PRELIMINARY DRAFT. PLEASE DO NOT CITE

WHY NOT USING THE WHEEL? EVIDENCE FROM COLOMBIA AND CALIFORNIA

Xavier Duran[1]

The first overland transport revolution – wagon transportation and turnpikes –, led to important transport productivity gains and positive externalities on the rest of the economy. Andean countries used mostly arrieria roads, similar to mule-pack roads, as a major transport mode even up to early 20th century. Arrieria roads do not use the wheel. Why didn't these countries use the wheel frequently? Why didn't they take advantage of the first transport revolution and its benefits?

Examining the Cambao road, the only wagon road in Colombia during the latter part of the 19th C, several hypothesis are tested. Results indicate that Colombia's not experiencing the first overland transport revolution cannot be attributed to i) geography, ii) expectations of low or negative wagon road profitability, iii) government's small size relative to the resources required by the wagon projects or iv) not having formal institutions like tolls to facilitate private venture. Explanations exploring in more detail the risks to private investment in infrastructure projects are being examined.

[1] Xavier Duran is assistant profesor, Business School, University of los Andes. Email address: xh.duran21@uniandess.edu.co

1. Introduction

Many Andean countries used arrieria roads to transport freight and passengers between cities, instead of wagon roads, until early twentieth century. Arrieria roads are narrow, stretch roads, paved similarly to roman roads, over which a mule carrying freight or a passenger travels. Arrieria roads function similarly to mule pack roads.[2] In consequence, arrieria roads do not take advantage of using wheels to move freight or passengers. Why did not Andean countries use the wheel?

The long delay to use the wheel in the Andes is not unique. Transport technologies typically take long periods to diffuse throughout the world. For instance, while the first commercial railroads were developed in the U.K. in the 1820s, France and the U.S. started using the technology less than a decade later. But countries as diverse as Switzerland, Denmark, Portugal and Chile took three decades to build their first rail mile, while Brazil, Japan, the Ottoman Empire and Romania took half a century. Passenger cars were developed in the Germany, France, the UK and US almost simultaneously, but it took more than three decades for Costa Rica, China and Venezuela to import the first 1,000 cars.[3]

It is remarkable that transport technologies take so long to diffuse widely between countries. Transport is a key sector in an economy. Development of transport infrastructure generates a positive externality on the rest of the economy, with important

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[2] Ferro (1994), Safford (2011) p. 354, 358, Zegarra (2011), p. 365-366.

[3] CNTS database. Downloaded in 2007 from http://www.databanksinternational.com/

effects on various measures of economic performance.[4] It is striking that, although benefits to be reap are high, the international diffusion of transport technologies is slow.

The productivity gains on transport activities and substantial positive externalities typical of other transport technology were also present for the use of wagon roads for inter-city transport on the Andes. Transport physical productivity increased substantially when using the wheel. A mule on an arrieria road carried 0.15 tons, while each mule on a wagon road pulls between 1 and 1.5 tons. Certain objects simply cannot be carried on arrieria roads due to the mule's back size restrictions. Traveller accounts in the Andes during the nineteenth century frequently described how steam engines, security boxes, and other advanced machinery of the time laid bare and rusty in the warehouses on the shores of a port. The machinery could not be transported to the cities on the Andes using arrieria roads. Thus, the effects of the wheel could have been of substantial, increasing transport productivity and generating a positive qualitative difference in the set of technologies available to the rest of the economy.[5] Not using the wheel inhibited the spread of the industrial revolution and modern economic growth. If potential benefits derived from using the wheel were so great, why did not Andean countries develop the infrastructure to use the wheel? Why did not Andean countries experience the first overland transport revolution?

The paper examines various hypotheses explaining why Colombia (as a representative example of the Andean countries) did not use wagon roads during the second half of the nineteenth century. The method to examine these hypotheses is to compare characteristics of arrieria roads that did not develop into wagon roads against

[4] Banerjee, Duflo and Quian (2012), Bogard (2005), Coatsworth (1979), Donaldson (2010), Fogel (1962, 1964), Fishlow (1965), Nadiri and Mamuneas (1996), Ramirez and Pachon (2006), Summerhill (2005)
[5] Ferro (1994) p. 1048, Lord (1883) p. 193 indicates that a ten-mule team frequently dragged 10 to 15 tons.

characteristics of actual wagon roads during the second half of the 19th century. The difference(s) in characteristics between the two groups of roads identify the key characteristic(s) in triggering the process of adoption of the wheel.

Colombia's arrieria road network is examined and five roads are selected for detailed study because of their high potential to develop into wagon roads. The sample is completed with two mule pack roads in California that did turn into wagon roads – the benchmark case of successful late development of wagon roads in a mountainous region. The characteristics of the roads considered allow exploring hypotheses categorized as i) supply or adoption cost, essentially determined by each region's geography, ii) demand or profit expectation, essentially determined by existing and potential commerce at the time, and iii) institutional setting.

Preliminary results indicate that in the case of the Andean countries, not experiencing the first overland transport revolution cannot be attributed to i) geography or ii) expectations of low or negative wagon road profitability. Explanations exploring in more detail the risks to private investment in infrastructure projects are being examined.

The next section of the paper introduces the sample of Colombian arrieria roads and Californian wagon roads to be analyzed. Section three, four and five discuss the importance of supply, demand and institutional explanations to wagon non-adoption, respectively. Finally, conclusions are put forward.

2. Sample of arrieria and wagon roads

The sample contains arrieria roads likely to transform into wagon roads in Colombia and mule pack roads that transformed into wagon roads in California. The difference between the Colombian and the Californian roads should help to identify key factors determining likelihood of transformation of an arrieria road into a wagon road.

Colombian arrieria roads

The sample contains arrieria roads likely to transform from arrieria to wagon transport. In turn, the likelihood of going from arrieria to wagon transport is given by the road's political or economic importance. Government, merchants or transport entrepreneurs were willing to invest to transform an arrieria road into a wagon road to reap the political or pecuniary pay-off derived from cheaper and /or faster transportation.

Political importance of the road is given by the political importance of the settlements a road connects' or of the resources (taxes, foreign exchange, …) it provides access to. No straight forward measure of political importance exists, but a good proxy are whether a settlement on the road is political capital, whether settlements have an important military base or whether the road provides access to a taxable resource like mining, alcohol, or tobacco. Economic importance is given by traffic level that results from the economic activity of the settlements connected by a road. Ideally, traffic statistics should guide selection by economic importance.

No systematic arrieria road traffic statistics exist in Colombia. Sample selection is guided based on a combination of political importance (capital of country or department on the road), qualitative accounts of the relative importance of several roads, and availability of archival material to study the road. The five roads included in the sample are identified in figure 1.

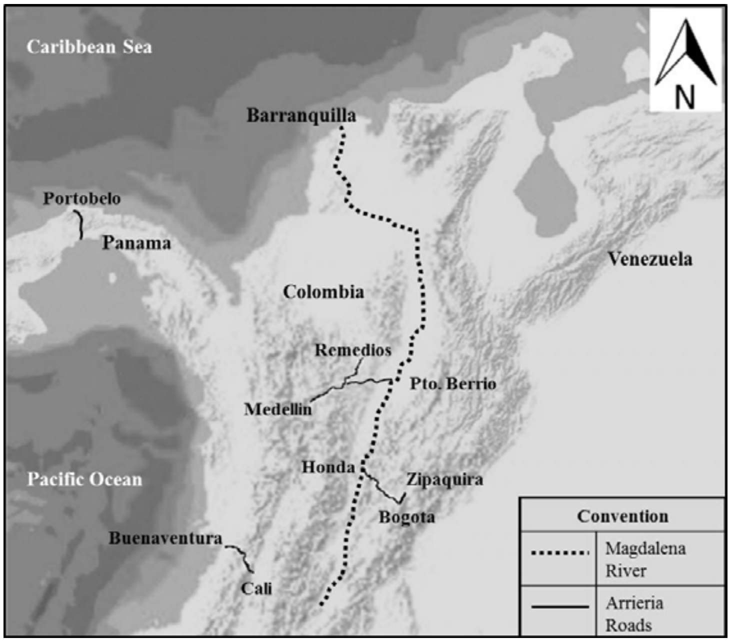

Figure 1. Sample of five arrieria roads likely to transform into wagon roads, Colombia

(1). Bogota-Honda (B-H): Bogota is the capital and largest city of Colombia (almost continuously since Colonial times). It is located on the top of the eastern cordillera of the Andes, 2,600 meters above sea level, on a large and fertile sabana. Honda is a small colonial port town settled at the head of navigation of the Magdalena river, the transport artery of the country in the nineteenth century. It is located at approximately 250 meters above sea level, northwest of Bogota. The arrieria road is a colonial one finished in 1570 that slides over the western slope of the eastern cordillera (see figure 1). The road was the most important arrieria road and operated essentially unchanged throughout the seventeenth to nineteenth centuries. A short wagon road operated on the Bogota sabana's segment of the road. Bogota exports little, but, because it is the political capital and largest settlement, taxes, food, goods, including luxury goods, and passengers come regularly to Bogota.[6] In the late 1850s and 1860s Salvador Camacho Roldan and other entrepreneurs proposed a series of projects to build a wagon road connecting Bogota and the Magdalena river, but without any success.[7] In 1885 the first and only inter-city wagon road built in Colombia in the nineteenth century, the Cambao road, was completed at a cost of $100,000 connecting Bogota and Honda, under peculiar circumstances.[8]

(2). Bogota-Zipaquira (B-Z): The town of Zipaquira developed before the arrival of the Spanish around a large salt mine, 38 miles north from Bogota and at about the same altitude. Zipaquira was the main supplier of salt for Bogota, many settlements on the Magdalena river and other Andean locations. Salt, in turn, is a key commodity because it was taxed and played a central role in the conservation of other foodstuff during the nineteenth century. The arrieria road was built during colonial times following an indigenous people route. The first plan to build a wagon road between Zipaquira and Bogota was included in Salvador Camacho Roldan's project to connect Bogota to the Magdalena river. He examined a route taking the road north of Bogota and heading west to the river through the Santander Department. The route passed by Zipaquira, and it was built and finished as a railroad in 1896, but never as a wagon road.[9]

(3). Panama isthmus (P-P): Spanish colonies with coast on the Pacific Ocean used an arrieria road over the Panama isthmus to carry gold and silver into the Atlantic Ocean and then to Spain. The road is located over the two slopes of a low but steep and humid mountain, with summit at 339 meters above sea level. Silver and gold provided high traffic during the seventeenth century, but the road came to decadence during the first

[6] Otero (1947) pp. 624-628, Melo (1995) pp. 149-152.
[7] Camacho Roldan (1858), Gaviria (1978) p. 63, Lievano (1869).
[8] Corredor y Nieto (1880) pp. 6-18, Lesmez et al (1883), Nieto (1885)
[9] Melo (1995) p. 134, Camacho Roldan (1858) pp. 21-24, Ramirez and Pachon (2006) p. 5.

half of the eighteenth century. It gained revived activity after California's gold rush. A group of American entrepreneurs negotiated a concession contract with Colombia's government to build a railroad. Construction started in 1850, was difficult and finished in 1855 with the most expensive per mile railroad built by Americans. The Panama Railroad came to be one of the most profitable ventures on mid-century America, while the arrieria road was left unused.[10]

(4). Cali-Buenaventura (C-B): Cali was a growing city leading the fight of the Valle del Cauca region to separate from the Cauca region, in the Department of Cauca, an old colonial mining region in decadence by the nineteenth century. Cali is located in a fertile valley at 1,000 meters above sea level. It is the last stop on the colonial arrieria road that connected mainland Colombia to the Pacific Ocean, before starting the climb to cross the western cordillera of the Andes. The road is located over the two slopes of a steep and high mountain, with summit at approximately 1,900 meters above sea level. Colonial Cauca used to transport silver to the Pacific Ocean through this road. Nineteenth century Valle del Cauca entrepreneurs expected to export agricultural goods like quinine, tobacco, coffee and sugar, and twentieth century ones actually export sugar and coffee through this route. Several projects to build a wagon road over this route were proposed, 1850-1875, but none achieved success. In the last quarter of the 19th century a railroad project was promoted following a similar route, and finished in 1914.[11]

(5). Medellin-Puerto Berrio (M-P): Medellin was the second largest city in Colombia during the nineteenth century and capital of the Department of Antioquia. Medellin is located on the central cordillera of the Andes, at approximately 1,500 meters above sea

[10] Maurer (2011) pp. 23-29, 35-49, Duran (2012) supplementary online material 4 pp. 35-36
[11] Neal (1971) Eder (1959).

level. The region was a mining area during the nineteenth century, with some industrialized mining. Gold and silver produced in the northeast, close to Remedios, was transported to Medellin via the arrieria road. Merchants then used the road to trade locally or to export gold and silver to the United States and Europe. Gold and silver exports were taxed and generated most foreign exchange during the ninetieth century. The road is located over a long and steep downward slope to the Magdalena river.[12]

No other road exists in Colombia were politic and economic importance of the arrieria road suggest likelihood to transform into a wagon road and sources to study the road are available. The sample provides a variance in terms of geography and location with respect to political and economic power.

Californian wagon roads

In California many wagon roads were developed, most as toll roads. The first toll road boom, 1853-1865, generated 44.2% of all toll road incorporations during the nineteenth century. The road was frequently built as a succession of short, approximately 15 mile long toll roads, which completed a road communicating two locations. Most incorporation activity took place in the northern Sierra Nevada of California and Nevada states, where mining was growing rapidly in counties like Nevada, Placer and El Dorado.[13]

A sample of two roads is selected to be representative of this archetypical mining road of the first toll road boom in California. The two wagon roads connecting Sacramento to Comstock, Nevada, via north and south of Lake Tahoe are selected. The one on the north of Lake Tahoe, via Nevada City, followed roughly today's California

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[12] Melo (1995) pp. 213-224.

[13] Klein and Yin (1996) p. 481-483. Nevada, Placer and El Dorado counties represent 20% of all incorporations during 19th century.

State route 49 and 89 or State route 49, Henness Pass dirt road and State route 89 (see figure 2). The one on the south, via Placerville, followed roughly today's U.S. route 50. Both roads start at Sacramento, at 8 meters above sea level, climb the steep western slopes of the Sierra Nevada, cross the summit at more than 2,200 meters (line K-K in figure 2), and then descend to Nevada, at 1,400 meters. Eliot Lord, a 1850s and 1860s miner, indicates that in 1859 these two routes connected California to Comstock through mule-pack roads. In 1860, reacting to booming mining transport demand derived from the 1859 gold rush in Comstock, entrepreneurs incorporated several toll road companies. The two routes were improved into wagon roads.[14]

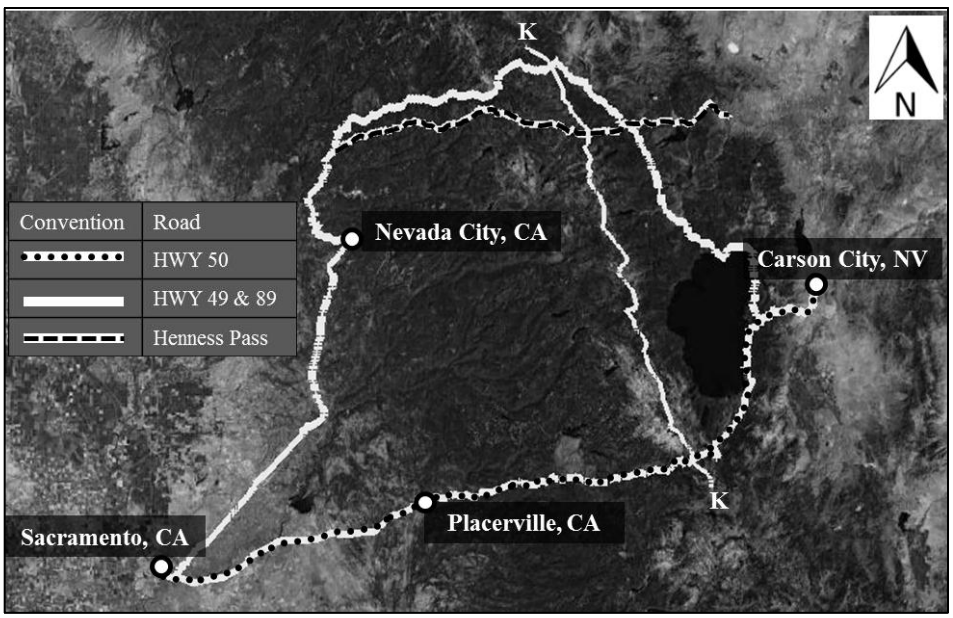

Figure 2. Sample of two mining wagon roads, California

3. Supply/adoption cost (geography)

[14] Improvement of roads described in Lord (1959) p.191

Technical knowledge and expertise is an important determinant of the adoption of a technology. Wagon roads were used in Colombia (and other Andean countries) within cities and for short flat journeys. For instance, the Bogota-Faca segment of the Bogota-Honda arrieria road, 26 miles on the Bogota sabana, operated a wagon road since early colonial times. Additionally, no where in any of the contemporary documents it is indicated that knowledge to build the road, to drive horses, mules or oxen, to operate a carriage or maintain the road, the animals or the carriages is unavailable or limited in Colombia's economy. Thus, lack of technical knowledge is unlikely explain why supply of wagon roads was limited in this economy.

Geography plays a key role in determining construction and operation costs for a wagon road. Its role has been acknowledged since early ninetieth century, at least. Steepness is a key dimension of geography for wagon roads and overland transportation generally. Steeper mountains offer fewer choices for the route's design to achieve the maximum grade acceptable for a wagon road. Alternatively, human interventions can shape geography. Cuts, tunnels and bridges overcome some of the limitations imposed by geography, but imply substantial additional construction costs. Steeper mountains also imply higher propensity for soil to experience erosion, making maintenance and operation costs for the wagon road higher. Another important dimension of geography is extreme weather. High rainfall or intense winter snowfalls impede works and unsettle the soil supporting the road, increasing construction and operation costs.[15]

The Andean countries have highly sinuous geography, and experience high rainfall in certain regions. In Colombia, in fact, the Andes mountain chain breaks into

[15] Gillespie (1847) is a classic road construction textbook used during the nineteenth century. Probably the only dimension of geography critical for road construction not acknowledged appropriately during the 19th century was soil erosion.

three high mountain chains that create two deep and fertile valleys. Thus, the Andean geography, and Colombia's one in particular may impose an important hurdle to development of wagon roads.

The literature on transportation in Colombia examines the impact of railroads and provides historical narratives of the use of porters, arrieria, railways, and automobile roads.[16] The most commonly cited explanation for Colombia not using wagon roads is that the Andean geography is so difficult that it only allows for arrieria roads.[17] To examine this hypothesis in detail the environment over which the five Colombian arrieria roads and the two California wagon roads were built is compared. The environmental characteristics considered are distance, elevation, grades, temperature, and rainfall – this includes all the relevant characteristics identified in the ninetieth century as critical for wagon road construction.[18]

The data measuring geography's characteristics is collected from various sources. First, the roads are digitized on Google Earth (GE). The sources of information to identify roads are images on ninetieth century maps, the Augustin Codazzi (AC) (Colombia's geographic data agency), GE and field work on the road with civil engineers. Digitization of the road is always performed at maximum resolution available. Arrieria roads are still operational (for tourism) today and have not experienced any additional works since colonial and ninetieth century times. Thus, arrieria roads may be digitized into GE following visual recognition. Wagon roads lie beneath modern undivided highways with one lane for each direction. The automobile road is digitized

[16] Ferro (1994), McGreevy (1971), Melo (1995), Ramirez (2006). Safford (2010) and several chapters in Davila (2003) discuss various transport technologies during ninetieth and twentieth century.
[17] I am grateful to Frank Safford, Marco Palacios, Luis Fernando Molina and Andres Guhl, who have fleshed out the tradition and the nature of this hypothesis, widely believed but rarely formulated explicitly.
[18] See Gillespie (1847) for 19th century wagon roads.

into GE following visual recognition. Second, the digital elevation model of GE is used to calculate distance from origin location and elevation at every pixel on the road. Grades are calculated as the percentage inclination between one side and another for each pixel. Third, data drawn from Global Climate Data are merged with GE to calculate temperature and rainfall. The road is divided into 5 kilometre intervals and an observation of the relevant variable is measured at the limit of each interval. Average and standard deviation are calculated over all observations on the road.[19]

The analysis of the data indicates two main results. First, arrieria roads were built over routes following difficult terrain, while routes following a more gentle terrain were also available – arrieria road builders did not choose the smoothest route available. Second, Colombia's geography is not generally more difficult that California's one.

Arrieria roads were built over routes following difficult terrain, while routes following more gentle terrain were also available.

Arrieria roads in Colombia were built using the simplest pass over the summits and its approaches. Frequently railway and motorway roads are also built within the nearby region to take advantage of the summit crossing. It is therefore common to have an arrieria road, a railroad and an automobile road in the same stretch of landscape in Colombia. Thus, it is possible to compare the environment over which each transport mode crosses. To take advantage of this opportunity to compare, the railroad and the motorway routes are digitized analogously to arrieria roads and elevation, distance and grades are calculated – temperature and rainfall are similar for the three transport modes.

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[19] Google Earth data downloaded from http://www.google.com/earth/index.html, Global Climate Data downloaded from http://www.worldclim.org/. See appendix for measurement details.

Grades are the single most important factor when developing a wagon road. The nineteenth century contemporary civil engineering textbooks indicate roads should follow long zigzagging routes with moderate grades, rather than short direct routes with high grades.[20] Technology to intervene the landscape and mechanical power to overcome steep grades were still limited in the mid-nineteenth century for most of the world, including Western North America and South America, so a geometric design of the route identifying the appropriate zigzagging for the road to exhibit low grades was critical. Contrary to this intuition, arrieria roads are actually relatively short and steep.

An example helps to appreciate the point. The trip between Bogota and the Magdalena River could be performed via one of three different routes during the first half of the twentieth century: the arrieria road, the railway route, and the motorway. All three routes are close to each other and cross the summit of La Tribuna. In figure 3 the line K-K shows the mountain’s knife edge and the undercut that characterizes the La Tribuna summit pass. The region east of the summit is a smooth decline leading to the flat sabana of Bogota. The region to the west of the summit line is a steep decline to the settlement of Alban and eventually ends up on the Magdalena River. The three roads cross the summit close to each other, taking advantage of the summit pass. The dashed thick white line is the arrieria raod and follows an almost straight line. The railway line follows the thick white line and the automobile road the dotted thick white line. Both zigzag around to cover the terrain in a longer distance, but gentler slope. The arrieria road takes 4.6 kilometres and faces a maximum absolute grade of 28.2%. The motor road takes 6.8 kilometres, almost 50% longer than the arrieria road, to reduce maximum absolute grade to almost a third, 10.9%. The railway takes 13.5 kilometres, almost three times longer, to

[20] Gillespie (1847) indicates grades are the single most important variable for a wagon.

reduce grades to almost sixth, 5.1%. Thus, the routes used by the railroad and motor road, with substantially lower grades, were available to people who built and operated the arrieria roads.

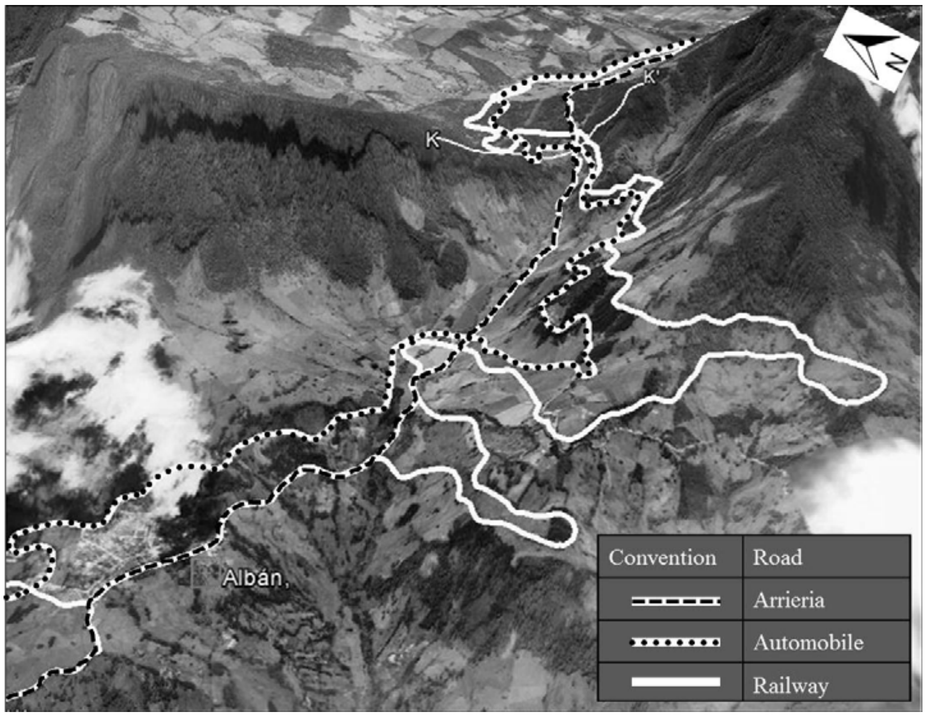

Figure 3. Arrieria, railway and automobile roads on La Tribuna summit pass

Source: Google Earth and field work.

Additionally, the Cambao wagon road, the only intercity wagon road project built in Colombia's nineteenth century, demonstrates it was possible to build a road with nineteenth century technology and lower grades than the arrieria road. The maximum grade was 10% for a short stretch and then it went down to 7%.[21]

Colombia's geography is not more difficult than that of California.

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[21] Paris (1885) p. 14.

The geographical data collected allows a more general comparative approach as well. Descriptive statistics of distance, total elevation gain/loss, grades, temperature and rainfall for the arrieria and wagon roads are calculated. The results reveal that the roads in Colombia are shorter and imply a total elevation change that is lower than that of roads in California (see table 1). The arrieria roads in Colombia exhibit the highest maximum absolute grades, well over 20% inclination, except for the Bogota-Zipaquira (B-Z) road over the relatively flat sabana of Bogota. Wagon roads in Colombia and California have similar maximum absolute inclinations, all around 10%.

Road	Distance	Absolute elevation gain/loss	Maximum absolute slope	Temperature coldest month		Precipitation wettest month		Water erosion vulnerability
	miles	meters	%	°C		millimetres		
				mean	SD	mean	SD	
B-H (arrieria)	63		28.2%	10.1	4.0	204	79	High
B-H Cambao (wagon)	84	4,872	10.0%	13.5	5.6	216	81	High
B-Z (arrieria)	32	1,053	9.7%	6.6	0.5	210	83	High
P-P (arrieria)	53	2,942	23.1%	21.1	0.9	408	86	Moderate
S-C HWY 50 (wagon)	131	5,460	8.7%	-2.4	4.9	160	47	Moderate
S-C HWY 49 & 89 (wagon)	200	8,803	9.7%	-2.3	5.1	186	59	Moderate
S-C Henness Rd (wagon)	186	6,990	11.0%	-2.4	5.2	178	59	Moderate

Table 1. Statistics of distance, altitude, grades, temperature, rainfall and soil erosion

Note: B-H: Bogota-Honda, B-Z: Bogota-Zipaquira, P-P: Panama-Portbelo, S-C: Sacramento-Carson City. Soil's water erosion index has three levels, low, medium, high. Sources: See text.

Weather on Colombia's roads is warmer and wetter than that on California roads, while snow also affects California roads. Since snow transforms into water during short periods of time in spring, the effects of snow are similar to those of high rainfall. The effects of rainfall and snow are increase the need of culverts and bridges and, consequently, construction and operation cost.

A weather variable not considered by nineteenth century road engineers but identified by modern civil engineering as important is soil's vulnerability to erosion caused by water. Colombia's roads exhibit higher vulnerability to this source of erosion than California's ones. Again, the effect of a road's higher exposure to water erosion is to increase construction and operation costs.

In sum, the single most important variable affecting road construction and operation in nineteenth century are grades. Colombia's roads do not necessarily exhibit steeper grades than California's ones. On other dimensions of geography, both regions face different but important difficulties for road construction and operation.

4. Demand/expected profit (commerce)

One alternative hypothesis is that the Andean countries, although apparently rich in agricultural and mineral resources, did not experience enough (inter-regional or international) trade to create substantial traffic and trigger construction of wagon roads. The expected profit of expanding the arrieria road into a wagon road for Colombian roads and the ex-post profit for California wagon roads is calculated to estimate the private returns from building the wagon road.

Information on expected construction and operation cost, and observed transport prices and traffic over the arrieria roads is drawn from contemporaries, wagon project proposals, and government documents. Entrepreneurs in the nineteenth century used this information to calculate an estimate of minimum expected profit. Information on ex-post wagon road construction and operation cost, and observed transport prices and traffic is drawn from contemporaries and government reports.

Road	S-C HWY 50 (wagon)	B-H (wagon)	B-H (wagon)
Type of information	Observed	Expected	Expected
Time period	1862-69	1858	1869-73
Source	Lord	Camacho	Pinzon
Construction cost	505,000	363,000	150,000
Operation cost	252,500	30,000	30,000
Transport revenues	6,838,000	366,126	658,214
Toll revenues	580,750	52,764	155,106
Operation toll profit	328,250	22,764	125,106
Entry threshold toll profit	0.65	0.06	0.83
NPV toll profit	877,708	-267,112	376,992

Table 2. Construction and operation cost, transport and toll revenues, and profit (dollars)

Source: Lord (1859) pp. 192-195, Camacho Roldan (1858) p. 42, 60, Pinzon (1880) p. 23.

Note: NPV assumes construction is finished in year one, operation profit flows continuously at the same level for the next five years, and discount rate of 6%.

The contemporary information indicates both California roads were profitable ventures. For instance, the Sacramento-Placerville-Comstock wagon road (S-C HWY 50) construction cost was just over $0.5 million, operation cost $0.25 million per annum, transport revenues almost $7 million per annum and toll revenues almost $0.6 million per annum. Expected profit derived from toll revenues (less operation costs) is just over $0.3 million per annum. Entrepreneurs used to take investment decisions in the nineteenth century using the ratio of expected operation profit over construction cost. If the ratio was higher than 15%, they decided to enter. The ratio is 64%, a highly profitable proposition by this standard. More modern methods yield a similar conclusion: the NPV is $877,708.

In 1858 the Bogota-Honda's wagon road construction estimate was still too high and traffic too low to render profitable the road project. By the early 1870s the region over which the road was to be built was also better known; construction cost estimate was halved to $150,000 - the ex-post construction cost was $100,000.[22] Transport demand also grew during the 1860s, almost doubling. Reduction of construction cost and increase in traffic was enough to make the road expected to be profitable by the early 1870s. Thus, after the 1870s at least some wagon roads should have been expected to be privately profitable and socially beneficial in Colombia, although California transport entrepreneurs faced a much more dynamic economy than Colombian ones.

An important issue needs discussion before proceeding to the next section. If the wagon road is built, and transport costs go down, commerce should increase. It is possible to build under a low commerce setting, expecting to reduce transport cost, and move rapidly down the demand schedule to operate in a high commerce setting. If this was the case, the results presented are downward biased: more arrieria roads should have been expected to be profitable than it is identified in this analysis. For the purposes of this analysis, this is an acceptable bias that confirms the main conclusion of this section: wagon roads were not built in Colombia not because they were not expected to be profitable.

5. Institutions

Another alternative hypothesis is that Andean countries never had the institutional setting conducive to building wagon roads. Economic historians have suggested two main institutional arrangements to build a wagon road. Government may coordinate (directly

[22] Lesmez et al (1883) p. 7.

or indirectly) construction and operation of the road. Alternatively, government may provide property rights and private entrepreneurs may build the road and collect returns either through tolls or through higher land values and access to markets for their products – this was the prevalent mechanism used in the United States, including California.[23] The first institutional arrangement requires availability of resources either through current taxes or government debt. And both institutional arrangements require political collective decision making to agree to perform either direct construction and/or operation of the road, or contract with private investment procurement, concession, or lease of the road. Thus, lack of access to capital or impediments to political agreement may delay adoption of wagon roads.

Colombia's public expenditure on transportation (maintenance of arrieria roads and construction of bridges) in the mid nineteenth century was high enough to finance construction of, at least, a few key wagon road projects. In 1836 the government's annual transport budget was less than $30,000, but by the mid-nineteenth century the budget was already $1.2 million.[24] And Colombia's government also had access to the international capital market. For instance, in 1863 government issued bonds for $970,000 at the London stock exchange. The loan was secured with revenues derived from salt mines and the Panama railroad. The purpose of the loan was to invest in transport projects, but it was invested in other activities and the 1860s Civil War.[25] Given that in the 1860s the Bogota-Honda wagon road was expected to cost between $0.1 and $0.2 million, Colombia's fiscal capacity was strong enough to finance construction of at least a few strategic wagon roads during the 1860s.

[23] Klein and Yin (1996), Bogart and Majewski (2011) and Wallis and Weingast (2005)
[24] Safford (2011) p.
[25] Eder (1959) p. 114.

The construction of the Cambao wagon road between Bogota and Honda sheds light on how impediments to political agreement may delay adoption of wagon roads. In 1858 the first project for a wagon road between Bogota and the Magdalena river was proposed by Salvador Camacho. The project indicates the most convenient route is the southern one connecting Bogota to Girardot. A series of wagon road projects were proposed after this initial project. Competition between the northern route, close to the colonial arrieria road between Bogota and Honda, and the southern route between Bogota and Giradot became apparent. The arguments for the competition were technical and economic, but it was clear that only one project could be privately profitable as the main flow of traffic were imports coming through the Magdalena river to Bogota.[26] Either one project could be built without subsidies, but not both.

In 1874 the Department of Cundinamarca developed a project to build a railroad from Bogota to Honda. The project divided construction and operation into two contracts: 1) a railroad over the flat sabana of Bogota, from Bogota to Faca - the Sabana Railroad and 2) a mountain railroad from Faca to Honda - the Occidente Railroad. The Sabana railroad was to be built and operated by the Department of Cundinamarca. The Occidente railroad was to be built and operated by a private entrepreneur, partially subsidized by the Department of Cundinamarca. The works on the Occidente railroad were delayed and the contract became a thorny issue in Cundinamarca's legislature. As a consequence, the Department of Cundinamarca decided to contract construction of a wagon road, the Cambao road, to transport inputs and rolling stock from Honda to Faca to build the Sabana Railroad. The Cambao road was finished in 1885 at a cost of $100,000.[27] Inputs

[26] Camacho (1858), Lievano (1866),
[27] Corredor y Nieto (1880) pp. 6-18, Lesmez et al (1883), Nieto (1885)

could now be taken to the sabana and the Sabana railroad was completed in 1889.[28] In a simultaneous process that also started in 1874, the federal government contracted construction of another railroad line from Bogota to Girardot, the Girardot railroad. Construction was also delayed and the contract also became a thorny issue is Cundinamarca's legislature and Colombia's Congress.

The events connected to the construction of the Cambao wagon road suggest several layers of political conflict initially delayed the project and then created circumstances favouring its construction. First, during the 1860s competition between Cundinamarca's northern and southern routes to the Magdalena river made difficult a political agreement to promote construction of a wagon road over one of the routes. Proponents of the northern (southern) route feared that construction of a southern (northern) route led to relative decline of the region on the northern (southern) route. The consequence was political deadlock over construction of a wagon road. Second, as the 1860s progress some political interests support the idea of building a railroad connecting Bogota to the Magdalena river, but others consider it too expensive a solution compared to a wagon road. As railway technology is proven it became clear a railway could provide a more efficient long term connection between Bogota and the Magdalena river. In the mid 1870s contracts are allocated to build railways connecting Bogota to the Magdalena river via the northern and southern routes and wagon roads are leapfrogged. Third, the wagon road was actually built because political competition between proponents of the northern and the southern route led to the allocation of two independent contracts to build a railway on each route, as a way to overcome political deadlock over railway construction. However, the consequence of building both railways was that at least one

[28] Ramirez (2006) p. XX, Escobar (2008) p. 158.

railway could not be profitable and the fiscal effort doubled. Consequently, entrepreneurs building the Occidente and Girardot railroads prefer to profit during construction rather than waiting to see if they can profit from operation, and end up tainted in various corruption scandals. The two railways are delayed. In turn, Cundinamarca's legislature decides to contract construction of the wagon road to transport inputs to build the Sabana railroad.

6. Conclusion

The Andean countries did not use wagon roads. It is striking why these countries did not develop roads to allow utilization of the wheel for transport. The paper examines three different hypothesis explaining non-adoption of wagon roads. Geography is unlikely to play a major role in non-adoption. The slopes and weather traversed by Colombian arrieria roads are not steeper or more extreme than those traversed by California wagon roads. Economic activity creating transport demand was high enough to induce construction of wagon roads for profit in Colombia after the 1860s, although California was a much more dynamic economy. The institutional setting suggests political conflicts between regions in Cundinamarca initially delayed construction of wagon roads. But by setting the circumstances under which the railways would fail and delay, the political conflict created the urgent need to build the railway.

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