chemicals", but these results are spurious, due to the extremely limited exports of these products in the 1960s and 1970s (see further below).

Figure 6: The impact of distance on Bolivian exports, 1962- 2004



Source: Authors' estimation based on trade data from Comtrade and World Development Indicators.

It is not obvious why distance should have become more important over the last 4 decades. Basic transportation costs have likely decreased over the last decades, which means distance should have become less important. On the other hand, more sofisticated production, assembly and distribution technologies all over the world (just-in-time production, global supply-chaining, etc.) implies a vastly increased preference for timeliness, speed and reliability for goods shipments, which would tend to punish distance.

The regression results reported above suggests that the latter effect is dominating, implying that geographically periferical countries such as Bolivia is getting increasingly disadvantaged.

The increased importance of distance is consistent with the attempt to reduce export distances by trading more with neighboring countries and less with distant markets.

It is also consistent with a change in export composition towards goods with more value added and with a higher value per kilo. This is indeed what has happened in Bolivia over the last 40 years. Figure 7 shows the composition of exports in 1964, 1984 and 2004.

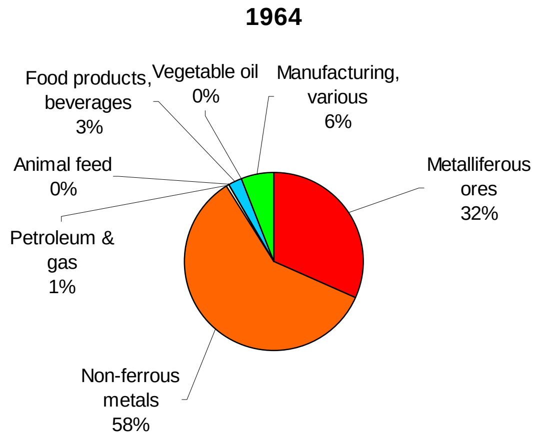
In 1964 fully 90% of the total value of exports consisted of metalliferous ores and non-ferrous metals. Twenty years later this share had dropped to 46%, and by 2004 it accounted for only 18% of exports. Instead, petroleum and natural gas exports increased tremendously in importance, rising from 1% in 1964 to 51% in 1984. This was possible due to the construction of a natural gas pipeline to Argentina, which reduced transportation costs from prohibitively high to close to zero. Its share dropped to 38% by 2004, not because natural gas export volumes decreased (they actually increased dramatically due to a new pipeline to Brazil), but rather because exports of non-traditional goods increased tremendously during the last 20 years.

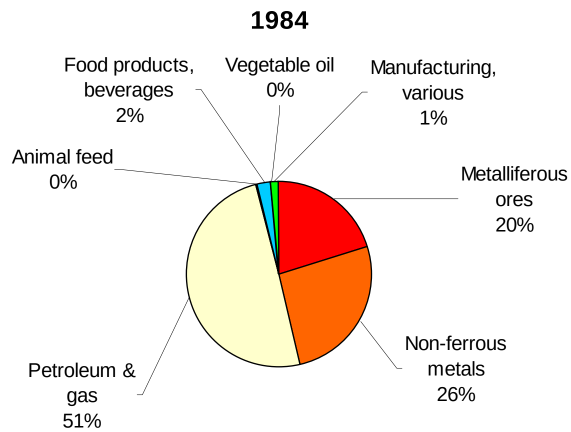
In contrast to 1984 where exports consisted almost exclusively of metals and hydrocarbons, by 2004 the country showed considerable export diversification. Animal feed and vegetable oil (both based on soy beans) accounted for a considerable share of exports (18%), whereas it was non-existing in the earlier periods. This is not exactly a good with high value per kilo, but Bolivia benefited from the Andean trade agreement, which secured Bolivian soy producers a price premium on soy products, compared to the nearest competitor, Brazil.

The most dramatic change is probably in the export of various manufactured goods and food products, which include products with much more value added than metals, gas and soybeans. The share of manufactured goods and food products increased from only 3% in 1984 to 26% in 2004.

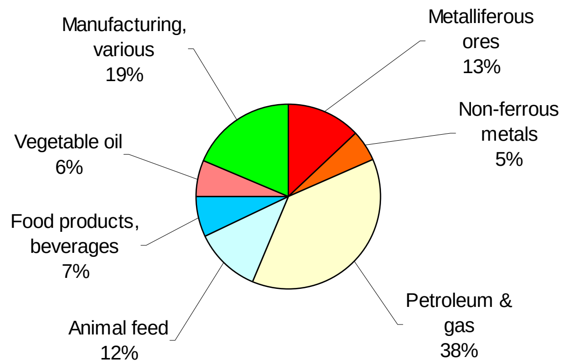
The move away from heavy metal exports (to Europe) towards light natural gas (to neighboring countries) and goods with more value added (to a variety of countries) is a natural reaction when faced with strong and increasing geographical constraints.

Figure 7: The change in composition of Bolivian exports, 1964, 1984, 2004





2004



Source: Author's elaboration based on data from Comtrade.

7. Conclusions

At first view, Bolivia is a country with a problematic natural endowment. It is landlocked, located in the tropics, and extremely resource-rich – factors which have been shown in the international literature to be related with slow growth. Indeed, Bolivia is the poorest country on the South American continent. However, within Bolivia, the areas that are located farthest away from the ocean, have the hottest climate, and also holds most of the hydrocarbon reserves, do considerably better than the areas located closer to the ocean, with temperate climates and no hydrocarbon reserves. It is therefore not obvious how exactly the various geographical factors affect development in Bolivia.

This paper argues that although the geography of Bolivia is pretty much constant over time, the importance of the geographical constraints can change over time, through various mechanisms.

First of all, given the large size and geographic diversity of the country, people can presumably move to places in the country where the climate suits them or where they find better economic opportunities. The analysis of migration patterns made in this paper indicates that economic opportunities weigh more heavily in the migration decision than geographical factors, such as temperature, rainfall, or distance to the ocean. People strongly prefer to move to urban agglomerations with sufficiently large and dense populations to secure economies of scale and a diversity of opportunities. In contrast, they are vacating sparsely populated municipalities, if they are able to do so. There is evidence that some groups are too poor and too tied to their lands to be able to move, which implies that they are left behind in extreme poverty and with less and less economic opportunities.

Second, through adequate investments in man-made infrastructure, some of the geographical constraints can be overcome. The construction of natural gas pipelines is probably one of the clearest examples of how transport costs can be reduced from prohibitively high (no exports) to close to zero (Bolivia now exports millions of cubic meters of natural gas every day at almost zero marginal costs). Roads, on the other hand, have not contributed much to increased integration nor reduced transportation costs over the last few decades. Allthough the fundamental road network has expanded slightly, there are frequent interruptions in connectivity due to natural disasters (especially land slides and flooding) and deliberate road blocks by discontented population groups.

Third and fourth, the composition of exports and buyers can be changed towards goods with a higher value per kilo transported and towards buyers located nearby instead of across oceans. Both changes can indeed be observed in the patterns of Bolivian trade over the last 40 years. The average export distance has dropped from around 8300 km in 1962 to 6400 by 2004. These are still very long distances, though, especially for heavy, primary products with little value added. But there has also been a considerable change in the composition of export products, with much less reliance on heavy metals and more on light natural gas and a large variety of manufactured products with more value added.

However, these four mechanisms for reducing geographical constraints have not been fully exploited in Bolivia. Urbanization rates are still very low by Latin American standards, implying that large parts of the population do not take advantage of the economies of scale and variety of opportunites that cities usually offer. While pipelines are very efficient means of exporting natural gas, the national road network offers only a crude and unreliable means of national and international integration. Export distances still average more than 6000 kilometers and export products still consist mainly of primary products with little value added.

In addition, technological developments and the widespread adoption of just-in-time technologies for production, distribution and retailing all over the world imply that speed, reliability and punctuality have become increasingly important, to the disadvantage of geographically distant and disorganized countries, such as Bolivia.

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