Determinants of city growth in Colombia

Gilles Duranton[*‡]

University of Pennsylvania

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Abstract: I develop an integrated approach to examine the drivers of population growth in Colombian cities between 1993 and 2010. Fertility plays an important role. Much of the higher growth of some Colombian cities can also be associated with higher wages. In turn, this wage advantage of some cities can be, in part, traced back to city education and industry shocks. I also find that roads matter but obtained mixed evidence about the role of urban amenities and no evidence regarding measures of urban costs and other drivers of urban growth that have been commonly considered by past literature. Some determinants of long-run city growth are also explored.

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[‡]Wharton School, University of Pennsylvania, 3620 Locust Walk, Philadelphia, PA 19104, USA (e-mail: `duranton@wharton.upenn.edu`; website: `https://real-estate.wharton.upenn.edu/profile/21470/`). Also affiliated with the Center for Economic Policy Research, the Spatial Economic Centre at the London School of Economics, and the Rimini Centre for Economic Analysis.

1. Introduction

This paper examines the drivers of population growth in Colombian cities between 1993 and 2010. Its main novelty is to consider a comprehensive set of determinants. I uncover a number of important results. First, fertility plays an important role. Cities with higher growth also enjoy stronger inflows of newcomers and fewer out-migrants. Then, much of the higher growth of some Colombian cities can also be associated with higher wages and productivity. In turn, this productivity advantage can be, in part, traced back to city education and industry shocks. City education nonetheless affects city growth beyond contemporaneous wages. I also find that city roads matter both because they facilitate travel within the city and, perhaps to a lesser extent, because they give better access to other cities. I obtained mixed evidence about the role of urban amenities and no evidence regarding measures of urban costs or other drivers of urban growth that have been commonly considered in past literature. Taken together, these findings suggest that Colombian cities should be considered first as local labour markets.

Taking an integrated approach to the determinants of urban growth is important for several reasons. First, many countries attempt to control the location of their population and limit the growth of their cities. Desmet and Henderson (2015) report that 80% of governments in developing countries are concerned by the geographic distribution of their population and 70% have policies in place to reduce internal migrations. Example abound in developing countries, from China's hukou system to restrictions on mobility and urbanisation in India or Tanzania. Many developed countries, including France and the UK, also have a strong tradition of centralised policies to affect urban evolutions. They use instruments such as location-based incentives for firms or the relocation of public sector activities. Understanding the drivers of urban growth and their strength is also useful to assess whether restrictive policies can have any effect at all and what their welfare implications might be. More generally, knowing what drives urban growth is an important first step to assess how much people gain from moving to a city.

Second, it is the case that growing cities in developing countries require massive investments to accompany their population growth. According to Glaeser (2011), America's cities in 1900 were spending as much on their water system as the federal government spent on everything, except for the military and its pensions. These investments have then extremely long-lasting implications. For instance, the streets dug by Roman soldiers more than 2000 years ago when creating new cities in Western Europe are often still major arteries today. Better sanitation in cities in Europe and North America has had immense and long lasting public health consequences. The beautification of Paris by Baron Haussmann nearly 150 years ago is still a fundamental reason why so many tourist visits this city and a major amenity for its population. To be able to invest in a timely manner in major urban infrastructure such as water, roads, school, or sanitation, it is important to have the best possible predictions about future urban growth. While the drivers of tomorrow's growth may not be the same as those of yesterday's, a good understanding of what drives urban growth is likely to yield better results than simple extrapolations. Both under- and over-investment in infrastructure can be very costly. Investing in the 'wrong' cities is also costly.

Considering a large set of possible drivers of urban growth is also of academic importance. With the main exception of Glaeser, Scheinkman, and Shleifer (1995) who consider a limited number of factors ranging from human capital to local policies, much of the literature on the growth of cities has so far focused on making the case for one particular driver or another without really confronting these drivers to each other. For instance, Glaeser, Kallal, Scheinkman, and Shleifer (1992) focus on a few characteristics of the production structure of cities, Glaeser and Saiz (2004) focus on human capital, Rappaport (2007) and Carlino and Saiz (2008) focus on amenities, Duranton and Turner (2012) focus on roads, etc. A lot has been learnt from 'one-factor' studies. In particular, these studies have started recently to pay attention to causal identification by developing a range of instrumental variable strategies (e.g., Duranton and Turner, 2012). The objective of this paper is to retain what has been learnt from these one-factor studies, in terms of both substantial results and methodology, but upgrade their approach to a larger collection of factors. This paper also fills a number of gaps regarding determinants that have been neglected by recent literature such as the level of wages, local demography, or local governments.

Finally, this study is also a rare study looking at urban growth in a development context. While there is now a well-established literature about the growth of cities in developed countries (see Duranton and Puga, 2014, for a recent review), very little is known about the systematic drivers of urban growth in developing cities. Work by da Mata, Deichmann, Henderson, Lall, and Wang (2007), who examine the growth of Brazilian cities, is a rare exception.[1] This paucity of literature is all the more surprising given that the number of cities with more than 100,000 inhabitants nearly

[1]One may also mention the work by Deliktas, Önder, and Karadag (2013) on Turkish cities but it is of more limited scope. Duranton (2014*a*) reviews more broadly the literature on cities and growth in developing countries.

trebled between 1960 and 2000 and another two billion urban dwellers are expected over the next 50 years (Henderson and Venables, 2009). While there is little doubt that a staggering number of people will move to cities, it is deeply unclear which cities they will choose. Looking at a more advanced developing country like Colombia should be informative in this respect.

The first main challenge to the development of an integrated approach to urban growth is one of data. Being able to consider most of the key drivers of urban growth requires a broad array of city level variables. For this purpose, I collected rich municipal data for Colombia. Among others, they cover city demographics, history, economics (including the composition of economic activity), geography, amenities, infrastructure, the built environment, public finances, etc. I also rely on data about trade and agglomeration produced in prior work (Duranton, 2014*b*, 2015).

The second main challenge regards the identification of the causal effect of city characteristics on city growth. Standard urban growth regressions typically regress city population growth over a period of time on a set of city characteristics at the initial period. However, being predetermined does not make an explanatory variable exogenous. Many decisions are made on the basis of expectations about future local growth. While climate and many other geographical characteristics of cities are arguably exogenous, it is hard to make a similar case for most other potential drivers of city growth.[2]

In absence of large-scale randomised experimentation about urban growth or natural experiments, instrumental variables are going to provide the main levers used to establish causality. Plausible instruments are unfortunately not available for each and every possible driver of urban growth, only for some of them. Based on previous literature, early road networks provide reasonable predictors for current roads networks and, after using appropriate controls for long-run growth, a good case can be made that these road networks are correlated with contemporaneous population growth only through current roads. For some other variables such as city education, one can rely on the number universities and institutions of higher learning. This increases the lag between the measure of education used in the regression and contemporaneous growth but does not make the variation used for identification unquestionably exogenous. For some variables, such as local wages, it is even harder to provide any instrument. Hence, although this paper endeavours to use best practice from extant research, it is by no means perfect and these limitations will need

[2]Even though climate is, to a first-order approximation, 'exogenous', nothing guarantees that its coefficient is appropriately identified in standard urban growth regressions. This is because climate is likely to be correlated with other determinants of urban growth which may be missing from these regressions. See below for further discussion.

to be kept in mind when interpreting the results.

The rest of this paper is organised as follows. Section 2 describes the data at hand. Section 3 discusses the main drivers of urban growth and the literature on the subject. Section 4 reports the main results regarding the demographic and productivity determinants of urban growth. Section 5 reports results regarding amenities, roads, and other determinants of urban growth. Section 6 examines the determinants of the long-run growth of cities. Finally, section 7 concludes.

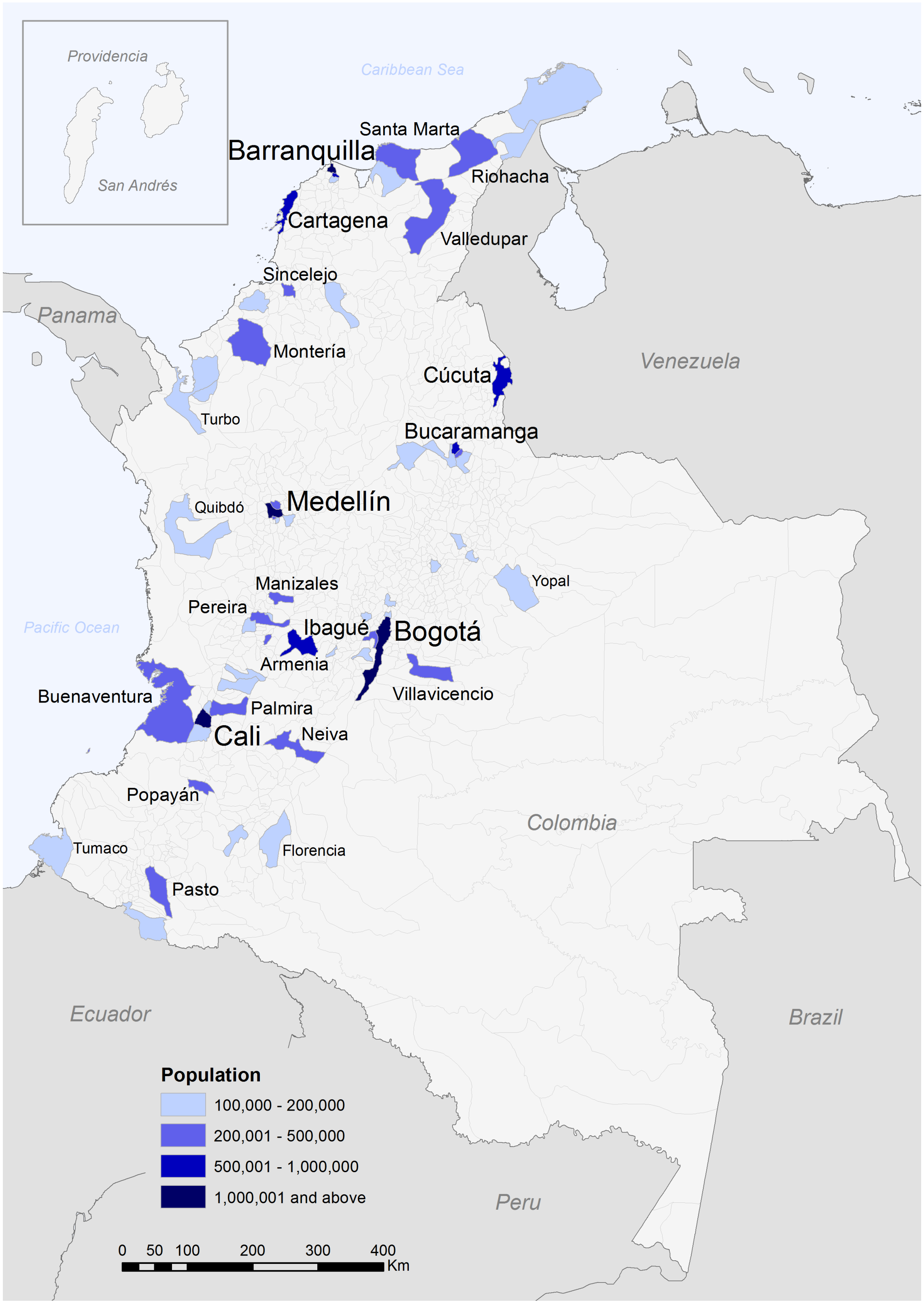
2. Context and data

At the end of our study period in 2010, the population of Colombia was about 44 million over a territory of 1.1 million square kilometers. It is located at the Northern tip of South America. Like many countries of the continent, it is already highly urbanised with 75% of its population living in cities. It is also economically more advanced than developing countries in Africa and much of Asia with a GDP per capita of about $8,000. Importantly for our purpose Colombia has a balanced urban system with 60 municipalities with a population above 100,000. This is in contrast with other developing countries dominated by a primate city. Another attractive feature is that the boundaries of Colombian municipalities have been extremely stable over time.[3] This enables both the use of deep population lags as controls and the exploration of long-run population growth patterns.

Note also that the geography of Colombia is extremely varied with much of its territory either dominated by the mountains of the Andes or, at the other extreme lowlands covered by an equatorial jungle. As a result, most of the Colombian population lives either along the Caribbean coast or on the high plateaus of the interior. Finally, we also keep in mind the existence of large regional disparities within Colombia. The GDP per capita of the poorest Colombian department is only about a sixth of that of Bogotá. Hence, despite a high rate of urbanisation, the Colombian urban system is perhaps far from 'mature'. See figure 1 for a map and table 1 for some descriptive statistics about the population of Colombian municipalities.

[3]The caveat is that this stability is true for the Northwestern half of the country, not for the so-called new departments. Because only a small fraction of the population lives in the Southeastern half of the country, the municipalities in this part of the country get dropped from our main sample.

Figure 1: Map of Colombia and its main municipalities



This map represents all Colombian municipalities with population above 100,000 in 2010.

Table 1: Descriptive statistics

	Mean	Standard deviation	Number of municipalities
1993 population ('000)	35.55	194.55	1063
	73.97	324.56	373
2010 population ('000)	41.93	255.44	1063
	90.64	428.59	373
1993-2010 growth	0.060	0.367	1063
	0.065	0.333	373
Fertility	1.570	0.489	373
Wage (municipal fixed effect)	-0.207	0.223	373
Education	0.111	0.076	373
Road index	4.667	3.050	373

Notes: Fertility is the number of children (0-18) per adult population averaged over 1998, 2005, and 2010. The wage is a municipal fixed effect computed as described in the text. Education is the share of the workforce with a university degree or assimilated in 2005. The road index is for 2010 and sums the log number of roads + 1 , the log number of exits + 1, the log length of roads + 1 minus the log distance to roads (if the municipality lacks a main road).

Table 1 indicates that Colombian municipalities had a mean population slightly above 40,000 in 2010. When we focus on a more restricted sample of municipalities for which municipal data, and especially wages, are more broadly available, the 2010 population mean is much higher at around 90,000. Colombian municipalities grew only by about 6% over 1993 to 2010. The standard deviation of this growth rate is however higher that the mean by a factor of 6 which suggests considerable variation in population growth across places. We can also easily see from the 1993 and 2010 population means that the Colombian population grew by about 18% during the period. A low mean municipal growth and strong aggregate urban population growth can only be consistent if population growth is heavily skewed towards large municipalities. This would be consistent with the high standard deviation of municipal growth. This conjecture can be verified directly: Municipalities with a population above 20,000 in 1993 grew by 11% during our study period and those with a population above 50,000 by 26%. This indicates that urbanization is still on-going during our study period. The second part of table 1 also documents considerable variation across cities for some key possible determinants of population growth for Colombian cities.

Throughout the paper the dependent variable is population growth. It is usually measured as the difference in log population between 1993 and 2010 for each Colombian municipality. Population in 1993 is from the population census organised by the Colombian National Statistical Agency (DANE) the same year. The last census is from 2005. To expand the study period, DANE's population estimates for 2010 are used. These population estimates are not mere projections of the 2005 population data. They take migration flows, births, and deaths between 2005 and 2010 into account. I nonetheless verify the robustness of the main results using population growth from 1993 to 2005.

To control for past growth trends, log census populations from 1918, 1938, 1951, and 1964 are often included as controls. In some regressions, I also use log population change between 1938 and 2010 as dependent variable and control for population in 1912, 1851, and 1843. Finally, some regressions even consider population growth since 1870 or 1843. Historical population data for Colombia are discussed in Duranton (2014*b*).

While most of the analysis is done at the level of Colombian municipalities, I verify below that the results are robust to using population in the 'core' of the municipality as Colombian data often distinguish between the (urban) core of a municipality and the (rural) periphery. For large cities, most of the population lives in the core. More rural areas have a larger share of population living outside the core. In some regressions, I also verify that the main results are robust to using metropolitan areas instead of municipalities. Metropolitan areas are defined as in Duranton (2013*a*) using cross-municipal commuting patterns. This makes little difference because only 22 metropolitan areas are formed of more than one municipality. Most of the 99 satellite municipalities that send more than 10% of their work force to other parts of their metropolitan areas are suburban municipalities located in the immediate vicinity of the largest Colombian urban cores. Because most of the analysis below is performed on a sample of municipalities with a large population, I often refer to them as cities.

To measure many aspects of Colombian municipalities, I use a wealth of data from DANE and provided to me by the National Planning Ministry (DNP). These variables measure demographic changes, education, housing, and local public finances. Measures of the structure of employment in Colombian municipalities are computed from the 1990 and 2005 census of production. Sánchez and Nuñez (2000) gathered a large number of geographical characteristics for Colombian municipalities including climate, availability of natural resources such as gold, coal, or oil, altitude, soils, or availability of water among others. Meisel Roca and Pérez (2012) also collected a rich set of amenity and tourism variables containing information about museums, public libraries, hotels, restaurants, and airport arrivals and departures.

Wages play a particularly important role in the analysis below. The main source of information on wages is the Colombian Great Integrated Household Survey (GEIH) administered by DANE between 1996 and 2010 (with 2006 and 2007 missing) using 2,090,945 observations in total. As in Duranton (2014*b*), where this data source is discussed at greater length, I estimate a municipality fixed effect in a wage regression where I control for the gender of individuals, their age, its square, and dummies for each level of educational achievement and each year. Only municipalities with more 100 observations are retained. To assess the robustness of the main findings, municipal fixed effects are sometimes estimated only for 1996 to 2001. Average municipal wages are also sometimes used.

Finally, various measures of roads and market access for Colombian municipalities are also used to assess the importance of transportation for urban growth. These data cover the Colombian road network from the country's colonial era to the current-day network and various market access variables measured either directly using wages in Colombian municipalities and travel time distance from Google Map or indirectly using a large-scale internal trade survey. These data are further described in Duranton (2015).

3. Possible factors of urban growth

At the most immediate level and in accounting terms, city population growth over a period of time is equal to births minus death plus net migration flows. Should everyone be perfectly immobile, the growth of cities would boil down to analysis of the local determinants of natality and morbidity. At the opposite extreme, the dynamism of a city's internal demographics should play no role when the population is perfectly mobile. While there is a sizeable literature on how urbanisation or urban structure may affect fertility (e.g., Aiura and Sato, 2014) or how, at the country level, fertility may affect urbanisation (e.g., Jedwab, Christiaensen, and Gindelsky, 2014, Jedwab and Vollrath, 2015), there has been surprisingly little interest in the extent to which, locally, natural population growth determines overall population growth.[4]

Although an analysis of the role played by a city's internal demographics may not be of much interest in a country like the US where we expect population to be fairly mobile, it is informative to assess the contribution of the natality of cities to their population growth in a developing country like Colombia where mobility between regions is low for geographic and historical reasons (Bush-

[4]The determinants of urban growth and the literature on the size distribution of cities are reviewed in Duranton and Puga (2014). See also Duranton (2013*b*) for a less technical exposition focused on the US.

nell, 1993). The difficult geography of the country has led Colombian regions to evolve in relative isolation from each other. As a result, they have developed different regional cultures and senses of belonging. Beyond this, the demographic question is salient in Colombia where demographic differences across cities are extremely large. For instance, the 2010 birth rate in Quibdó, the main city of the Chocó region along the Pacific coast, is about 50% higher than in Cartagena, the fourth largest city on the Caribbean coast. The 2010 birth rate in Quibdó is also twice as high as in Bogotá, the capital and largest city, and three times as high as in Medellín, the second largest city. Relative to the low-fertility cities of the Coffee region, the natality gap is even higher.

After demography, initial population is another crucial variable that is at the heart of three important issues regarding urban growth. First, there is a worry that large cities in developing countries may be growing faster than smaller cities, and, somehow, may be growing too big. For many years, Colombia was hailed as a virtuous example of a country with a balanced urban system, which included four major cities in roughly the same size league. This is in contrast with a country like Argentina for which the metropolitan area around the main city, Buenos Aires, hosts nearly a third of the country population. Greater Buenos Aires is also nearly 10 times as large as the second largest metropolitan area. This said, the last decades have seen the rising prominence of Bogotá in the Colombian urban system. This may be a concern in a country where a balance between the main regions is perceived as important politically.

Whether the population growth of cities depends on their initial size has also important implications for the long-run size distribution of cities. In particular, there has been a salient controversy in the literature regarding whether Gibrat's law holds for city population growth. Gibrat's law (a.k.a., the law of proportional effects) is the statement that growth over a period is orthogonal to the initial level. In turn, Gibrat's law implies either a log normal city size distribution or a Pareto distribution (a.k.a., Zipf's law) depending on minute differences regarding the growth of cities at the bottom tail. Both distributions appear to be appropriate first-order description of the size distribution of cities.[5]

The third reason why initial population size should be included in city growth regressions is more technical. Consider first a hypothetical situation where population is highly mobile across

[5] See Eeckhout (2004) and subsequent literature for the Gibrat's law controversy for US cities. The relationship between the size distribution of cities and their growth is discussed at length in Duranton and Puga (2014). See Duranton (2013*a*) for a discussion of the size distribution of Colombian cities. See finally, Ioannides and Skouras (2013) for a recent discussion of how to evaluate the shape of the distribution of city sizes.

cities. Then, a change in a city's characteristics leads to a change in its population soon afterwards. To be concrete, assume that a new road leads to an almost immediate influx of population. To capture this type of phenomenon, it is appropriate to regress changes in city population on changes in the roadway using a 'difference-*on*-differences' regression. However, as noted by Duranton and Turner (2012), if population only gradually adjusts to the new infrastructure, one should regress changes in population on the initial level of roads and initial population. Given that our results about city demographics strongly suggest that mobility is far from perfect in Colombia, regressing city population changes on the initial levels of population and key determinants of population also measured in level appears appropriate. Estimating this type of 'difference-*on*-levels' regression is in line with much of the literature on urban growth.[6]

Then, from standard reasoning, we expect net migration flows in or out of a city to be determined by the wages and incomes that this city offers, the quality of life in this city, and the costs of living in this city, mainly determined by housing and transportation costs. Regressing city population growth on city wages constitutes an interesting exercise for two reasons. First, incomes and wages are arguably important proximate causes of urban growth. Obviously, the causal effect of city wages on city population is unlikely to be perfectly identified from such regression. Importantly, the estimated elasticity of wages with respect to population is likely to be downward-biased since we expect workers to base their location decisions on long-run wages not on the wages measured for any given year (which are also likely to be mismeasured). Wages and population growth are also expected to be simultaneously determined as population inflows will lower local wages (at least in the short run).

Second, it is also interesting to estimate the effect of other, perhaps deeper, factors of urban growth in conjunction with wages. For instance, human capital in a city may cause urban growth for a variety of reasons. City human capital may increase productivity through local human capital externalities. It may also increase future productivity through learning by workers surrounded by more educated workers. Alternatively, a larger share of more educated workers in a city may generate local amenities that are directly valued by the residents. Considering wages and measures of city human capital both together and separately in city growth regressions will be informative and provide suggestive evidence regarding the channels through which city education affects city growth.

[6]See Duranton and Puga (2014) for further discussion of this issue.

It is somewhat puzzling that wages and productivity are seldom used in city growth regressions. An early exception is Glaeser *et al.* (1995), who consider wages in conjunction with other determinants of population growth for US cities, but estimate mostly insignificant coefficients. More recently, Beaudry, Green, and Sand (2014) have developed a new approach to estimating the effects of changes in city wages on city population growth. Their estimation strategy relies on differences in national wage premia across sectors. More specifically, wages in a city are expected to grow faster when sectors with high premia become locally more important or if the more important sectors of activity of a city experience a growing premium nationally. For US cities, Beaudry *et al.* (2014) estimate an elasticity of city population with respect to city wages of about two over a ten-year time horizon.

As already stated, high wages can only constitute a proximate factor of city population growth just like aggregate investment is a proximate factor of GDP growth. To go deeper, it is important to understand what drives urban wages. It seems natural to expect higher wages to result from a stronger demand for labour locally. The demand for labour may increase for idiosyncratic reasons following, for instance, the breakthrough of an entrepreneur who develops a very successful new business.[7] There may also be a systematic component to changes in labour demand. As sectors of economic activity rise and decline at the national level, cities with a 'favourable' mix of sectors should experience rising wages and increasing population while cities with an adverse mix will decline. Following Bartik (1991), it has become commonplace to use city shares of sectoral employment multiplied by their national growth and summed across sectors as a more exogenous surrogate for city employment growth. Although these predictors of city growth have often been used as instruments for population growth, when the latter is used as an explanatory variable for something else, there has been very little work that focuses on the effects of changes in labour demand on city population.

In Duranton (2014*b*), I examine determinants of local wages to estimate agglomeration effects in Colombian cities. While its focus is different, this analysis of agglomeration effects leads a to number of findings that are relevant here. Most importantly, there is some evidence, albeit modest, that city education, as measured by the share of university graduates, and market access

[7]In Duranton (2007), I explore the implications of such idiosyncratic discoveries for the size distribution of cities in an urban system. I also provide empirical evidence about some of these implications including the fast churning of sectoral employment in cities. Following Glaeser *et al.* (1992), there have been many claims regarding the importance of entrepreneurship in local growth. These issues are best explored by focusing on the evolution of employment at the level of sectors of economic activity across locations. This will constitute the object of a separate analysis.

both matter in determining wages. On the other hand, there is no evidence that roads or amenities have any effect on wages.

Following Glaeser *et al.* (1995), Simon and Nardinelli (2002), Glaeser and Saiz (2004), and many others, city-wide measures of human capital have often been considered in city growth regressions. While human capital in an area can be measured in many ways, the share of university-educated workers is a popular measure. For 20th- and 21st-century cities in developed countries, this measure of city-wide human capital is usually a strong and robust predictor of future growth. The evidence for earlier periods is also supportive, though not as strongly. Simon and Nardinelli (1996) find robust evidence of an important role of human capital for the growth of English cities in the second part of the 19th century and the first part of the 20th. For US counties over the last 200 years, Glaeser, Ponzetto, and Tobio (2014) find an uneven role for city human capital in the early part of their study period.

After Moretti (2004) and others, a strong case can be made that a greater proportion of university graduates in a city in the US is associated with higher wages. Although, as already mentioned, the evidence for this type of effect is less strong in Colombia, this is certainly a possible channel of transmission. Because city education may generate human capital externalities that translate into higher wages, more education in a city will eventually lead to an inflow of newcomers.

While a direct effect of city education on wages is possibly a key channel of transmission, this need not be the only one. There may be more to the relationship between city education and wages as higher wages may also be a delayed response to human capital externalities that generate some learning. In the extreme, workers might migrate to a city in large numbers to learn and then leave to reap the benefits from their learning elsewhere. As a result, much of the effect of city human capital may not go through contemporaneous wages and we may observe an important effect of city human capital on subsequent growth even after controlling for city wages. Following, Shapiro (2006), it is also possible that human capital affects city growth through the formation of positive local amenities associated with human capital.

Regressing city population growth on the initial level of city human capital may not identify a causal effect of city human capital on population growth. More educated workers might be flocking to growing cities ahead of other workers, perhaps because they are more mobile. More prosperous cities, which grow faster, may also be able to provide their residents with more and better education. The literature on US cities has used the establishment of land grant colleges in the second part of the 19th century in small places at the centre of many states as a source of exogenous variation for city education (Moretti, 2004, Shapiro, 2006). The estimates that use this source of variation confirm those of simple cross-sectional regressions. Glaeser and Saiz (2004) perform a number of other robustness checks and further buttress the case that city education has causal effect on city population growth in US cities.

Urban amenities are also often acknowledged to play an important role in the growth of cities. While standard economic analysis in the spirit of Roback (1982) makes it clear that cities with better amenities should be larger, it is less immediately obvious that cities with better amenities should grow faster. A key reason behind the possible positive effect of amenities on city growth could be that urban amenities are normal goods (or even perhaps luxury goods) for which households are willing to pay increasingly high prices as they get richer.

There is strong empirical evidence regarding the role of a specific amenity in US urban growth: the weather. Glaeser, Kolko, and Saiz (2001) argue that January and July temperatures are the most reliable predictors of city growth in recent US history. These findings have been confirmed by subsequent literature in the US and by Cheshire and Magrini (2006) for European countries. It could nonetheless be the case that good weather is correlated with another potential explanation of city population growth. For instance, warm January temperatures in the US are predominantly found in the South. Southern US cities also make it easier to build housing, a potential confounding factor. Fears of a spurious correlation have been alleviated by Rappaport (2007) who shows that the relationship between good weather and population growth is true outside of the US South. Adding to this, Carlino and Saiz (2008) show that tourism visits, which may be understood as an overall measure of amenities, is a robust predictor of city population growth in the US even after controlling for weather. They also provide plausible instruments which confirm their main results. Taken together, findings by extant literature strongly support the notion of a positive effect of amenities, and particularly of nice weather, on city growth. Whether such findings also hold in developing cities is an open question.

The transportation infrastructure, the road infrastructure in particular, is another possible determinant of urban growth that has been considered in the literature. Urban roads may matter for two reasons. First, they are expected to ease travel within cities and allow residents to reach their destinations, work in particular at a lower costs. In turn, roads will induce them to travel further to reach better jobs or restaurants they like better. Roads will also allow residents to travel more often. Lower travel costs will also alleviate the scarcity of land and thus lower housing costs. Standard economic models of city structure in the spirit of Alonso (1964), Mills (1967), and Muth (1969) imply that more roads should make cities more attractive and thus foster their population growth. Duranton and Turner (2012) provide some evidence regarding the role of roads in the growth of US cities between 1984 and 2004. They claim that a 10% increase in a city's roadway leads to a 1.5% larger population 20 years later. These results have been replicated for various countries, including Spain (García-López, Holl, and Viladecans-Marsal, 2014).

The second reason why urban roads matter is that they offer convenient ways in and out of the cities and foster trade. Duranton, Morrow, and Turner (2014) provide evidence that US cities with more interstate highways export more in volume because of this. In Duranton (2015), I show that a similar effects also occur in Colombian cities for both exports and imports, in volume and in value. The main difficulty when regressing urban outcomes on city roads is that roads may follow from these 'outcomes' rather than cause them or that city population growth and roads are simultaneously determined.

Several solutions to this identification issue have been proposed (see Redding and Turner, 2015, for a review). Duranton and Turner (2012) use old road networks as exogenous predictors for current urban roads. These include a plan of the US interstate highway system prior to its development after 1956, late 19th century railroads, and early exploration routes of the continent. These instruments are statistically powerful enough predictors of the current transportation network since initial highway maps have been by and large implemented, old railroads have often been turned into roads, and old exploration routes have been slowly upgraded into modern roads. A case can also be made in favour of their exogeneity since old road networks were mostly about linking cities whereas our concern here is mostly about travel within cities. This case can be made stronger by controlling for possible factors that may be correlated with both contemporaneous city population growth and old road networks such as geographic features or the long run propensity of some cities to grow. We follow a similar approach here and use data extracted from maps of old road networks from Colombia dating back to the colonial era.

Beyond roads, the relative location of cities may also matter. Cities with good market access may grow more. For instance, Redding and Sturm (2008) document that (West) German cities close to the Iron Curtain, which divided Germany for nearly 30 years, lost much of their market access after the Iron Curtain was erected. They also experienced a process of relative population decline. Being close to large markets has nonetheless theoretically ambiguous implications. A city with large markets nearby will enjoy a higher demand for its products. It will also face stiffer competition from producers located in these neighbouring markets. The resulting effect of these two forces will be in general non-linear and will depend on subtle issues such as the nature of competition on product markets (Head and Mayer, 2004).

As imentioned above, there are strong reasons to expect city wages to affect city population growth. By the same line of reasoning, a higher cost of living could potentially affect negatively city population growth. While developing a good measure of the overall cost of living in Colombian cities is beyond the scope of this paper, I can nonetheless use some measures of housing costs to provide a preliminary exploration of this issue. Finally, the popular press (especially in Colombia) is always keen to highlight the role of local leadership in cities. Even though I am not able to establish causality, I can nonetheless provide an early exploration of correlations between some unique measures of local governance and city population growth.

4. Key drivers of the growth of Colombian cities

All the regressions estimated below are of the same general form:

$$\Delta_{t,t+1} \log \text{pop}_c = \alpha \log \text{pop}_{ct} + X_{ct}\beta + \epsilon_{ct} \,, \tag{1}$$

where the dependent variable is the change in log population between t and $t+1$. I usually take 1993 as the beginning of the study period and 2010 as its end. Cities are indexed by c and X is a vector of city characteristics. These characteristics include a number of variables of interest such as city wages, education, or roads, among others. They also include a number of control variables such as regional or departmental dummies and past log populations.

An important issue to note here is that most of the regressions below regress a difference in population on the initial level of the determinants of urban growth. As already discussed, this is justified when equilibrium population adjusts only slowly to changes. The first part of the analysis that follows makes the case that population mobility is far from perfect in Colombia by focusing on city demographics.

A full accounting exercise that decomposes changes in the population of all cities into births, deaths, and migration flows in and out of the city is beyond the scope of this paper for two reasons. The first is that counts of births are available only for certain years and information about migration flows is even more restricted. Birth rates are computed using the number of birth per adult population in 1993, 2005, and 2010. Migrations flows are only available since 2008 and it is unclear how precisely the Colombian government is able to track households that move.[8] The second reason for not doing a full accounting exercise is that using a regression like described in equation (1) will make it easier to compare the results about city demographics with those for other determinants of city growth.

In table 2, column 1 regresses the change in log population between 1993 and 2010 on log 1993 population and the log birth rate for all available Colombian municipalities. The coefficient on log initial city population is insignificant. This is a precisely estimated zero since the standard error on this elasticity is less than 0.01. The coefficient on log birth rate is 0.24 and highly significant. Again, under perfect mobility, this coefficient is expected to be zero as natality in a city should be uncorrelated with its population growth rate.[9] Under perfect immobility, this coefficient should be close to one as the population can only increase through births.[10]

Column 2 of table 2 uses a broader measure of internal demographic dynamism. Namely, it replaces the birth rate used in column 1 by a fertility rate computed using the number of children below the age of 18 relative to the adult population. This alternative measure yields a marginally higher coefficient of 0.27 instead of 0.24, perhaps because it measures long-run fertility better. Column 3 uses instead the log counts of migrants in and out of the city. The coefficient on out migrants is negative and low at -0.04. The coefficient on in-migrants is much larger and positive at 0.11. Considering flows of migrants together with the fertility rate in column 4 makes little difference to the results obtained so far. In essence, growing cities are cities with stronger internal demographic dynamism, greater flows of in-migrants, and smaller flows of out-migrants. While the analysis does not allow us to cleanly compare the contributions of fertility and migration flows to urban growth, we can note that the sum of the coefficients on migration flows is slightly smaller than the coefficient on fertility but of the same magnitude. It is also easy to see that both migration flows and fertility appear to have roughly the same explanatory power with respect to urban population growth. This suggests that both migration and fertility are equally important

[8] Unfortunately, this variable is only available towards the end of the study period. This may not matter much as we expect this type of variable to be persistent over time.

[9] This also requires a lack of correlation between natality and other determinants of city population growth not considered in the regression. This issue is tackled below.

[10] In absence of mobility, city growth should be entirely explained by the differential between natality and mortality.

Table 2: Changes in log population between 1993 and 2010 and fertility, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population	0.0027	0.025^a	-0.051^a	-0.023^c	-0.0077	-0.026	0.036	0.0017
	(0.0096)	(0.0089)	(0.013)	(0.014)	(0.020)	(0.021)	(0.037)	(0.035)
log birth rate	0.24^a							
	(0.025)							
log fertility rate		0.27^a		0.24^a	0.23^a	0.22^a	0.17^b	0.27^a
		(0.028)		(0.033)	(0.058)	(0.058)	(0.070)	(0.070)
log out-migrants			-0.042^a	-0.062^a	-0.071^a	-0.057^a	-0.050^a	-0.047^a
			(0.0083)	(0.0088)	(0.012)	(0.011)	(0.013)	(0.015)
log in-migrants			0.11^a	0.092^a	0.099^a	0.088^a	0.083^a	0.071^a
			(0.0094)	(0.0095)	(0.015)	(0.015)	(0.015)	(0.016)
log wage						0.27^a	0.27^a	0.33^a
						(0.076)	(0.087)	(0.096)
Past populations	N	N	N	N	N	N	Y	Y
Location dummies	N	N	N	N	N	N	Reg	Dpt
R^2	0.13	0.11	0.16	0.22	0.27	0.30	0.32	0.43
Municipalities	1,041	1,041	934	915	344	344	344	344

Notes: OLS regressions with a constant in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variables of interest and controls are as follow. The variable log birth rate is the natural log of the average number of recorded births per adult for 1998, 2005, and 2010. Fertility rate is the average number of children below 18 per adult for 1998, 2005, and 2010. Out-migrants and in-migrants are the number of migrants in and out, averaged over 2008-2010. The variable log wage is a wage index as described in the text. Past populations are the logs of population for 1918, 1938, 1951, and 1964. In column 7, the geographic dummies are Caribbean, Andean, and Oriental (with Pacific being the base). In column 8, the geographic dummies are for the 32 Colombian departments and the Bogotá capital district. Starting column 5, the sample of municipalities is restricted to municipalities for which wage and other variables used below is available.

in accounting for urban growth. In turn, this probably implies significant frictions in terms of residential mobility.

Next, column 5 duplicates column 4 but uses a smaller sample of Colombian municipalities. This sample is mostly the sample of cities that will be examined in much of what follows. These are larger municipalities for which wages and other data are available. The results are essentially similar across the larger and smaller samples of municipalities. Column 6 also includes log municipal wages. This wage variable is a wage index estimated as in Duranton (2014*b*) using the Colombian households survey. Individual wages that are regressed on individual characteristics, a city fixed effect, and a year effect for the 1996-2010 period.[11] City effects are kept only for municipalities for which more than 100 observations are available and used as a wage index. While the coefficient

[11] The characteristics are gender, age, its square and an indicator variable for each year of education.

on log wages is fairly large at 0.27 and highly significant, the coefficient on natality remains the same while those on migration are only marginally lower in size. Column 7 further adds indicator variables for the four main regions of Colombia and log population in 1918, 1938, 1951, and 1964 as control variables. These controls are important for two reasons. First, regression (1) is equivalent to regressing the log of 2010 population on the same variable for 1993. If the error term is serially auto-correlated, this can bias the estimation of the coefficient on initial population. Hopefully the bias, if any, will be much attenuated by adding further population lags as controls. We also expect past populations over nearly a century to control for many important unobservables that drive city growth and could be correlated with city demographics. Column 8 restricts identification further by also imposing indicator variables for departments. Despite only considering variation within fairly small units, the coefficients on the demographic variables remain about the same as in column 6.

The first important lesson that can be drawn from table 2 is that migrations in and out of cities play in important role as proximate factor for the population growth of cities in Colombia. Although this probably was to be expected, this legitimises the rest of this analysis and an attempt to understand what makes some cities more attractive to newcomers. The second main lesson from table 2 is that city fertility plays, perhaps, a surprisingly large role. Cities with a higher fertility grow faster with an elasticity of about 0.25. Hence, while there is some mobility, it is far from perfect and this justifies our focus in most of what follows on differences-on-levels regressions instead of differences-on-differences regressions. Since city demographics is only a proximate factor behind city growth, for the rest of the analysis we turn to deeper determinants and ignore city demographics.

A third finding of table 2 is the suggestion that wages also play an important role in city growth. The regressions reported in table 3 provide further support for this result. Column 1 regresses the change in log population between 1993 and 2010 on log wages. The estimated elasticity is 0.50. Adding initial population, past populations and regional indicators in column 2 or departmental indicators in column 3 makes little difference. Again, these wages by city are estimated from the Colombian labour force survey over the period and finely control for standard observable characteristics of workers such as their gender, age, and educational achievement. To assess the effect of this particular choice, column 4 uses mean wages computed directly from the data. This

Table 3: Changes in log population between 1993 and 2010 and wages, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population		0.17[a]	0.12[a]	0.15[a]	0.096[b]	0.12[a]	0.14[a]	0.12[c]
		(0.035)	(0.032)	(0.036)	(0.040)	(0.036)	(0.036)	(0.065)
log wage	0.50[a]	0.41[a]	0.48[a]	0.32[a]	0.32[a]	0.28[a]	0.75[a]	0.56[a]
	(0.070)	(0.087)	(0.093)	(0.065)	(0.095)	(0.094)	(0.15)	(0.20)
log wage^2							0.61[a]	
							(0.21)	
Past populations	N	Y	Y	Y	Y	Y	Y	Y
Location dummies	N	Reg	Dpt	Reg	Reg	Reg	Reg	Reg
R^2	0.13	0.24	0.36	0.24	0.15	0.15	0.26	0.43
Observations	373	373	373	373	286	373	373	79
Sample	mun.	mun.	mun.	mun.	MSA	urb. core	mun.	big mun.
Wage	FE	FE	FE	mean	FE	FE	FE	FE

Notes: OLS regressions with a constant in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variable of interest is as follows: wage estimated as a municipal fixed effect in columns 1-3 and 6-8, deflated mean municipal wage over 1996-2010 in column 4, fixed effect estimated for the urban core. The sample of observation is the base set of municipalities in all columns except for column 4 (MSAs), column 5 (urbanised parts of municipalities), and column 8 (municipalities with population above 50,000 in 1993).

leads to a somewhat lower coefficient on wages, perhaps because raw wages provide a worse measure of potential earnings in a locality. Another important choice made so far was to use Colombian municipalities as unit of analysis. Column 5 repeats column 2 but uses metropolitan areas as defined in Duranton (2013*a*). Column 6 focuses instead only on the urbanised part of municipalities. In large municipalities, the urbanised part often represents nearly all the population of the municipalities but this is not the case for smaller municipalities. In both cases, the estimated coefficient on wages is lower than in column 2 and the R-squared is lower as city growth appears to be better measured and explained at the municipal level in Colombia. To look at possible non-linearities, column 7 introduces a quadratic term in log wages. The positive and highly significant coefficient on this term suggests a convex relationship between city growth and log initial wages. This finding is confirmed in column 8 which repeats column 2 but restricts the sample to only 79 large municipalities with a population above 50,000 in 1993.

The key conclusion of table 3 is that there is a strong association between wages and population growth during the study period. The elasticity appears to be at least 0.3. Our preferred estimates from columns 2 and 3 are around 0.4-0.5 and even larger in larger municipalities. A limitation of this analysis is that we cannot assert for sure that this relationship is causal. A reason why the coefficients on wages may be over-estimated is that a greater population may foster wages through agglomeration effects. In Duranton (2014*b*), I estimate these 'opposite' elasticities to be about an order of magnitude smaller in Colombian cities. It is hard to be believe that agglomeration effects could be a major source of bias here. Instead, the coefficients estimated here may be too small as, in the short run, the arrival of more workers may act to dampen the pressure on wages.[12] We return to the identification of wage effects on urban growth below.

Knowing that the growth of cities has a strong association with wages might be expected. It is also reassuring that workers respond to economic opportunities. The results of table 3 are also useful because adding further determinants of urban growth below will allow us to assess how much of these extra determinants matter because they boost income or because they provide an amenity value. The last lesson we draw from table 3 regards the coefficient on initial city population. It is significant throughout the table and typically around 0.10 or above. This implies that a city that was 10% larger in 1993 grew by 10% *more* between 1993 and 2010. This result is confirmed by a large majority of the specifications we estimate below. Cities that were larger in 1993 grew on average faster between 1993 and 2010. While the population divergence between Bogotá and other major cities in Colombia over the last 50 years in well known, the finding here hints at a broader phenomenon. In the regressions of table 3, Bogotá is not an outlier in terms of growth rate and excluding it makes no difference to the results since all cities are weighted equally in the regressions. Put differently, there is a clear pattern of divergence in city population that violates Gibrat's law between 1993 and 2010.

To complement the analysis of table 3, table 12 in Appendix reports results for a number of regressions using changes in wages instead of their average over the period as key explanatory variable. In the simplest regression of changes in city population on changes in wages over the same period, the coefficient on the change in wages is insignificant. Adding controls for initial and past populations and indicators for regions or departments makes no change. In one specification, I instrument for wage changes using labour market shocks in the spirit of Bartik (1991). Instrumenting wages changes by changes in the demand for workers based on the initial composition of economic activity and the growth of sectoral employment during the period yields again insignificant results, in part because the instrument is weak. We view the negative findings

[12]Another worry is that if population is mismeasured, changes in population will be mechanically negatively correlated with initial levels. This plays against the results found here and suggests that patterns of divergence may be even stronger.

Table 4: Changes in log population between 1993 and 2010 and education, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population		0.0051	0.14^a	0.099^a	0.14^a	0.15^a	0.14^a	0.14^a
		(0.018)	(0.038)	(0.034)	(0.038)	(0.038)	(0.037)	(0.038)
log wage		0.43^a	0.36^a	0.44^a	0.36^a	0.37^a	0.35^a	0.37^a
		(0.089)	(0.090)	(0.096)	(0.090)	(0.098)	(0.090)	(0.092)
Share educated	1.43^a	0.82^a	0.58^b	0.49^c	0.66^b	0.38^c	0.019^a	-0.060
	(0.18)	(0.27)	(0.26)	(0.25)	(0.31)	(0.23)	(0.0070)	(0.80)
Share educated^2								2.45
								(2.22)
Past populations	N	N	Y	Y	Y	Y	Y	Y
Location dummies	N	Reg	Reg	Dpt	Reg	Reg	Reg	Reg
R^2	0.12	0.19	0.25	0.37	0.25	0.30	0.26	0.25
Municipalities	373	373	373	373	373	317	373	373
Education	univ.	univ.	univ.	univ.	log univ.	post-second.	high. ed. enrol.	univ.

Notes: OLS regressions with a constant in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variable of interest is as follows: share of workers with university education in column 1-4 and 8, log share of workers with university education in column 5, share of workers with post-secondary education in column 6, and log higher education enrollment +1 in column 7.

of table 12 as a confirmation of the fact that changes in population in Colombian cities are sluggish and react to past levels more than they react to current differences.

As argued above, human capital is widely accepted as a major determinant of city growth in developed countries. The evidence for developing countries is much thinner. The specifications reported in table 4 focus on city education. It is measured in a variety of ways. My preferred measure is the share of the workforce with a university degree but I also use the share of workers with any post-secondary education, the log share of workers with a university degree, or the log number of students in higher education. While the coefficients differ, the results are consistent throughout. The fraction of workers with some form of higher education is a strong determinant of city growth. Despite controlling for past and initial populations, regions, and wages, the elasticity of wages with respect to the share of university educated workers is 0.66 in column 5 of table 4. These results are of the same magnitudes as those of Glaeser and Saiz (2004) for US cities.

Two other interesting results arise from table 4. The first is that controlling for city wages lowers the coefficient on city education by a factor of about two. At the same time, adding city education only reduces the coefficient on log city wages by 10 to 15%. These two results are consistent with

Table 5: Changes in log population between 1993 and 2010 and education, IV specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	TSLS	TSLS	TSLS	TSLS	TSLS	TSLS	LIML	GMM
log 1993 population	0.085^c	-0.96^b	-0.00034	0.11^b	0.031	0.082	0.085^c	0.085^c
	(0.050)	(0.43)	(0.058)	(0.053)	(0.062)	(0.051)	(0.050)	(0.050)
log wage	0.28^a	-1.32^c	0.15		0.19^c	0.27^a	0.28^a	0.28^a
	(0.100)	(0.78)	(0.11)		(0.11)	(0.10)	(0.100)	(0.100)
Share educated	1.61^b	21.6^a	3.24^a	1.80^a	2.65^a	1.94^b	1.61^b	1.61^b
	(0.66)	(8.28)	(0.77)	(0.65)	(0.95)	(0.79)	(0.66)	(0.66)
Instruments:								
# of establishments	log	N	log	log	level	log	log	log
Sena seats	N	log	log	N	level	N	N	N
First-stage stat.	39.1	6.70	23.8	41.7	13.9	39.6	39.1	39.1
Municipalities	373	373	373	373	373	373	373	373

Notes: Regressions controlling for regional dummies and past population (1918, 1938, 1951, and 1964) in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variable of interest is the share of workers with university education in all columns but 6 where it is taken in log. The overidentification test is failed in columns 3 and 5.

those of Shapiro (2006) for US cities and we interpret them as follows. First, a large part of the effects of higher education that drive city growth are pecuniary in nature. This interpretation is consistent with the dramatic effect of the inclusion of wages on the coefficient on city human capital. Second, wage effects are only in small part effects of city education. This is consistent with the small effect of city human capital on wages. Shapiro (2006) interprets the non-wage effects of city education as amenities. While this interpretation makes sense in a US context, it is less obvious in the Colombian context. As shown below, the evidence about urban amenities as a driver of urban growth in Colombia is weak. City education might appeal to Colombian workers beyond current wages because of learning and expectations of higher future wages (De la Roca and Puga, 2012). Providing evidence of such learning effects would go beyond the scope of this paper. Another limitation is that, in Duranton (2014*b*), I could provide only weak evidence that human capital fosters wages in Colombian cities.

To provide further evidence about the role of city education, table 5 reports a number of two-stage least square estimations where city education is instrumented. The main identification worry in table 4 is that fast growing cities might attract primarily more educated workers or that the education of a city's workforce might be determined jointly with the growth rate of that workforce. To address this concern, we need surrogate variables that determine city education but are not otherwise correlated with city population growth. Put slightly differently, a good instrument for city education in this context affects the supply of education of a city but not its demand for education. A possible candidate instrument for city education could be the number of local university graduates that enter the workforce. A greater rate of new graduate entry in the workforce is expected to affect the education of a city's workforce but will be less likely to be caused by contemporaneous growth especially if we control for past growth through past log populations. Instead of the number of recent local graduates, I prefer to use the number of higher education institutions, most of which were established well before our study period.

I also use the number SENA seats. The SENA ('SErvicio Nacional de Aprendizaje' or National Service of Learning) is a technical teaching institution established in the 1950s throughout the country. It depends on the Colombian Ministry of Labour and aims to provide a free technical education to Colombians who cannot afford any other form of learning from the age of 16, while aiming to improve the technical capabilities of the workforce. Importantly, the SENA branches are present only in some cities and specialised by field of study.[13] These locations and specialisations appear to be stable over time. The number of seats that each branch offers is roughly proportional to the population of the region it covers in the specialities that it offers. Although the establishment of the SENA is more recent than that of land-grant colleges in the US used by Moretti (2004) and Shapiro (2006), this instrument is in the same spirit. Even with controls for broad geographic regions and for past populations, one may think of a number of reasons why the exclusion restriction associated with these two instruments may not not be satisfied. Using the number of higher education institutions and the number of SENA seats nonetheless provides a useful check on the OLS results proposed in table 4.

It is easy to see that, in table 5, the point estimates on instrumented city education are larger than in OLS. Unfortunately and despite the strength of the instruments, the standards errors are also large so that it is not possible to make a definitive comparison with the OLS results above. To close on the role of city education, we can also note that the share of university educated workers is retained as an explanatory variable in most of the specifications below. This variable remains generally significant with a coefficient around one despite considering a broad variety of controls.

[13]For instance, the branch in Pasto, close to the Pacific Ocean offers training in "logistics, human resources, cooking, agriculture, finance, accounting, food preparation, natural resources management, construction, systems, crafts, accounting, livestock management, and pharmaceutical services."

Table 6: Changes in log population between 1993 and 2010 and industry composition, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population	0.066^a	0.14^a	0.060^a	0.083^b	0.029^c	0.086^b	0.0043	0.064
	(0.012)	(0.039)	(0.022)	(0.041)	(0.017)	(0.041)	(0.027)	(0.041)
log wage		0.32^a		0.28^a		0.26^b		0.21^b
		(0.090)		(0.099)		(0.10)		(0.10)
Share educated		0.74^b		0.93^a		0.89^a		1.03^a
		(0.31)		(0.31)		(0.31)		(0.32)
Bartik 2d	-0.029	0.017					0.038	0.060^c
	(0.034)	(0.027)					(0.035)	(0.033)
Bartik 4d	0.15^b	0.11					0.084	0.043
	(0.068)	(0.074)					(0.093)	(0.10)
Manuf. share					0.57^a	0.25^b	0.82	1.71
					(0.11)	(0.11)	(0.95)	(1.08)
Service share							0.37	1.49
							(0.95)	(1.08)
Bus. serv. share					0.40	0.64	0.72	1.96
					(0.59)	(0.59)	(1.12)	(1.20)
Specialisation index							0.057	-0.017
							(0.32)	(0.28)
Relative specialisation			0.0053^a	0.0036^a			0.0029^b	0.0031^a
			(0.0011)	(0.00090)			(0.0011)	(0.0011)
Diversity index							0.018	0.0049
							(0.012)	(0.011)
Relative diversity			-0.035	0.037			-0.060	0.019
			(0.044)	(0.040)			(0.055)	(0.053)
Past populations	N	Y	N	Y	N	Y	N	Y
Regional dummies	N	Y	N	Y	N	Y	N	Y
R^2	0.10	0.27	0.09	0.29	0.12	0.28	0.16	0.31
Municipalities	360	360	285	285	285	285	282	282

Notes: OLS regressions with a constant in all columns. Robust standard errors in parentheses. a, b, c: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variables of interest are as described in the text.

Now that the explanatory power of city education in the growth of Colombian cities is more firmly established, we can return to the role of wages. Although it is hard to think of reasonable instruments for wages, we expect wages to reflect local shocks in the demand for labour. Any positive shock to the demand for labour should lead to higher wages and attract more workers. Then, controlling directly for the demand for labour should weaken the estimated coefficient on wages.

To measure local shocks to the demand for labour, table 6 uses a variety of metrics. The first two are standard shifts-share predictors of employment growth in the spirit of Bartik (1991). These predictors of city employment growth are based on their initial sectoral composition of employment interacted with the national growth of sectors. I compute them for both two-digit and four-digit industries. I also cruder measures of the initial composition of employment by considering the share of employment in manufacturing, business services, and personal services. Finally, I use finer measures of the composition of economic activity with two specialisation and two diversity indices. I measure specialisation through the share of the largest four-digit industry either in absolute terms or relative to its national share in employment. Similarly, I measure diversity through a Herfindahl index, again of absolute or relative employment as in Duranton and Puga (2000). Following Glaeser *et al.* (1992), there is an important body of evidence showing that patterns of specialisation and diversity provide good predictors of local growth.

A number of conclusions can be drawn from the results of table 6. First, the coefficient on the wage is divided on average by a factor of around two relative to the specifications in tables 3. That is, introducing variables that proxy for local labour demand shocks or variables that have been shown to be associated with local labour changes by past literature has a dramatic effect on the estimated elasticity of population with respect to wages. Rather than revealing some fragility in our previous results, we interpret this finding as lending credence to the fundamental importance of local labour market conditions to explain the growth of cities. Local labour demand shocks will leads both the number of workers and wages to adjust. That controlling for 'quantities' as well as 'prices' should lower the estimated coefficient on 'prices' is to be expected.

The second main conclusion to be drawn from table 6 is that the coefficient on city human capital is barely affected by the inclusion of proxies for labour market shocks. We concluded from tables 4 and 5 that some form of human capital effects were behind part of the wage coefficients we initially estimated in table 3. From table 6, we just concluded that changes in local labour demand are an even bigger part of the wage effects. However, controlling for the local composition of economic activity or for proxies for local labour demand shocks does not appear to affect our results for city education, as if they were two distinct phenomena. Third, as deeper determinants of city growth, changes in local labour demand are a big part of the wage effects we initially estimated. Nonetheless, the variables we introduce in table 6 do not drive the wage coefficient to zero. Wages appear to affect city growth beyond what happens through city human capital and the local composition of economic activity. As we shall see below, the wage coefficients remain significant even when we consider further determinants of urban growth.

This said, it would nonetheless be wrong to interpret what is left of the wage effect after controlling for 'everything else' as a 'pure' wage effect. The reason is that there might be some determinants of city growth omitted from this analysis that affect city growth through higher wages. In addition, the variables we use in table 6 most likely account for changes in local labour demand only partially.

The last conclusion we can draw from table 6 is less positive and points to the difficulty of characterising local labour demand changes. Nine different variables are used and only the relative specialisation index is a consistently significant determinant of city growth. The other measures of the local composition of economic activity are less robust. They affect the coefficient on wages but it is hard to pin down one specific metrics that plays a decisive role.

Ultimately, we expect residents to choose their city of residence based on the real wage it offers, not on its nominal wage. Hence, a lower cost of living could, in theory, act just like a higher wage. To look at this conjecture in greater detail, the regressions reported in table 13 in appendix consider a variety of measures or proxies for urban costs. These regressions include the share of land that is developed, the floor to area ratio in 2005 and 2012, and the average assessed price of residential space per square metre. All these variables are considered in level or in log depending on the specification. Unfortunately, the coefficients on these urban costs variables are either insignificant or, in the case of housing values, have a 'perverse' sign. The main problem in these regressions is that housing values are highly correlated with population and wages as both theory and intuition suggest they should be. As a result, it is not possible to identify the effects of wages on urban growth separately from those of property prices. Adding to this, we also expect high property prices to be a consequence of fast population growth as a well as possible factor that limits it. Developing a new approach that would allow us to separately identify the (positive) effects of wages from the (negative) effects of urban costs would go beyond our scope here. We can only hope future work will tackle this issue.

So far, the results paint a fairly clear picture about urban growth in Colombia. Colombian cities are labour markets. Places that offer higher wages grow more. We can trace these higher wages back to local labour shocks and, to a lesser extent, to a more educated workforce. This said, mobility across these labour markets is far from perfect as evidenced by the fact that the growth of cities is strongly correlated with their internal demographic dynamism. We can also note that, although wages matter a lot for urban growth, the measured elasticities of population growth with respect to wages are well below those that have been estimated for the US.

5. Further determinants of urban growth in Colombia

We now turn to further determinants of city growth. As mentioned above, there is a large literature that highlights the importance of amenities in the growth of US and European cities. This literature has considered climate and other geographic characteristics of cities. These measures have the great merit of being more exogenous. More endogenous amenities such as museums, which make cities nicer, or low crime rates, which make cities more liveable, have also been considered despite considerable difficulties in identifying causal relationships when such variables are considered.[14] The literature has also considered broad summary measures of amenities such as leisure visits Carlino and Saiz (2008).

The results are reported in table 7. They are generally mixed. In part, these mixed results are due to data limitations. Some amenity variables are available only for a subset of less than 100 cities. A limited number of observations may be a key reason why the variables associated with tourism, hospitality (measured through hotels and restaurants), libraries or museums do not yield any significant result. The evidence about geographic variables is also limited. Precipitations has a negative significant sign in regressions that include our main sample of more than 300 cities. A measure of temperature that is available for less than 100 cities has a coefficient that is negative and significant. This provides modest evidence that a cooler and drier climate may foster city growth. I did not find robust evidence of a non-linear effect of climate where warm cities located between 1000 and 2000 meters are more attractive than hot coastal cities or colder cities higher up in the mountains.

The evidence is about violence in what is historically a highly violent country is also limited. I used various measures of political violence since the 1990s, counting attacks from the various armed groups or the number of casualties. These measures are arguably of high quality since they were used internally by the government to guide its counterinsurgency effort. It is also well known that civil unrest in Colombia led to extremely large population displacements. Despite this, it is

[14]See Duranton and Puga (2014) for further discussion of this literature.

Table 7: Changes in log population between 1993 and 2010 and amenities and resources, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population	0.13^b	0.12^a	0.13^a	0.070	0.14^a	0.081	0.13^a	0.098
	(0.060)	(0.039)	(0.040)	(0.087)	(0.039)	(0.060)	(0.040)	(0.066)
log wage	0.47^b	0.34^a	0.38^a	0.41^c	0.36^a	0.42^b	0.39^a	0.59^a
	(0.19)	(0.089)	(0.090)	(0.21)	(0.090)	(0.19)	(0.089)	(0.18)
Share educated	-0.35	0.64^b	0.76^b	0.12	0.62^b	-0.43	0.59^c	0.67^c
	(0.38)	(0.31)	(0.31)	(0.44)	(0.31)	(0.35)	(0.31)	(0.34)
Temperature	-0.012^a							-0.0087^c
	(0.0044)							(0.0049)
Climate		0.038					0.0097	
		(0.043)					(0.023)	
Altitude		-0.044						
		(0.040)						
Water		0.11						
		(0.11)						
Precipitation		-0.058^a					-0.044^a	0.0010
		(0.020)					(0.016)	(0.022)
Coal			0.023					
			(0.043)					
Gold			0.030					
			(0.043)					
Oil			0.17^a				0.19^a	0.061
			(0.050)				(0.050)	(0.061)
Libraries pc				-0.044				
				(0.047)				
Museum pc				-0.023				
				(0.033)				
Hospitality pc				0.0046				
				(0.043)				
Tourism					0.0031			
					(0.0047)			
Homicide pc						-0.077^c		-0.11^a
						(0.045)		(0.042)
Violence						-0.068		
						(0.044)		
R^2	0.36	0.26	0.26	0.35	0.25	0.41	0.27	0.39
Municipalities	99	368	368	89	373	99	368	95

Notes: OLS regressions controlling for regional dummies and past population (1918, 1938, 1951, and 1964) in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variables of interest are as described in the text.

hard to find much robust and systematic evidence that less exposure to civil unrest is a major driver of city growth in Colombia. Two speculative reasons can be offered for this, perhaps, surprising result. First, the end of our study period is in 2010, at least 5 years after political violence became much less prevalent in Colombia. Second, the worst forms of civil unrest typically took place in remote rural areas which are not part of the the data used here. In addition, while civil unrest may have had a large effect on the urbanisation process, it may have been only a push factor for small municipalities outside our sample, not a pull factor. Displaced rural populations moved to cities but these populations may not have chosen their city of destination because of their level of civil unrest, which was much less than in rural areas in most cases. Instead, displaced populations may have chose more prosperous local labour markets.

While political violence does not appear to explain why some cities grew more than others, city criminality is negatively associated with cities growth. While data about homicide per capita is limited to a smaller sample of less than 100 cities, cities with fewer homicides have grown more between 1993 and 2010. The measured elasticity of city population with respect to homicides per capita is about -0.1. Nonetheless, this large effect should be interpreted with caution because a high level of criminality may be determined jointly with other determinants of city growth like a high level of underemployment. Population growth may also affect criminality.

Finally, table 7 also report results about a number of natural resources. In regressions not reported here, I also explored the effects of a number of other resources such as precious stones. The only natural resources that appears to matter is oil. It is robustly significant in most specifications, except when I restrict the sample to the 100 or so large cities for which other measures of amenities are available. This is arguably because oil in Colombia is overwhelmingly located in smaller peripheral cities.[15]

Overall, the evidence regarding amenities is fairly weak. These findings are consistent with those of Meisel Roca and Pérez (2012). These authors also report that Colombian households spend a minimal fraction of their income on 'entertainment', around 1% instead of 5 to 10% in more developed countries. Colombian households appear to favour socialising with family members instead. Regardless of whether these patterns are caused by different cultural preferences or by the lower level of income in Colombia, it may not be surprising that Colombians are not willing to move to cities offering better amenities. If they do not spend much for their leisure, they may not

[15]The 'oil capital of Colombia', Barrancabermeja, is an exception with a population above 300,000.

want to pay indirectly for amenities by relocating to amenity-rich cities.

Related to amenities, table 14 reports results on a number of other local characteristics which might affect how appealing a municipality might be. I first used two variables for local inequalities that measure the unequal distribution of land. None of these two measures is remotely significant. Then, I also used a measure of stated quality of life. It is highly significant and is associated positively with population growth. That places for which residents state they enjoy a high quality of life are also places that retain their existing population and attract newcomers is unsurprising. This does not say much beyond providing some minimal validation for this stated-preference variable. Interestingly, this measure of stated quality of life makes the coefficient on city education insignificant but it barely affects that on wages. This suggests that the stated local quality of life may not have much to do with wages. In this respect, this finding is mildly puzzling because table 7 struggles to offer robust evidence about local amenities beyond, perhaps, crime and climate.

Finally the last part of the table explores a range of measures of the quality of local government. These measures were developed for the later part of our study period by the Colombian Planning Ministry to gather some information about the governance of Colombian municipalities, which, after the decentralisation reforms of the early 1990s, started to enjoy significant powers without much oversight by the central government. As argued by Duranton and Puga (2014), very little is known about the effects of local governance and local leadership on local outcomes such as population growth. Nonetheless, these factors are usually strongly emphasised in popular discussions of local growth and local economic performance.

I use five different measures of local government. The first three are outcome measures. They concern fiscal performance, a measure of administrative performance, and a measure of overall performance. I estimate a positive and significant coefficient for these three measures. The last two measures result from assessments of the administrative capacity of a municipality and the quality of its management processes. For these two process-based measures, I estimate insignificant coefficients. While these findings are clearly speculative, the positive and significant associations between growth and municipal performance together with the absence of a relationship with the local processes is suggestive of some simultaneity or reverse causation between measures of municipal performance and growth. Whether the lack of association with measures of processes is caused by the poor quality of these variables or indicative of something deeper should be the object of future research.

As argued above, there is a strong theoretical case that roads should be a major driver of the population growth of cities. There is supportive empirical evidence from a variety of countries, including the US (Duranton and Turner, 2012). Measuring the roadway is challenging in the present context. While the mileage of highways and major roads is often the explanatory variable of choice in more developed countries, using it is problematic in an environment where nearly half the municipalities in 1995 do not have direct access to a major road and where a difficult geography might distort the mileage. Instead, as in Duranton (2015), I use an index of roads that accounts for the mileage, the number of road segments (or rays), the number of exits in and out of a municipality, and the distance to the nearest road for municipalities that do not have any.

Another issue is that for the early part of the study period, my only source of data is a 1995 road map from the Colombian geographical institute (Instituto Geographicó Agustin Codazzi) which is fairly sparse. More specifically, this map contains only 'principal' roads for which the mileage is limited.[16] For 2012, I use an official map of Colombian roads which contains all roads that essentially can be used by a truck (principal roads, secondary roads, and 'carriage' roads).

Table 8 reports results for a number of OLS specifications where the change in log municipal population between 1993 and 2010 is regressed on a road index for 1995 or for 2012. In line with previous tables, the more complete specifications control for log wages, the share of higher education, initial and past populations, and region indicators. This type of specification is close to those estimated in Duranton and Turner (2012). The estimated coefficient on roads, which can be loosely interpreted as an elasticity, is small but positive and significant in five specifications in eight. The three cases where this coefficient is insignificant are precisely estimated zeroes. Looking at the entire table, we can rule out positive elasticities of 5% or negative elasticities of 3%.

As noted by Duranton and Turner (2012) and many others, the provision of roads is likely to be simultaneously determined with other local characteristics, many of which are unobserved. To deal with this identification issue, I follow the same approach as Duranton and Turner (2012) and instrument contemporaneous roads with long lags of the road network. I also use the same strategy in Duranton (2015) when I examine the effects of roads on trade between Colombian cities. The instruments I use are from the 1938 road network and from the colonial road network ('caminos

[16]There are about 8,000 kilometers of principal roads reported for 1995. Although, they are called 'principal', there were barely any highways and expressways. A majority of these roads were single lane roads. They are probably better described as non-local roads. For the sake of comparison, France, which is about as big as the 'populated' part of Colombia, counts more than 400,000 kilometers of non-local roads.

Table 8: Changes in log population between 1993 and 2010 and roads, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population	0.064^a	0.13^a	0.16^a	0.054^a	0.10^a	0.053^a	0.10^a	0.12^a
	(0.013)	(0.038)	(0.049)	(0.013)	(0.038)	(0.014)	(0.038)	(0.041)
log wage		0.35^a	0.17		0.36^a		0.36^a	0.23^b
		(0.090)	(0.15)		(0.089)		(0.088)	(0.10)
Share educated		0.64^b	1.35^a		0.71^b		0.73^b	0.89^a
		(0.31)	(0.40)		(0.30)		(0.30)	(0.32)
Road Index	0.0100^b	0.0065	0.0039	0.015^a	0.015^a	0.021^a	0.023^a	0.021
	(0.0042)	(0.0040)	(0.016)	(0.0050)	(0.0048)	(0.0075)	(0.0071)	(0.013)
Past populations	N	Y	Y	N	Y	N	Y	Y
Regional dummies	N	Y	Y	N	Y	N	Y	Y
R^2	0.10	0.26	0.33	0.11	0.27	0.10	0.27	0.26
Municipalities	373	373	198	373	373	373	373	279

Notes: OLS regressions controlling for regional dummies and past population (1918, 1938, 1951, and 1964) in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variables of interest is a road index. In column 1-3, the index sums the log number of roads, log road length, and the log number of exits for 1995. The index is equal to -1 - log distance to the closest major road for municipalities with no roads. Column 3 considers only municipalities with roads. A similar index for 2012 is considered in columns 4 and 5. Columns 5 to 8 do not consider the distance to other roads for municipalities with no roads. Column 8 ignores municipalities with no roads.

reales'). Maps and more details about these historical instruments are provided in Duranton (2015). Because these two historical road networks were even sparser than the 1995 network of principal roads, I do not mirror with historical road data the indices I compute for contemporaneous roads. Instead, I simply use the length of historical roads in a municipality and the distance to the nearest road.

To be valid, this instrumenting strategy must satisfy two conditions. The first is that historical roads (or their absence in many places) must be a good predictor of contemporaneous roads conditional on the control variables. As can be seen from the first-stage statistics reported in table 9, the instruments we use are strong in some specifications, marginal in others, and weak in two specifications. The limited predictive power of old road networks must be acknowledged. Second, these instruments must be such that old road networks should be uncorrelated with the error term in the regression and influence current population growth only through the contemporaneous road network. This exclusion restriction is discussed at length in Duranton and Turner (2012).

When regressing changes in log population on instrumented roads without further controls, the

Table 9: Changes in log population between 1993 and 2010 and roads, IV specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population	0.039^c	0.10^b	0.12^c	-0.041	-0.031	0.0067	0.0034	-0.049
	(0.021)	(0.040)	(0.068)	(0.064)	(0.080)	(0.076)	(0.066)	(0.11)
log wage		0.34^a	0.17		0.36^a	0.36^a	0.36^a	0.40^b
		(0.091)	(0.15)		(0.10)	(0.095)	(0.095)	(0.18)
Share educated		0.57^c	1.79^a		0.90^b	0.84^b	0.93^a	1.70^a
		(0.32)	(0.52)		(0.36)	(0.34)	(0.34)	(0.57)
Road Index	0.026^b	0.026^b	0.10^b	0.073^b	0.072^b	0.056^b	0.086^a	0.12^a
	(0.011)	(0.012)	(0.051)	(0.035)	(0.028)	(0.027)	(0.032)	(0.045)
Instruments:								
1938 roads	Y	Y	Y	Y	Y	Y	Y	Y
Caminos reales	N	N	N	N	N	Y	N	N
First-stage stat.	20.2	16.1	7.83	6.77	6.39	4.10	8.50	4.26
Overid. p-value	0.68	0.20	0.38	0.38	0.75	0.67	0.88	0.72
Municipalities	373	373	198	373	373	373	373	198

Notes: LIML regressions controlling for regional dummies and past population (1918, 1938, 1951, and 1964) in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variable of interest is is a road index. In column 1-3, the index sums the log number of roads, log road length, and the log number of exits for 1995. The index is equal to -1 - log distance to the closest major road for municipalities with no roads. Column 3 considers only municipalities with roads. A similar index for 2012 is considered in columns 4, 5, and 6. Column 7 does not consider the distance to other roads for municipalities with no roads. Column 8 ignores municipalities with no roads. The two 1938 roads instruments are the distance to roads and the length of roads at that time. The same two measures are used for the colonial road instruments ('caminos reales').

exclusion restriction is unlikely to be satisfied for several reasons. For instance, richer cities today may have been able to obtain more roads in the past. More generally, cities with a better growth potential may have been provided with more historical roads. This is why controlling for past populations in all specifications of table 9 is fundamental. These controls will hopefully subsume all the characteristics that made cities grow over most of the 20th century, from 1918 to 1993. The IV specifications of table 9 also include a variety of other controls for wages, education, and regions.

The estimated coefficient on the instrumented road index varies between 0.026 and 0.12 with typically larger coefficients in more complete specifications or specifications using a greater sample of municipalities. Using a similar instrumenting strategy, Duranton and Turner (2012) estimate an elasticity of city population with respect to roads of about 0.15 over a 20 year time horizon. Hence, the effect of roads on population growth in Colombia appears to be slightly weaker than in the US but of a roughly similar magnitude.

As argued by Duranton and Turner (2012), the effects of roads on the population growth should be interpreted in light of standard urban models where urban roads facilitate travel within the city. This channel is arguably at play in US cities where interstate highways usually penetrate well inside the central parts of those cities. This is less obvious that major roads play such a role in Colombia. Road construction in Colombian cities sometimes involves the construction of a by-pass to avoid too much through traffic. As a result, the main roads of Colombia might not be as important to foster urban growth as in some other countries.

Another reason why roads might affect city population is through trade with other cities. In Duranton (2015), I use the same approach as Duranton *et al.* (2014) and present evidence that roads in Colombia foster trade. Cities with more roads export and import more, all else equal. While a full exploration of the infrastructure-trade-population growth nexus would go beyond the scope of this paper, preliminary steps can be taken by looking at the effects of market access on city population growth.

What constitutes a good access to market is more complicated than it first seems. The reason is that proximity to large cities implies a tradeoff. While large cities represent large markets with many potential customers, they are also tougher markets for which the presence of more producers will lead to lower prices. This occurs because of tougher price competition, the elimination of weaker firms, or a simple market crowding effect.[17] In practice, market access can be measured through a simple market potential index that sums the GDPs of a municipality's neighbours, discounting them by distance. Following Redding and Venables (2004), an alternative is to reconstitute a theory-consistent measure of market access using trade data. In models of economic geography in the tradition of Fujita *et al.* (1999), a simple gravity estimation of trade patterns allows one to recover a theory-consistent measure of market access despite the absence of price data for the goods being traded. This is the strategy followed in Duranton (2015). Here, I use both types of measures. Because the effect of market access is not expected to be linear, especially for the more ad-hoc market potential measures, I use both a log and its square in the regressions.

The results are reported in table 10. The first key feature that arises from this table is a negative relationship between the true measure of market access used in columns 1-4 and city population growth. When using a more ad-hoc measure of market potential in columns 5-8, the estimated effect is bell-shaped. This is likely to be a reflection of the faster growth of 'suburban' municipalities

[17] There is a large theoretical literature on market access. See Fujita, Krugman, and Venables (1999) for a starting point.

Table 10: Changes in log population between 1993 and 2010 and market access, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population	0.073[a]	0.064[a]	0.12[a]	0.090[b]	0.089[b]	0.080[a]	0.13[a]	0.090[b]
	(0.012)	(0.013)	(0.038)	(0.038)	(0.038)	(0.012)	(0.044)	(0.042)
log wage			0.34[a]	0.35[a]	0.34[a]		0.32[a]	0.32[a]
			(0.091)	(0.089)	(0.088)		(0.099)	(0.096)
Share educated			0.66[b]	0.71[b]	0.64[b]		0.90[a]	0.91[a]
			(0.31)	(0.30)	(0.31)		(0.32)	(0.32)
MA	-0.022	-0.057[b]	-0.047[c]	-0.033	-0.013	-0.015	0.13[c]	0.13[c]
	(0.023)	(0.029)	(0.028)	(0.028)	(0.030)	(0.0093)	(0.075)	(0.074)
MA^2		-0.020[a]	-0.017[b]	-0.014[b]	-0.019[a]		-0.0054[c]	-0.0052[c]
		(0.0076)	(0.0072)	(0.0072)	(0.0069)		(0.0029)	(0.0028)
Road Index				0.013[a]	0.017[a]			0.017[a]
				(0.0050)	(0.0051)			(0.0051)
Road × MA					-0.013[b]			
					(0.0063)			
Past populations	N	N	Y	Y	Y	N	Y	Y
Regional dummies	N	N	Y	Y	Y	N	Y	Y
R^2	0.09	0.10	0.25	0.27	0.27	0.10	0.28	0.31
Municipalities	363	363	363	363	363	311	311	311

Notes: OLS regressions controlling for regional dummies and past population (1918, 1938, 1951, and 1964) in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variables of interest is a measure of market access. In column 1-5, market access is measured in a theoretically consistent was and estimated as in Duranton (2015). In columns 5-8, it sums municipal GDP in 2009 across all neighbouring municipalities discounting by the road distance between municipalities. The road index is as in the previous two tables for 2012.

adjacent to the largest urban centers in the country.

A negative effect of market access on population growth might seem puzzling. This could nonetheless be consistent with the two key results obtained so far. First, in Duranton (2014*b*) I show that wages are lower in municipalities with better market access. This fact can be easily rationalised if a better market access predominantly affects the price of local goods. Cheaper local goods must then imply lower nominal wages if some form of real wage equalisation. Second, we show above that population growth occurs predominantly in more vibrant local labour markets. It is possible to imagine that Colombian workers might be lured predominantly by job market opportunities and high nominal wages rather than places with high market access that offer lower nominal wages and a lower cost of living. While this explanation is arguably speculative, the stronger conclusion to be drawn from table 10 is that the OLS coefficient on roads is unchanged by the introduction of market access variables in the regression. This is a useful check on the robustness of their effect and an indication that roads are likely to matter predominantly because of local travel rather than inter-city trade.

From the broad exploration of the determinants of city growth conducted in this section, the main takeaway result concerns to the importance of roads. There are further suggestions that city roads matter because they facilitate travel within cities. Two secondary results relate to the importance of natural resources, and particularly oil, and of local criminality. Interestingly, two of these three results reinforce the conclusions drawn from section 4 highlighting the importance of viewing Colombian cities as local labour markets. This is because oil is a key determinant of the demand for labour in the municipalities where it can be found and because easier travel within a city will benefit to commuters going to work.

6. Long-run growth of cities in Colombia

Although a lot of the municipal data used so is for the late 20th and early 21st century, municipal population data in Colombia is available since 1843. The roads instruments used above also go back to the colonial (or even pre-colonial) era. Together with information about resources and natural geography, this allows us to have a peek at the long-run determinants of urban growth in Colombia. Given data limitations, this analysis of the long-run growth of Colombian cities should be viewed as even more tentative than the analysis conducted so far.

Panel A of table 11 report results for population growth between 1938 and 2010. Because past populations dating back to 1843 (used as controls in columns 2-8) are not available for many (smaller) municipalities, the sample size here is about 30% smaller than in the tables above. The specifications in panel B examine an even longer time period, 1870-2010 for columns 1-5 and 1843-2010 for columns 6-8. As Colombia became independent in 1819 and 1843 is arguably its first usable census, these specifications cover most of the history of modern Colombia.

Four main results emerge. The first regards mean-reversion in population across municipalities. While there is evidence above of some population divergence over 1993-2010, there is neither convergence nor divergence over the longer time period of 1938 to 2010. Interestingly, there is strong mean-reversion if we go back to 1870 or 1843. These results are consistent with the notion that the Colombian population first spread across the country with the expansion of its agricultural

Table 11: Long-run changes in log population, OLS and IV specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: 1938-2010								
log 1938 population	0.080	0.22	0.27^c	0.12	0.051	-0.25	-0.36	-0.38^c
	(0.092)	(0.17)	(0.16)	(0.16)	(0.15)	(0.24)	(0.23)	(0.23)
Altitude		-0.71^a			-0.84^a		-1.15^a	-1.13^a
		(0.27)			(0.25)		(0.34)	(0.35)
Altitude^2		0.17^b			0.21^a		0.31^a	0.31^a
		(0.083)			(0.077)		(0.11)	(0.11)
Water		0.67^b			0.78^b		1.07^a	1.10^a
		(0.33)			(0.30)		(0.39)	(0.39)
Precipitation		-0.27^a			-0.22^a		-0.079	-0.069
		(0.081)			(0.075)		(0.11)	(0.11)
Coal			0.12					0.080
			(0.15)					(0.16)
Gold			0.022					-0.032
			(0.14)					(0.20)
Oil			0.15					0.076
			(0.15)					(0.21)
Roads				0.14^a	0.12^a	0.45^a	0.43^a	0.44^a
				(0.024)	(0.024)	(0.16)	(0.14)	(0.14)
R^2	0.00	0.25	0.20	0.26	0.33	-	-	-
First-stage stat.						6.74	6.25	6.06
Municipalities	373	260	260	265	260	265	260	260
Panel B: 1870-2010 and 1843-2010								
log initial population	-0.40^a	0.040	-0.043	-0.081	-0.088	-0.56^a	-0.47^a	-0.42^a
	(0.13)	(0.20)	(0.25)	(0.24)	(0.20)	(0.15)	(0.17)	(0.15)
Altitude		-1.02^a			-0.73^b			-0.94^b
		(0.33)			(0.34)			(0.41)
Altitude^2		0.19^c			0.12			0.18
		(0.10)			(0.10)			(0.12)
Water		1.29^a			1.23^a			1.46^a
		(0.38)			(0.38)			(0.40)
Precipitation		-0.28^a			-0.26^a			-0.28^a
		(0.094)			(0.091)			(0.093)
Coal			0.011		0.057			0.23
			(0.18)		(0.17)			(0.18)
Gold			0.29^c		0.094			0.18
			(0.17)		(0.16)			(0.18)
Oil			0.54^a		0.44^b			0.73^a
			(0.19)		(0.21)			(0.22)
Roads				0.10^a	0.095^a		0.10^a	0.095^a
				(0.026)	(0.026)		(0.029)	(0.027)
R^2	0.05	0.39	0.32	0.31	0.43	0.11	0.28	0.42
Municipalities	309	261	261	266	261	276	276	271

Notes: OLS regressions (columns 1-5 in panel A and all columns of panel B) and LIML regressions (columns 6-8 of panel A). All specifications except for those of columns 1 control for regional dummies and past population (1843, 1851, 1870, and 1912 in panel A and 1843 and 1851 in columns 2-5 of panel B). Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1938 and 2010 in panel A, between 1870 and 2010 in columns 1-5 of panel B, and between 1843 and 2010 in columns 6-8 of panel B. The road index is as in table 8 using 1938 data (panel A) or colonial-era data (panel B).

frontier but then, in the more recent past, started to concentrate more in its largest cities. As already noted, this movement of spatial concentration goes well beyond the emerging primacy of Bogotá in the Colombian urban system.

Second, there is strong evidence of a role for natural geography in the long-run. This role is limited to non-existent for the recent past, as shown in table 7. Since 1938 and prior to this, the availability of water matters a lot. There is a also a negative association between long-run population growth and precipitation. Interestingly, the effect of altitude is non-linear. Population growth is minimum in panel A at about 2,000 metres. Even for high-altitude cities like Bogotá and Tunja (at 2,600 and 2,800 meters respectively) the effect remains strongly negative relative to coastal cities.

Third, the evidence in favour of natural resources is mixed. As we saw above, among natural resources only oil appears to play a role over 1993-2010. I do not observe any effect of any natural resource over 1938-2010. Over an even longer time horizon, there is evidence of an association with the presence of oil, and perhaps gold. This result regarding oil since 1870 or even 1843 is arguably spurious as the Colombian oil industry has been active for no more than 40 years. It illustrates the limitations of the exercise conducted here. These positive coefficients on oil are probably due to the peripheral locations of oil fields in Colombia. Hence, positive coefficients on oil are likely to capture the long-run patterns of settlement of the country.

Finally, we measure a positive effect of roads. For 1938-2010 population growth, the OLS elasticity with respect to 1938 roads is slightly above 0.10. When instrumenting 1938 roads with colonial roads, the estimated elasticity of population with respect to roads jumps to between 0.40 and 0.50. This increase must be in part caused by the poor measurement of 1938 roads that is improved by instrumenting. In panel B, colonial roads are directly used as an explanatory variable. They are significant again with a coefficient of about 0.10. Again, measurement issues prevent us from reading too much into these magnitudes but it remains that roads appear to exert a long-run effect on population growth in Colombia.

7. Conclusion

While extant research on city growth mostly focuses on one determinant or another, this paper has taken a broader and more comprehensive approach to this question by considering a broad array of determinants of city growth. The main potential drawback of doing this is that the effect of each factor may not be as persuasively identified as in the best 'one-factor' studies. Although it must be acknowledged that the causal interpretation of some of the results derived here remains tentative, I have tried to minimize this problem by following the best practice defined by leading one-factor studies of city growth.

Against this possible drawback, the main benefit of the approach taken here is threefold. First, the whole is more than the sum of its parts. Having established that labour mobility across cities in Colombia is far from perfect allowed us to assess how the Colombian population gradually moves to cities offering higher wages. In turn, we could trace these higher wages back to labour market shocks. In turn, this suggests that Colombian cities are best characterised as local labour markets. Those that prosper and demand more labour grow in population. Second, this approach also allows for a more nuanced appreciation of city growth. While being a dynamic local labour market is the first-order determinant of city growth, it is not the only one: education, crime, and the ease of travel also play a role. Third, some of the key conclusions can be supported by a variety of results instead of only one. For instance, the fundamental role of cities as labour markets could be evidenced directly through wages and labour market shocks but also indirectly through the attenuation of the effect of city education when controlling for wages or the general lack of evidence about amenities.

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Appendix: Further results

Table 12: Changes in log population between 1993 and 2010 and changes in wages, OLS and IV specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population		0.073^a	0.078^a	0.23^a	0.22^a	0.23^a	0.17^b	0.22^a
		(0.018)	(0.019)	(0.048)	(0.053)	(0.048)	(0.065)	(0.046)
Δ log wage	-0.086	0.039	0.048	0.041	0.39^c	0.020	0.066	0.33
	(0.18)	(0.17)	(0.18)	(0.17)	(0.22)	(0.11)	(0.24)	(2.09)
Past populations	N	N	N	Y	Y	Y	Y	Y
Location dummies	N	N	Reg	Reg	Dpt	Reg	Reg	Reg
R^2	0.00	0.11	0.15	0.34	0.47	0.34	0.30	.
Municipalities	108	108	108	108	108	108	66	107
Wage	FE	FE	FE	FE	FE	mean	FE	FE
First-stage stat.								0.22
Overid								0.87

Notes: OLS regressions with a constant in columns 1-7. TSLS regression in column 8. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variable of interest is as follows: the change in wage estimated as a municipal fixed effect in all columns but 6 where the change in mean wage is used. The change is computed between 1996-2001 and 2008-2012. Only large municipalities are considered in column 7. The instruments in column 8 are Bartik employment growth over 1990-2005 at the 3 and 4 digit.

Table 13: Changes in log population between 1993 and 2010 and urban costs, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population	0.14^a	0.14^a	0.15^c	0.15^c	0.16^b	0.17^b	0.14^c	0.15^b
	(0.037)	(0.038)	(0.079)	(0.079)	(0.077)	(0.075)	(0.072)	(0.071)
log wage	0.32^a	0.32^a	0.14	0.14	0.16	0.18	-0.091	-0.0070
	(0.066)	(0.065)	(0.15)	(0.15)	(0.15)	(0.15)	(0.16)	(0.16)
Development ratio	0.0013							
	(0.027)							
log development ratio		0.059						
		(0.048)						
FAR 2005			-0.20					
			(1.03)					
FAR 2012				-0.095				
				(0.91)				
log FAR 2005					-0.013			
					(0.024)			
log FAR 2012						-0.025		
						(0.023)		
log dwelling value per m2 2005							0.20^b	
							(0.080)	
Dwelling value per m2 2005								0.78^c
								(0.44)
R^2	0.23	0.23	0.27	0.26	0.27	0.27	0.37	0.33
Municipalities	368	368	81	81	81	81	85	85

Notes: OLS regressions with controls for past populations and regions in all columns. TSLS regression in column 8. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. Floor to area ration (FAR) is calculated as average dwelling area times number of dwellings divided by area. Development ratio is the fraction of built-up and paved urban land.

Table 14: Changes in log population between 1993 and 2010 and inequality, local governments, and stated quality of life, OLS specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log 1993 population	0.13[a]	0.13[a]	0.12[a]	0.13[a]	0.11[a]	0.096[b]	0.14[a]	0.13[a]
	(0.039)	(0.039)	(0.038)	(0.038)	(0.039)	(0.038)	(0.038)	(0.038)
log wage	0.34[a]	0.35[a]	0.29[a]	0.35[a]	0.35[a]	0.29[a]	0.36[a]	0.34[a]
	(0.092)	(0.091)	(0.095)	(0.090)	(0.089)	(0.092)	(0.090)	(0.091)
Share educated	0.72[b]	0.70[b]	0.12	0.54[c]	0.45	0.31	0.66[b]	0.61[c]
	(0.31)	(0.31)	(0.36)	(0.31)	(0.31)	(0.35)	(0.31)	(0.31)
Inequality	0.066	0.13						
	(0.14)	(0.14)						
Quality of life			0.56[a]					
			(0.21)					
Local government				0.23[c]	0.37[b]	0.87[a]	-0.025	0.17
				(0.13)	(0.15)	(0.34)	(0.087)	(0.16)
R^2	0.23	0.24	0.27	0.26	0.26	0.29	0.25	0.25
Municipalities	368	368	373	373	373	373	373	373
Local characteristic	Gini Land val.	Gini land area		Overall perf.	Admin. efficacy	Fiscal perf.	Admin. capacity	Mgt process

Notes: OLS regressions with controls for past populations and regions in all columns. Robust standard errors in parentheses. *a*, *b*, *c*: significant at 1%, 5%, 10%. The dependent variable is the change in the log of population between 1993 and 2010. The explanatory variable of interest is as follows: gini index for land values in column 1, gini index for land area ownership in column 2, stated quality of life in 1993 in column 3, a measure of overall municipal performance in column 4, a measure of municipal efficacy in column 5, a measure of fiscal performance in column 6, a measure of administrative capacity in column 7, and a measure of municipal management processes in column 8.