Infrastructure Spending as a Path to Development: An Analysis of Latin America

Juan Andrés Malaver[a]
[a]Department of Economics, University of Minnesota - Twin Cities

Abstract

Endogenous growth theory outlines the effects of capital and labor on growth and productivity. This is reviewed in this paper with a focus on infrastructure as a key driver of capital endowment and promoter of productivity. In Latin American countries, this effect is mostly observed through the indirect impact on total factor productivity by the integration of markets and increasing returns to scale. The importance of Latin American economic history and the adherence to specific economic ideologies towards the end of the 20th century is emphasized. This paper focuses on the contribution that infrastructure investment has on labor productivity using distributed lag models with time series data from 1994 to 2018. The results suggest that countries that are closer to their Solow steady state do not benefit significantly from increases in infrastructure investment as countries that are in earlier stages of economic development. Policymakers should consider the developmental context of their economy when deciding to prioritize public expenditure towards specific industries and projects.

Keywords: infrastructure investment, labor productivity, endogenous growth, distributed lag models

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Introduction

Infrastructure is a cornerstone of modern economies, providing the tools for global supply chains to function efficiently. Economists and politicians tend to agree on the importance of infrastructure for economic development. Around the end of the 20th Century, a set of standardized economic reforms known as the Washington Consensus was being promoted by Washington D.C. institutions. As a result of neoliberal economic policies being popularized in emerging economies during the post Washington Consensus era, the significance of infrastructure investment within public and private expenditure has increased. No longer does the state take the burden of full investment in these assets, as the private sector has increasingly participated in the funding and construction of major infrastructure projects (Fay et al., 2017). This is especially true in Latin America, a region that reluctantly embraced free-market ideals some decades after North America or Asia did. Infrastructure investment and quality is relatively weak for many Latin American countries, as various bureaucratic, geographical, and financial obstacles have impeded the acceleration of infrastructure development. Nevertheless, the importance given to infrastructure as a path towards development both by academics and policymakers has become somewhat of an obsession in the region. How do different levels of infrastructure spending influence labor productivity? This paper will attempt to answer this question with a cross-sectional analysis using data from four major Latin American countries: Mexico, Colombia, Peru, and Brazil.

Latin American infrastructure schemes can be roughly separated into two categories: early 20th century projects that were likely sponsored by the United States or the United Kingdom, and more recent projects that stem from neoliberal policies, the latter of which generated widespread but not uniform increases in foreign direct investment. Neoliberalism advocates for free-market economies that do not overly depend on government intervention. From 1940 onwards, Latin American economists generally favored the ideas of structuralism and Import Substitution Industrialization, which supported economic isolation from foreign nations, and an increased presence of central government in the financing of public infrastructure (Reid, 2017). The region experienced slow and stable development for some decades until the debt crises of the 1980s, when various fixed currency regimes were confronted with sharp devaluations, making public debt unsustainable. Unable to finance investment projects, governments reluctantly accepted conditions from the International Monetary Fund in exchange for financial bailouts. These conditions aligned with the ideals outlined in the Washington Consensus (Armendariz & Larrain, 2017). As Latin American countries began embracing the free market, the private sector began taking over the business of infrastructure financing, construction, and operations. Major projects also attracted increasing amounts of foreign investment towards the turn of the century. As a result, the quantity and quality of infrastructure increased, leading to regional integration and introducing citizens to modern networks of infrastructure.

Developed economies in North America, Europe, and more recently Asia began investing in infrastructure at least 20 years before Latin America prioritized it in their policies. These regions benefitted from long-term positive effects on their economic growth due to their infrastructure development. Latin America, therefore, has a significant infrastructure gap with richer nations. An empirical analysis can reveal the effects of improving Latin American infrastructure on indicators of development. There is reason to believe that better infrastructure has a positive effect on productivity, since better networks of transportation, telecommunications, or energy improve labor conditions and the rate at which workers produce (Aschauer, 1989). In emerging economies, the effect can be substantial, since better access to these services can lower marginal costs for a variety of industries and generate previously inexistent economies of scale in domestic industries. While the effects on marginal costs are more immediate, an aggregate consequence may lead to higher rates of economic growth (Servén & Calderón, 2010). Improved infrastructure can also increase aggregate supply through lower input costs and aggregate demand through cheaper transportation and telecommunications. Likewise, improving technological access for citizens through better infrastructure enhances social mobility, which could lower income inequality in the long-term. This paper will look at the effect of infrastructure spending on labor productivity in the last three decades, a time frame that encompasses Latin America's heterogeneous shift towards neoliberal reform.

Data Selection

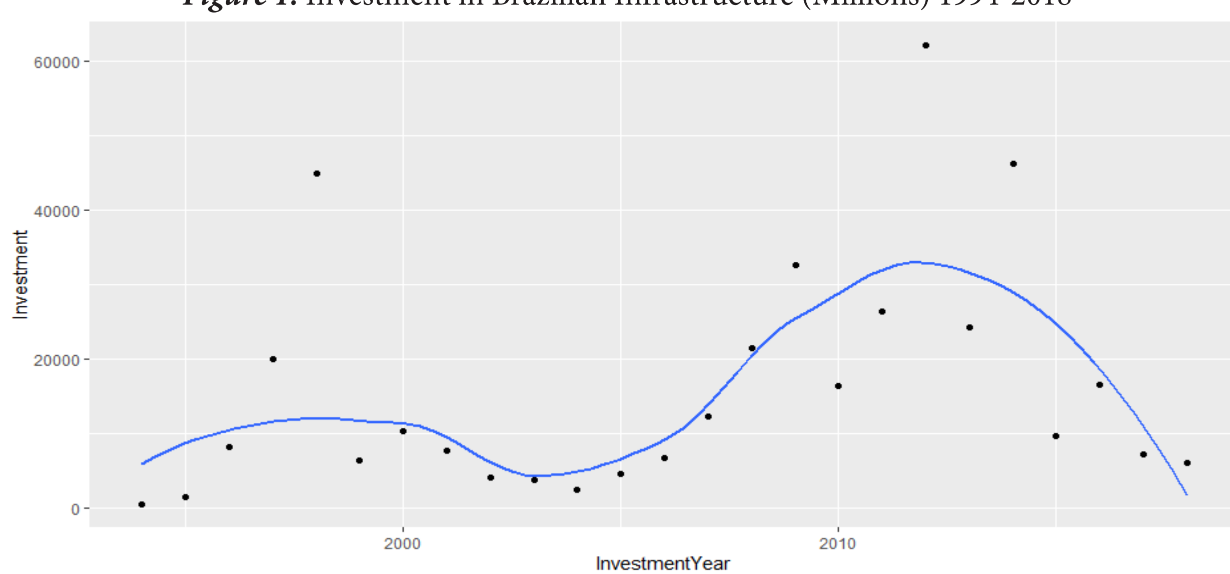
The main source for the data in this paper is the World Bank Private Participation in Infrastructure Database (PPI), which includes information on the total investment in infrastructure projects for the Latin American countries considered from 1990 – 2019. The analysis will use country-specific data, since not all economies are the same size and develop at the same rate. Smaller economies tend to have fewer and infrequent major infrastructure projects. Infrastructure itself can also be separated by sectors such as energy, transportation, and telecommunications. The basis for classifying infrastructure projects comes from Lanau (2017), who developed a model for positive growth returns as a result of improved infrastructure by sector in Latin America. Nonetheless, I chose to not divide the regressors of infrastructure investment by sector because the time series data would not be equispaced and thus more difficult to construct a model with. The variables considered will also be standardized to US dollars to account for disparities in exchange rates, which prove to be quite volatile for the countries analyzed.

Aschauer (1989) was one of the first papers to find a positive relationship between infrastructure and economic growth, focusing on the effects that infrastructure stock had on total factor productivity. Although the results have since been disputed by academics, it laid the groundwork for incorporating the concept of infrastructure into macroeconomic analysis. The objective of this paper is to study the variation in productivity using various inputs, known as regressors. The main regressor will be infrastructure investment, which has a direct effect on public and private capital, and the response will be labor productivity, which can be derived as the ratio of GDP and the total labor force for a given year. In addition, some control variables are considered to account for the macroeconomic trends that these countries underwent in the period considered. These include measures of trade openness (trade volume as a % of GDP), price stability (inflation rates), government burden (% of GDP), and income growth rates (GDP per capita). This allows for a robust long-term analysis like that of Teles and Mussolini (2012), but in a modern context. These authors were unable to find a relationship between infrastructure and growth in the mid-20th century, but my analysis begins in 1990, a moment when Latin American countries were adopting neoclassical development strategies outlined by the Washington Consensus. Part of these reforms sought to increase private investment in the infrastructure sector from negligible levels to the driving force of development in these kinds of projects, an important transition that Calderón and Servén (2010) point out when they find positive correlation between infrastructure and growth and a negative correlation for inequality in Latin American countries between 1995-2006.

Labor productivity is a viable response because I am using investment as the independent variable, which incorporates capital input, thus accounting for endogeneity in the regression model. Total factor productivity, meanwhile, includes both capital and labor inputs. Choosing infrastructure investment as a regressor is a different approach from the literature that measures infrastructure on physical aspects like power consumption, road network length, and telephone lines. Instead, my approach incorporates the financial aspect of infrastructure schemes, which highlights the role of the private sector in modern Latin American infrastructure.

Figures 1 and 2 show the trends in infrastructure investment from 1994-2018. All investment figures are in millions of US dollars during the year of investment in real terms, adjusted for world consumer price indices. The smooth splines are fitted using locally estimated scatterplot smoothing (LOESS). Brazil is plotted separately because absolute levels of investment are disproportionately higher than the other countries, overshadowing individual trends. Except for Mexico, which has seen a consistent upward trend in infrastructure investment, all countries showed signs of increasing investment levels in the 1990s and 2000s, followed by slowdowns in the 2010s. Figure 3 shows the general trends in the proportion of total projects that are considered public-private partnerships (PPPs). Brazil and Mexico show high proportions of PPPs over all infrastructure projects since the 1990s, while Colombia has a quadratic trend, and Peru has a positive linear trend. This variable is not the percentage of projects that have private investment but rather the proportion that have both public and private funds. The PPI database only has information on this variable. To know the proportion of public and private investment respectively, one would need to turn to a more specialized dataset like that of Calderón and Servén (2010), though the dataset used by these authors does not extend into the 2010s. Figure 4 shows the time-series of labor productivity for the four countries. This plot separates the countries into two categories: the relatively larger and more developed economies of Brazil and Mexico that have shown generally higher productivity, and the mid-size developing economies of Colombia and Peru that have shown signs of increasing productivity in the timeframe considered. The effect of infrastructure on productivity has an inevitable lag since investment is only the initial step. Construction may last several years, and the subsequent effects could accumulate over

Figure 1: Investment in Brazilian Infrastructure (Millions) 1994-2018



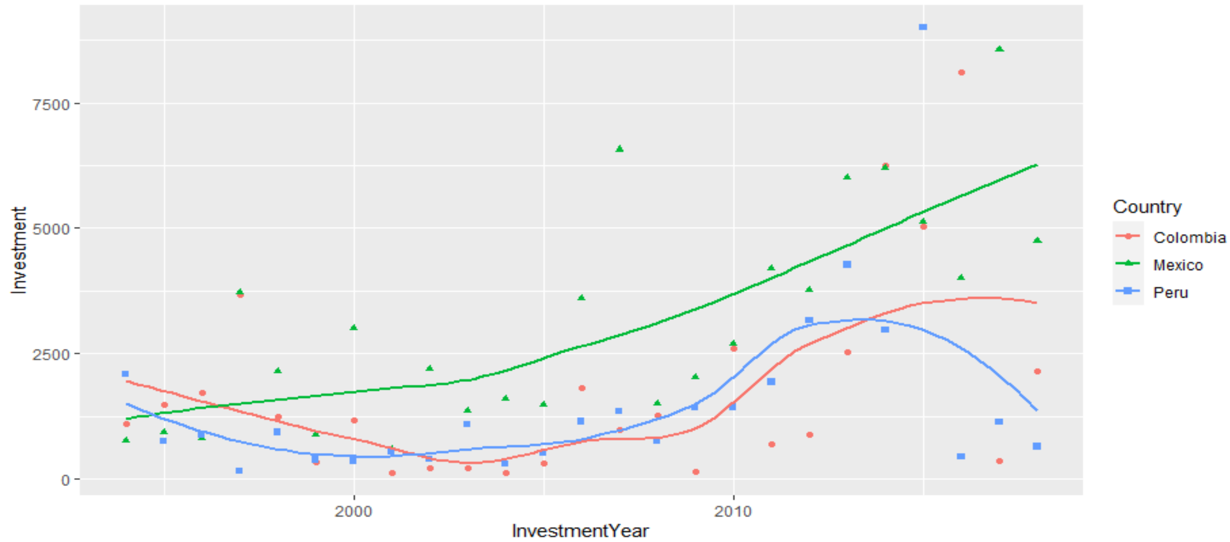


Figure 2: Investment in Latin American Infrastructure (Millions) 1994-2018

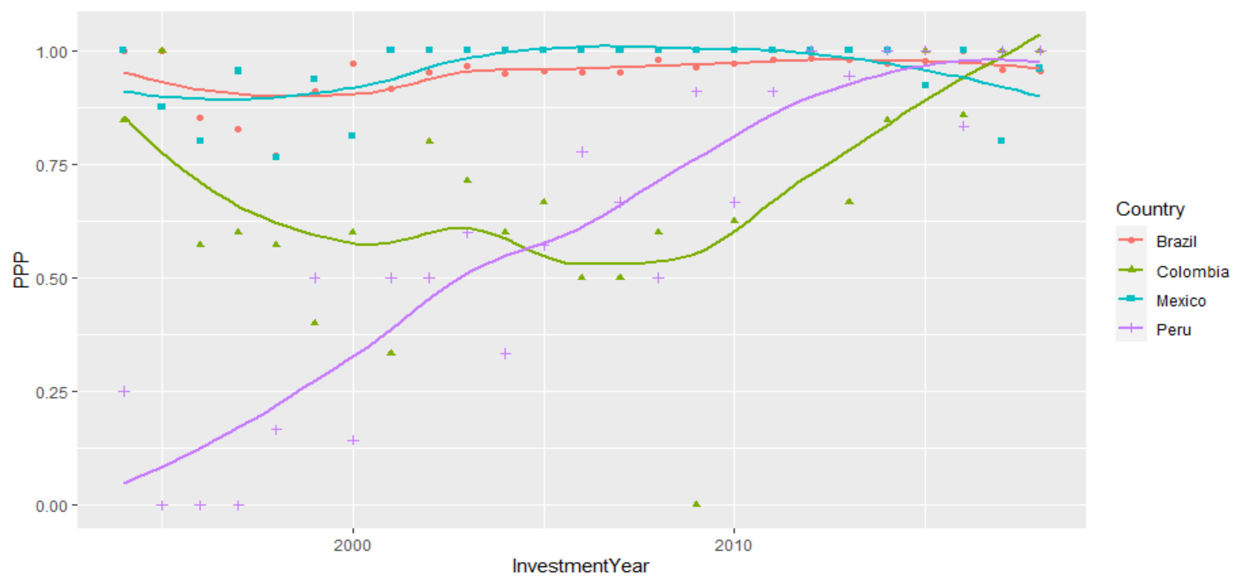


Figure 3: Proportion of Public Private Partnership Projects 1994-2018

decades. Even so, the PPI database records projects of all sizes, so the length of the lag could vary for different projects. This will be explored more in depth in the empirical analysis of the paper.

Literature Review

The transition from state-led growth to an embrace of the private sector at the end of the 1980s was a pivotal moment in Latin American economic development. Since the 1950s, the region had experimented first with structuralism and Import Substitution Industrialization, which meant high tariffs and global isolation. These policies sought to develop industrialized sectors of the economy. In the 1970s, this translated into dependency theory, a socioeconomic ideology that attributed the dependency on commodity markets of Latin American nations to the global hierarchies of economic development, usually blaming North America and Europe as the perpetrators of this world system. Relying on public debt to finance development projects in the 1970s as well as maintaining an overvalued fixed currency system led to several crises in the 1980s, when various countries defaulted on sovereign debt and suffered recessions. To

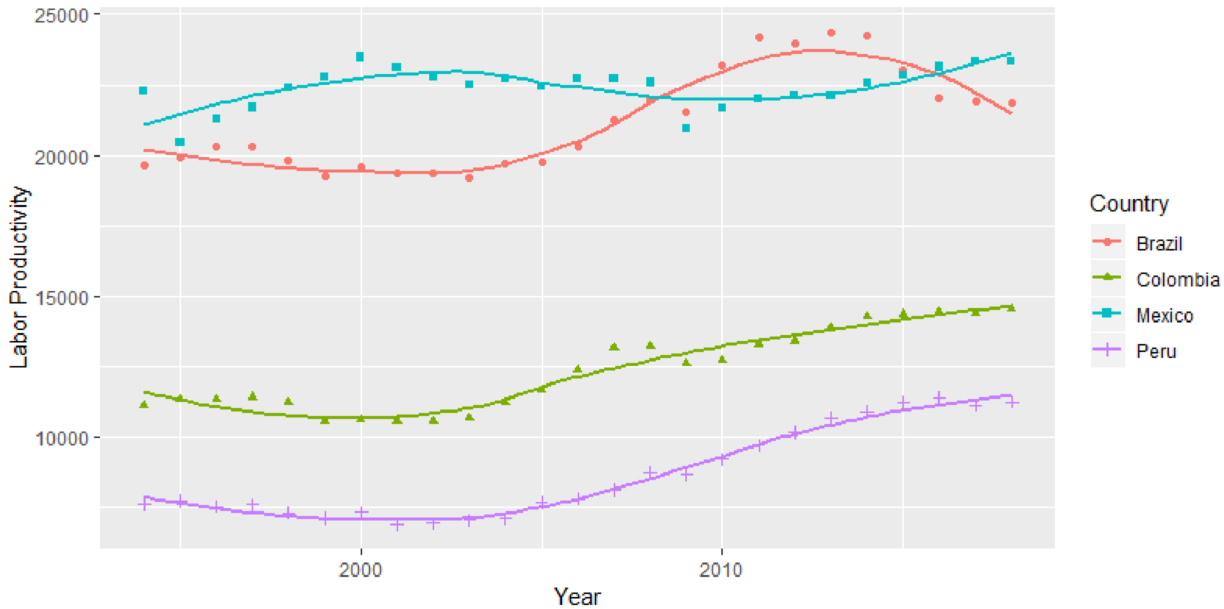


Figure 4: Latin American Labor Productivity (GDP per worker) 1994-2018

recover from these downturns, adjustments were needed, and a paradigm shift ensued. With the support of the World Bank and the IMF, Latin America looked to the free market and the private sector for the new models of development, often coined as neoliberalism. Yet these fiscal adjustments, which mostly consisted of a public sector withdrawal, often cut spending on important investments that would have otherwise boosted growth at the turn of the century. As a result, growth in the 1990s and 2000s was driven mostly by commodity exports rather than structural changes. The lack of long-term planning in many countries led to large reductions in the amount and scale of infrastructure projects. Latin America lags behind most of the developing world in terms of infrastructure, especially in transportation. The region is usually compared to fast-growing East Asian countries like Japan and South Korea that developed their infrastructure at exceptional speeds during a time when Latin America encountered bureaucratic, geographical, and ideological obstacles. One only needs to look at the latter half of the twentieth century to see how Latin America was superseded by other developing regions and why it was important to outline the essential factors of infrastructure-led growth models.

There were several studies at the beginning of the century to explain the limits, obstacles, and trends of infrastructure in Latin American economies. Easterly and Servén (2003) compile a volume of works with the support of the World Bank that highlight the pros and cons of a deliberate decrease in public infrastructure investment and an unexpectedly low private participation in some subsectors. The conditional reforms imposed by multilateral development organizations in return for financial bailouts often put limits on fiscal deficits. In order to meet these quotas, governments frequently decreased infrastructure investment, which was a short-term budgeting solution that had negative effects on long-term growth. The studies in this book hope to convince policymakers that intertemporal perspectives which go beyond

***Table 1*:** Summary of Data

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Investment	100	5,654.639	10,060.680	113.500	879.750	6,041.580	62,256.270
PPP	100	0.796	0.268	0	0.7	1	1
Labor Force	100	41,991,329	30,040,962	9,224,263	16,870,072	59,033,904	105,542,232
GDP Per Capita Growth	100	2.000	2.961	-7.832	0.279	3.640	10.221
Inflation Rate	100	28.402	206.999	0.193	3.529	7.628	2,075.888
Gov. Exp.	100	14.146	3.812	8.120	11.021	18.565	22.161
Trade Volume	100	40.337	14.402	15.636	29.529	50.259	80.448
GDP Per Capita	100	7,419.567	2,552.873	2,947.027	5,087.655	9,379.001	11,993.490
GDP (2010 USD)	100	819,987,780,291	735,320,916,608	70,290,744,142	187,541,250,000	1,315,905,000,000	2,423,270,000,000
Labor Prod.	100	16,166.780	6,001.601	6,906.536	10,848.690	22,058.890	24,378.440

political administration tenures are crucial to promoting fiscal solvency and allocating more resources to infrastructure. A more forward-looking approach is done by Fay and Morrison (2007), in which the components of infrastructure development with the highest potential in Latin America are highlighted. These components include: higher investment in infrastructure, which is below world average; better-targeted spending in more productive sectors; collaboration between public and private sectors to set countrywide objectives; and controlling investment risk by improving the framework and image of private participation.

With the advent of modern data collection methods and a general interest in constructing development models, econometric studies on infrastructure in Latin America have reinforced the industry as an essential component of regional prosperity. Calderón and

and Servén (2010) conduct an extensive empirical analysis on the role of infrastructure in Latin American development. The authors construct a regression model to analyze the relationship between infrastructure quantity and quality and macroeconomic indicators of development. Using instrumental variable methods, they find a positive relationship between their infrastructure index and economic growth, in addition to a negative relationship between the infrastructure index and income inequality. They expand on these conclusions by looking at the roles of public and private sectors in Latin American infrastructure. Private participation in infrastructure investments for the region was the highest in the world between 1996-2003 by a wide margin, which underlines the emphasis that governments gave to the private sector during the years of post-debt-crises fiscal reforms. The conclusions of the authors agree with Easterly and Servén (2003), in which the focus of fiscal consolidation was wrongly placed on fiscal liquidity rather than fiscal solvency, which resulted in lower infrastructure development and economic slowdowns throughout the region. Nevertheless, the private sector has continued to play an important role in infrastructure investment, as highlighted by Fay et al. (2017) in their report. These authors argue not necessarily for higher levels of spending, but rather for smarter ways to spend. Electricity has seen successful developments in Latin America, as it is one of the cleanest in the world, relying mostly on hydroelectricity. Likewise, telecommunications have been absorbed by an efficient private sector, and coverage is slowly becoming universal. Water utilities are stable but have room for improvement, especially in terms of sewage and wastewater treatment. It is transportation that suffers the most from underdevelopment, as seen by Latin American cities being some of the most congested in the world with a significant number of isolated rural areas in all countries. To show the importance of infrastructure in economic development, and to conduct a study based on this premise, theoretical econometric approaches that analyze the effects of infrastructure using Latin American time series are crucial. This is done in the first half of Calderón and Servén (2010) and exclusively in Lanau (2017), in which the author looks at the growth return of infrastructure by measuring the effects of infrastructure subsectors on GDP growth. The largest economies in the region have an infrastructure quality below the world median of the countries in the study. A frequently cited example in the paper states that if Colombia improved to this sample median, GDP growth would increase at least 0.1% and investment would increase 0.43%. Compounded across time, and accounting for derived effects of improved infrastructure in productivity, inequality, and competitiveness, one can see the potential for Latin American economic development based on calculated investment strategies.

The seminal paper by Calderón and Servén (2010) uses instrumental variables in their analysis because the regressors were stock variables of infrastructure (such as kilometers of roads, length of telephone lines, etc.), but this data is not available for the countries in recent years. Instead, investment is the main regressor in this analysis, so the response is treated as a time series and the model is chosen accordingly. Infinite distributed lag models are more appropriate when trying to find relationships investment regressors and their effects on macroeconomic indicators (labor productivity in this case).

Theory

Classic macroeconomic theory encompasses the effects of infrastructure on growth and productivity. This was the starting point for the first papers that were published on infrastructure. The AK model defines production using a Cobb-Douglas function:

$$Y=AK^{\alpha} L^{(1-\alpha)}$$

Where Y is output, K is capital, L is labor, A is a measure of total factor productivity, and α is a model parameter. More recent economics literature, such as that of Nobel laureate Paul Romer, considers A *t*o be endogenous in the model. This is important because increases in productivity have been shown to be a better indicator of long-term economic growth, rather than increases in the primary production factors. In this sense, infrastructure can increase output both by acting as a factor of production in the form of capital and by indirectly influencing productivity through the generation of structural changes in allocative efficiency and the reorganization of production methods.

This paper follows the idea of endogenous growth models, because improvements in infrastructure allow more access to efficient technologies that firms are interested in investing in. This creates economies of scale and knowledge spillovers that push economies closer to their technological frontiers and thus a steady state in the Solow model. The distance to the frontier can depend on multiple factors, such as political interests, integration into the world economy, and education levels. There is also an implication that it is easier to increase productivity from lower initial levels than to increase it for an economy that is closer to its steady state. The production function can be restructured to consider how infrastructure investment can influence growth rates:

$$y=f(k,kpub)$$

Where y is output per worker (labor productivity), k is capital per worker, and $kpub$ is public capital per worker. Such an equation is a special case of the AK model, where the Cobb-Douglas parameter α=1. This leads to the assumption that output is linear in capital, so that increases in capital result in constant returns to scale. This is the basis of the transformation done on the infrastructure variables: they are divided by the labor force. Public investment has a limited effect on output since the funds needed to finance projects must be acquired through taxes that disincentivize consumption. Private capital does not have this characteristic, which is why a transition from public to private predominance in Latin American infrastructure acted as a pivot on the effects it would have on labor productivity, even if the transition was not as significant as policy reformers hoped for initially.

Such a model does not focus on the direct effect that increases in capital will have on the variable A, total factor productivity, but instead focuses on the indirect effect it will have through integrated markets and increasing returns to scale. This paper considers both direct and indirect efforts on productivity but focuses mostly on the indirect impact. This is not because Latin America is a developed region, but because the countries considered are upper-middle-income economies that, despite having significant infrastructure deficits, are much closer to their steady state than smaller and poorer Latin American nations. In other words, Brazil, Colombia, Peru, and Mexico are relatively mature economies by Latin American standards since they are more integrated into the world economy and have already established an infrastructure network. Nonetheless, these networks can still be improved. For some countries, this might mean expanding the network itself, while for others still, it might involve more institutional changes that seek to increase the efficiency at which these networks are used.

This is related to convergence theory, which states that low-income economies grow at faster rates than high-income countries. This is certainly true for East Asian economies towards the end of the 20th century, but Latin America's story may be more nuanced. Larger Latin American nations are not considered low-income economies, so the increases on labor productivity are not as pronounced as they would be for poorer nations. These countries have already increased capital stocks to a point where diminishing returns are observable. This means that they are closer to their steady state. Even within the countries analyzed, Brazil and Mexico seem to be closer to their steady state than Colombia and Peru, as shown by the productivity time series plot. There is also a geographical factor that is crucial in understanding this difference. Colombia and Peru are countries that lie on the Andes mountain range, which is exceptionally difficult to transverse across and poses problems to large-scale infrastructure projects. Compare this to Mexico's flatter (yet more arid) terrain and Brazil's focus on coastal development. Brazil also has little incentive to expand their network inland since the rainforest poses another physical barrier that is difficult to get across and spikes controversy.

The returns of infrastructure investment tend to be higher when the amount of initial infrastructure capital is relatively scarce. This is because the marginal benefit of new infrastructure has a compound effect on labor productivity, giving industries the groundwork to produce at more efficient rates. When economies reach more developed states, the returns in infrastructure are not as high, as one would expect with diminishing marginal returns. The most recent empirical literature attempts to find relationships between infrastructure variables of economic development with cross-country panel data. There are issues, however, with reverse causations in these models, since new infrastructure may lead to economic growth, growth itself leads to higher demand, and higher demand may lead to more investments in infrastructure. The literature that accounts for reverse causation has consistently found a positive correlation between infrastructure investment and economic development.

The OECD and other international agencies have observed that poor-quality infrastructure is due to low levels of investments over extended periods of time. In the case of transportation infrastructure, this can look like projects that expand existing motorways but do not expand the main network itself. In other words, while there may be more lanes to drive on, the number of kilometers built does not change significantly. The consequences of poor infrastructure may look like this: higher congestion on roads, limited telecommunication coverage, insufficient energy production, and more recently, slower internet speeds. In one way or another, all of these may decrease potential growth of aggregate output. In that sense, infrastructure investment is a special kind of public and private expenditure because the main component of its benefits is grounded on saving time, which tends to have positive effects on consumer and producer welfare.

Economies that are closer to reaching a steady state might see lower returns on infrastructure investment due to the diminishing effects of excessive capital. For example, it would not make sense to build roads that nobody is going to drive on. There may be other paths that involve productivity but do not involve infrastructure, such as changing the pricing schemes to the users of the infrastructure. This may look like different types of toll roads, electricity bill rates, etc. This is a short-term solution to these issues, which intervenes directly into the market and tries to remove the negative externalities of consumption of scarce infrastructure. Nevertheless, in countries that have positive population growth rates and considerable rates of rural migration, these institutional reforms might not be effective in increasing long run productivity rates.

We treat the response variable as productivity calculated by output per worker, while the main regressor will be treated as infrastructure investment per worker. There is also an additional regressor which tells us the proportion of infrastructure projects financed each year that incorporated PPPs. By building a model like this, we are not only analyzing the effects on output of each infrastructure sector, but also considering the intrinsically different nature of marginal returns of infrastructure projects that are not entirely publicly funded. Understanding the economic history of Latin America, we know that the proportion of private investments increased during the time of neoliberal reforms, albeit at different moments and different rates for each country which depended (to a large extent) on the political context and openness to neoliberalism during the turn of the century.

The main argument of this paper states that if improvements in infrastructure lead to higher degrees of integration in markets, then productivity will increase due to the entry of firms that have abnormal profits which can be allocated towards R&D through fixed costs that stimulate innovation and increasing returns to scale. This is related to the endogenous growth model because the entry of firms increases market size, which increases the productivity benefit of innovation. The assumption here is that these developing Latin American countries are further away from their steady state than more developed economies and that their infrastructure is less developed, so investments in infrastructure will lead to considerable improvements in quality that will improve productivity immediately in previously large markets, and more slowly in markets that become larger as they are integrated with the help of improved infrastructure and well-connected organizational networks.

The final model focuses more on the indirect effect that increases in capital have on total factor productivity rather than the direct effect it has on marginal productivity of capital, ultimately because the direct effect is offset by the income taxes needed to finance public capital investment. This is significant in Latin America where public infrastructure investment is predominant due to historical economic ideologies adopted by these countries, particularly structuralism and import substitution industrialization.

Exploratory Analysis

Basic exploratory regressions will be run using the Colombian dataset because it is closest to the average in terms of economic size, productivity levels, infrastructure investment levels, and does not have any temporal anomaly. This means that simple models with plenty of assumptions might fit well with the data, but during the analysis these models were not always compatible with the data from other countries.

Since the main regressor is infrastructure investment, which has a lagged effect on productivity, static time series models are not appropriate for the analysis. These models assume strict exogeneity and no serial correlation, which is difficult to argue in this analysis because the theoretical models that inspired this paper focus on endogenous growth models. Static models are the closest one would come to a simple OLS regression between the regressors and response. For the Colombian data, none of the regressors proved to be significant.

Instead, to incorporate the lag effect, one can turn to Finite Distributed Lag Models, which look at the past values of the regressors to predict current values of the response.

$$y_t=\alpha_0+\delta_0 z_t+\delta_1 z_{(t-1)}+\cdots+u_t$$

It is up to the model builder to decide how many lags to incorporate in the model. This can become quite arbitrary when looking at cross-country data, since the magnitude of the lag effects depends on country-specific variables such as institutional quality, macroeconomic stability, and initial levels of infrastructure. These models also measure the cumulative effect of changes in infrastructure investment on productivity, known as the long-run propensity. This is equal to the sum of the coefficients δ_q. For the Colombian data, a simple regression incorporating two degrees of lag (each degree corresponds to a year), showed that both lags are significant. Also, an F test with a null hypothesis that all regressor coefficients are equal to zero led to a rejection of the null hypothesis with 99% significance. Yet a simple reiteration of these methods using the other countries' data showed both insignificant lag effects and a failure to reject the F-test hypothesis, implying that exogenous forces are influencing productivity significantly.

To account for macroeconomic trends, one can determine time trends for the dataset as a whole and incorporate that into the model as another regressor. The dataset includes all the control variables previously mentioned, so using a linear time trend will account for the variation in both the macroeconomic indicators, and the proportion of PPP infrastructure projects. This model showed positive results for all countries, where including the trend variable increased the model accuracy by significant amounts. Table 2 shows the output for the Colombian data, which increased the Adjusted R-squared from 0.163 to 0.895. The main issue with this model is that it does not include any kind of lag effect like the FDL model did. For the final model, investment lags are included as regressors, while macroeconomic trends are controlled with a linear trend. This is done by using the residual of the regression in Table 2, but without including the investment regressor in the first stage. That is, the residual of productivity is regressed solely on the linear time trend.

If one chooses to include assumption of stationary data and weak dependency, then asymptotic time series models may be appropriate. This is a relaxation from the strict exogeneity of static models, but still uses OLS

***Table 2*:** Regression Table for Time Trend Model (Colombia)

	Dependent variable:	
	Productivity	
	(1)	(2)
Investment	0.043^{**}	0.031^{***}
	(0.018)	(0.007)
trend(COL)		0.013^{***}
		(0.001)
Constant	9.847^{***}	9.548^{***}
	(0.182)	(0.069)
Observations	25	25
R^2	0.198	0.903
Adjusted R^2	0.163	0.895
Residual Std. Error	0.106 (df = 23)	0.038 (df = 22)
F Statistic	5.675^{**} (df = 1; 23)	102.794^{***} (df = 2; 22)
Note:		*p**p***p<0.01

estimation methods. Table 3 shows the regression output for such a model using the Colombian data and, surprisingly, none of the coefficients prove to be significant. That is, if we attempt to predict productivity just from lagged infrastructure investment, the model is not significant. This can be counterintuitive, since the FDL model, which includes all variables plus two additional lag variables, was significant for two of the four countries, but the asymptotic model is insignificant for all countries. This may lead one to believe that the only appropriate model would be one that incorporates both the macroeconomic trends for each country and the lag effects of infrastructure productivity, as is done in the final model. The failure of the asymptotic model may be that it is too similar to random walk models that work better with high frequency data. This kind of analysis does not work with the infrastructure data since there are only 25 observations per country and each observation corresponds to an entire year.

An analogous approach would include first differences in the regression models. The first differences can be applied to both the response and the regressors, including the lagged regressors. Table 4 shows the regression output for the Colombian data, which shows a significant effect for the first difference of the current and one-year lagged infrastructure

Table 3: Regression Output for Asymptotic Model (Colombia)

	Dependent variable:		
	Productivity		
	(1)	(2)	(3)
Lag(Investment)	0.034^{*}	0.030	0.036
	(0.019)	(0.021)	(0.022)
Lag(Investment, 2)		0.016	0.024
		(0.021)	(0.023)
Lag(Investment, 3)			-0.020
			(0.024)
Constant	9.765^{***}	9.884^{***}	9.832^{***}
	(0.192)	(0.238)	(0.265)
Observations	24	23	22
R^2	0.129	0.165	0.218
Adjusted R^2	0.089	0.081	0.088
F Statistic	3.256^{*} (df = 1; 22)	1.976 (df = 2; 20)	1.673 (df = 3; 18)
Note:			*p**p***p<0.01

investment on the first difference of labor productivity. This is inconsistent with the infrastructure data, however, since the impact of infrastructure on productivity can impact changes in productivity across wider time intervals than a single year. Also, a first differences model like this fails to include macroeconomic time trends that have previously shown to be influential on productivity levels. Therefore, attempting to use the same model with other countries' data led to insignificant coefficients. Also, the endogenous growth model theory does not specify whether productivity will react in a specific number of years after a change in capital. Instead, the theory states that the absolute levels of capital will influence output, directly through increases on marginal productivity of capital, and indirectly through market integration and increasing returns to scale.

Before building a final model, it is important to test for serial correlation in the error term of the dataset. This is important because if the error terms are serially correlated, then a Generalized Least Squares approach may be more suitable for the time series regression. A

Table 4: Regression Output for First Differences Model (Colombia)

	Dependent variable:	
	d(Productivity)	
	(1)	(2)
diff(Investment)	0.008^{**}	0.016^{***}
	(0.004)	(0.004)
Lag(diff(Investment))		0.016^{***}
		(0.004)
Lag(diff(Investment), 2)		0.003
		(0.004)
Constant	0.011^{*}	0.013^{**}
	(0.006)	(0.005)
Observations	24	22
R^2	0.165	0.539
Adjusted R^2	0.127	0.463
Residual Std. Error	0.027 (df = 22)	0.022 (df = 18)
F Statistic	4.348^{**} (df = 1; 22)	7.028^{***} (df = 3; 18)
Note:		*p**p***p<0.01

simple t test and a Breusch-Godfrey test using the fitted residuals of the first differences Colombian regression model led to a failure to reject the null hypothesis of no autocorrelation. A Durbin-Watson test also led to a rejection of the null hypothesis with 95% significance in favor of the alternative hypothesis that the true autocorrelation is greater than 0. One would expect the errors to be correlated since the time series show long-term trends in productivity that are influenced by the levels of productivity of adjacent years. When these tests were run again using the final model, the Durbin-Watson test led to a failure to reject the null hypothesis that the autocorrelation is equal to zero, implying that the final model accounted for autocorrelation in the model.

Even with the presence of serial correlation and heteroscedasticity, the unbiasedness and consistency of the OLS estimators are unaffected. What is influenced instead is the standard errors. One can thus use robust standard errors to account for heteroscedasticity in the model. Running a simple regression using Newey-West standard errors, which uses a different formula for the covariance matrix, the effects of lagged infrastructure investment on productivity were insignificant for Colombia. This is inconsistent with the theory and intuition that the effects of investment are not immediate but rather gradual and may last several years. Running these tests again using the final model showed similar results, which again is inconsistent with the theory and may imply that there is no need to use robust standard errors in the model. There may be exogenous shocks during the time frame considered that influenced productivity significantly and thus make the errors more volatile at certain points, but these are already incorporated in the final model by using a time trend, so there is no need to account for heteroscedasticity. In other words, it is expected that the errors will be more volatile during times of lower infrastructure investment since the effects on productivity will come from exogenous variables outside the model. This is also why ARCH models are not considered in this analysis, which are more commonly used for financial data with heteroscedasticity.

Empirical Analysis

To construct the final model, it is important to return to the distributed lag models that arbitrarily specify the number of lags considered in the model. Instead of considering a finite number of lags, an infinite distributed lag model looks at how the investment regressor will have an infinitely long impact on productivity. This type of modeling is questionable in practical terms because infrastructure is constantly rebuilt, becomes outdated, and deteriorates over time. Over the span of 25 years, however, it is reasonable to assume that an infrastructure project can have an impact on productivity for that long. In this model, the long run propensity would be the overall future impact of increasing infrastructure by one million dollars. For such a model to be estimated, however, additional restrictions must be considered. There are two versions of infinite distributed lag models and both will be considered for the four countries. Geometric lag models are the simpler version of the two: they are defined by a linear regression in terms of lagged responses.

$$y_t=\alpha_0+ \gamma\ z_t+\rho y_{(t-1)}+u_t$$

In this analysis, y is labor productivity, z is infrastructure investment, α is the intercept, γ is the impact of infrastructure on current productivity, ρ is the coefficient for the lagged productivity variable, and u is the error term. The rational lag model is a bit more general and includes both a lagged response and a lagged regressor.

$$y_t=\alpha_0+ \gamma_0\ z_t+\rho y_{(t-1)}+\gamma_1\ z_{(t-1)}+u_t$$

By simply incorporating the lagged response as a predictor in the model, one goes from having a fixed amount of lag effects to infinite lag effects, which is appropriate in the time frame considered. The following regression tables show the outputs for both the geometric and rational lag models for Brazil, Colombia, Peru, and Mexico. Since time trends were found to be significant for most countries, the productivity variable is detrended by running the simple trend regression shown in Table 3 and then adding the residuals of that regression as a regressor in the lag model. In other words, the response of the final model is not productivity itself, but the residual of the time series trend model between productivity and the macroeconomic trends that include both the control variables and the infrastructure investment regressors.

The results show that, accounting for lags and macroeconomic trends, Brazilian and

Table 5: Regression Output for Infinite Lag Model (Brazil)

	Dependent variable:	
	Trend	
	(1)	(2)
Investment	0.006	0.012
	(0.009)	(0.010)
Lag(Trend)	0.799^{***}	0.808^{***}
	(0.165)	(0.163)
Lag(Investment)		-0.009
		(0.007)
Constant	0.049	0.025
	(0.082)	(0.084)
Observations	24	24
Adjusted R^2	0.691	0.697
Note:		$^{*}p^{**}p^{***}p<0.01$

Mexican infrastructure investment has a positive but insignificant effect on labor productivity. Colombia and Peru, meanwhile, have more significant results. These results also confirm the hypothesis that Brazil and Mexico lie closer to their steady state than Colombia and Peru, and thus do not see as large a benefit from higher levels of infrastructure investment. Also, all the models except for Mexico fit the data well, as seen by the high adjusted R-squared. The reason for Mexican model do not fit the data well is unclear, but it may be that Mexican productivity is influenced by an additional exogenous shock that was not considered. This finding might imply that Mexican labor productivity is systematically different than its South American partners, which makes sense given Mexico's proximity to the United States and its arguably highest quality infrastructure network out of the four countries.

The control variables mentioned previously that account for macroeconomic trends are included in the regression analysis. They are not included in the output because of the nature of the final model. This is because the final model uses the residual of the regression of the response with main investment regressors and control variables to detrend productivity. This is essentially the residual of the regression in Table 2, though the regression would be only between productivity and the linear time trend. The detrended variable serves as a time series response in the final model. This two-stage procedure is

***Table 6*: Regression Output for Infinite Lag Model (Colombia)**

	Dependent variable:	
	Trend	
	(1)	(2)
Investment	0.014***	0.014**
	(0.005)	(0.005)
Lag(Trend)	0.617***	0.596***
	(0.118)	(0.161)
Lag(Investment)		0.001
		(0.006)
Constant	0.140**	0.153*
	(0.051)	(0.084)
Observations	24	24
Adjusted R^2	0.766	0.755
Note:		*p**p***p<0.01

common in infinite lag models, particularly to detrend the response variable (in this case, productivity). Therefore, the control variables do not show up explicitly in the regression output, but they are accounted for in the regression itself.

A shortcoming of infinite distributed lag models is the inclusion of a lagged dependent variable as a regressor. By including this, it can take away from the explanatory power of the other regressors, and potentially change the sign of the regressor coefficients. For the four countries analyzed, infrastructure investment coefficients were all positive, but the inclusion of the lagged time trend may also diminish the significance of infrastructure investment in the model. Nevertheless, both geometric and rational lag models prove to be useful for addressing some of the endogeneity issues that the regressors may have. This is because the regression is carried out in a two-stage process which first controls for macroeconomic linear time trends and then uses the residuals of the dependent variable in the second stage.

It may be insightful to include a regressor that accounts for political or institutional stability, as these factors may influence the efficiency of infrastructure investment, since public administrations and foreign investors are not keen to prioritize infrastructure during times of social instability, a phenomenon all these countries are familiar with. The geometric model improves the fit for Colombia and Mexico while the rational model is a better fit for Brazil and Peru, based on the

Table 7: Regression Output for Infinite Lag Model (Mexico)

	Dependent variable:	
	Trend	
	(1)	(2)
Investment	0.010	0.008
	(0.009)	(0.009)
Lag(Trend)	0.618***	0.604***
	(0.178)	(0.179)
Lag(Investment)		0.008
		(0.009)
Constant	0.098	0.158
	(0.088)	(0.108)
Observations	24	24
Adjusted R^2	0.307	0.304
Note:		*p**p***p<0.01

adjusted R-squared. This means that Colombian and Mexican infrastructure models work better under more restrictions, though only slightly. Another possible extension to this analysis would be to incorporate human capital variables such as secondary enrollment rates or indicators of institutional quality. The reason this was not done here is because the data was not equispaced for the four countries, so one would need to use interpolation techniques to include these variables in the time series analysis, which might have decreased the accuracy of the model. If development variables are available for all years, then one could improve the model by using lagged instrumental variables as an additional regressor to isolate the casual effects of infrastructure investment on productivity more clearly.

Conclusion

Over the past three decades, infrastructure spending in Latin America has fueled incessant debate. Avid supporters of neoliberal reform were quick to hail private infrastructure as a quick route to high income status for individual economies. Having had a reasonable amount of time to adjust to a modern global economy and leave structuralism in the past, Latin America’s major economies saw different benefits from improvements in infrastructure. Less developed Peru and Colombia could increase efficiency significantly by finding affordable ways to construct an infrastructure network across their difficult terrain. Brazil and Mexico, meanwhile,

Table 8: Regression Output for Infinite Lag Model (Peru)

	Dependent variable:	
	Trend	
	(1)	(2)
Investment	0.014	0.010
	(0.008)	(0.007)
Lag(Trend)	0.816^{***}	0.731^{***}
	(0.081)	(0.076)
Lag(Investment)		0.021^{**}
		(0.008)
Constant	0.126	0.292^{***}
	(0.078)	(0.090)
Observations	24	24
Adjusted R^2	0.837	0.877
Note:		*p**p***p<0.01

were one step ahead, with both nations already being globally recognized entities that had established higher quality infrastructure networks, albeit with less geographical obstacles.

The results of the empirical analysis coincide with conditional convergence theory, since all four countries have similar population growth rates and institutional quality. It also explains why Colombia and Peru have seen faster growth rates than the richer Mexico and Brazil. This would lead one to believe that Colombia and Peru will have similar income levels to Mexico and Brazil soon, and this may also apply to smaller Latin American economies as well. This analysis favors cross-country analysis within Latin American economies since, 30 years after the onset of neoliberal reform, the countries of this region have shown to be heterogenous in their development strategies. Whereas some nations have continued to strengthen their democratic institutions, others have turned to authoritarian power. Whether Latin American economies will manage to converge in terms of income levels depends on the sustainability of democratic values and the strengthening of institutions in the region. Nonetheless, for institutions to pave the way to high-income status, infrastructure can act as a foundation for economic efficiency and stability in the long run.

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