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Infrastructure Investment and European Economic Growth

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Introduction

As the global economy continues to recover from the impacts of the COVID-19 pandemic, there is significant discussion among policymakers as to the best mechanisms to stimulate economic recovery. One of those mechanisms is infrastructure investment. There is a large contingent of policymakers who believe that large, immediate spending on infrastructure will lead to significant economic growth. While another group is concerned about the secondary effects of such large government spending packages. With global economies still digging out of the covid shock and supply chains struggling to keep up with demand, there is no better time to explore the topic. This paper then will explore the historical, academic, and quantitative evidence for a relationship between infrastructure investment and growth rates. Specifically, this study's research question is how infrastructure spending has impacted the GDP per capita growth rates of European nations from 2008-2019. The aim will be to identify the existence of a casual relationship between infrastructure investment and growth. Furthermore, the study will determine its statistical significance and compare it to other forms of spending which are considered to promote economic growth. The study’s first objective will be to determine which sectors of spending have the most significant effect, second to determine if the effects are immediate or lagged (if so, how long does it take), third to determine the external impacts of infrastructure investment. The structure of the paper moving forward will follow this format, first, a review of the existing literature on the topic. Second, propose the variables for the regression and rationalize their inclusion. Third, format the regression equation and explain the rationale behind the design. After that, the paper will discuss the results and their interpretation statistically and in relation to previous research. Finally, the paper will include a conclusion to summarize goals of the paper, the results, and the external application of the study.

Review of literature

Introduction

Academic work on the relationship between infrastructure investment (transport, telecommunications, power) and growth rates in Europe is extensive. Most of the previous literature examines data from 1950-2015 with differences in specification and design and the magnitude of the relationship discovered between the two variables. Through the literature review, a more precise research question has been formulated, shifting from whether the impact of infrastructure is positive or negative to now determining the exact effect in a selected time frame when compared with other factors on economic growth. The literature review also affected the regression equation proposed later; specifically, the inclusion of 4 different variables (balanced budget, average tax rate, population growth, and military spending) and use of a two-stage least squares regression are attributed to previous research.

Positive impact of infrastructure investment

The consensus of academic research on infrastructure investment is that an increase in it positively affects GDP growth through direct and indirect mechanisms. The first work reviewed provides evidence for such a statement. In a 2016 study of Europe by Revoltella, Debora; Brutscher, Philipp-Bastian; Tsiotras, Alexandra; Weiss, Christoph, results showed higher rates of GDP growth occurred simultaneously with the government expanding public investment in infrastructure. Using numerous prior works as its baseline, the study broke Europe into 250 regions. The study found that in regions where infrastructure investment and capital stock were high, positive externalities such as easier access to global and local growth opportunities and faster rebound from economic recoveries were present. Although detailed within the variables chosen, it is a fair critique that their regression included a relatively limited number of variables, potentially affecting the accuracy of the regression through endogeneity. Nonetheless, the study's inclusion is evidence in support for the hypothesis proposed in the methodology section which says that infrastructure investment should be expected to have a statistically significant impact on GDP growth.

The phenomenon above is further supported through a study of 14 Organization of Economic Co-operation and Development (OECD) member states (Argimon, Paramo, and Roldan, 1997). Their work found empirical evidence to support the existence of a crowding-in effect of private investment. A phenomenon that infers an increase in public investment will result in an increase in private productivity and the economy’s total capital. This debunks an often-cited issue with government spending which has an inverse effect called "crowding out." The study used a complex model to find that the relationship between public investment and crowding out of private spending was statistically insignificant. The study's regression was later reframed to reduce the possibility of endogeneity and collider bias. When the researchers ran this regression, the results showed that infrastructure spending positively affects private expenditure. Therefore, when infrastructure investment increases, a crowding-in effect is anticipated. Regarding limitations, although the mathematical and theoretical portions were highly detailed, external validity is somewhat limited due to the relatively narrow scope of data. The study looks at nations that are a part of OECD; this infers a level of industrialization that some countries may not have. Therefore, it is reasonable to question if the study's findings would hold if the research team chose a more diverse nation set. Nevertheless, theoretically, the study's findings make sense as access to more efficient forms of infrastructure would increase the speed of commerce.

Further support for the existence of a significant positive relationship between infrastructure and growth is derived from a long-term study of infrastructure investment in the United States beginning in 1950 (Munnell 1982). Munnell was directly able to link higher spending on infrastructure to higher growth rates. Comparing states, she determined that states with higher levels of infrastructure investment had higher growth rates over an extended time frame. One issue that is notable is the study is rather old and there have been drastic technological changes since the time of publication. Secondly, it used the Cobb Douglas production function as a mathematical tool to draw connections rather than a typical regression, which can be seen both as a strength or a weakness. The study uses a different calculatory technique than the other studies reviewed and the data is rather old; however, the study is still important as it shows infrastructure as a statistically significant driver of GDP in a non-European setting.

Specific sectors of investment

Evidence suggests that a large proportion of the positive effects of infrastructure spending are driven by two specific sectors of it: transport and telecommunications. In their analysis of European nations, Gonzalez and Fernandez (2008) found that transportation and communications infrastructure investment played a large role in growth compared to other sectors of infrastructure. A study by Martijn Brons, Fotios Kalantzis, Emmanuelle Maincent, Paul Arnoldus (2014) assessed the magnitude in Europe since 1950 and reaffirmed Gonzalez and Fernandez (2008). This second study specifically showed higher rates of investment in transportation and electricity infrastructure resulted in higher growth rates. Narrowing down further, Brons et al separated infrastructure into three parts (energy, road, and rail). This specification gives their study tremendous applicability in the real world as it gives policymakers precise guidance as to where they should allocate funds. The study utilized a technical, structural approach that, through paneled data from 1950-2012, used lagged data and a regression free of endogeneity to distinguish between effects over time. Theoretically, investment in transportation and electricity and then expecting growth makes sense as improvement in these sectors should increase the nation's technological capacity, which would increase the nation's growth potential. A notable example of this phoneme would be the rapid increase in technology due to the 19th century industrial revolution that resulted in historic economic growth.

Monetary effects of infrastructure expenditure

In contrast to the above studies, empirical evidence exists that determined infrastructure investment did not have the significant level of impact on growth that many would expect. In a study of 28 EU member nations by (Stoilova 2016) found balanced budgets have a significant positive role in GDP growth. In her research, the empirical evidence shows that government expenditures frequently have negative externalities that reduce the positive effect of investments in the first place. Her study argued that although public spending on infrastructure would have a positive impact, it would be offset at least to an extent later on due to higher debt or higher taxes. These results would be supported by those who believe in supply-side economics or the Austrian school theories where taxes lower growth potential in an economy. Stoilova's findings give us a rationale for including balanced budgets and average income tax rates in the proposed regression.

Efficiency as a determinant of impact

Another factor that plays a role in the magnitude of the relationship is the efficiency, choice and rationale for infrastructure investment (Ansar, Flyvbjerg, Budizer, and Lunn (2016). In a study of China from 2000 onwards, inefficient deployment of capital was cited as a key reason for insignificant growth effects resulting from infrastructure investment. Flyvbjerg (2009) used a data set of OECD nations to show that frequent cost overruns of transportation projects and the tendency of policymakers to over/underestimate the cost/benefits of the proposed projects. This overestimation of benefits from infrastructure projects along with frequent cost overruns lead to skewed cost benefit analysis by policymakers who then allocate funds poorly. Although the two studies are actively looking for the negative effects they should not be written off as they provide possible guidance for explaining the results of the regression analysis

Conclusion

The review of existing literature points to a relationship between infrastructure investment and growth, as can be inferred from the sources in the first and second section. However, it is clear that effects are not uniform across the board. Results of investment vary from case to case. In this study an exact figure on the relationship between infrastructure and growth will be sought specifically from 2015-2020. The bulk of the reviewed work centers on data from 1950-2010, a period which has significant factors present, such as the Marshall Plan and the Cold War, which reduces applicability to the current world climate. That applicability is what this study will aim to satisfy by analyzing a more recent time frame, hence contributing more recent data and analysis to the knowledge than currently exists. The goal will be to utilize a regression that encompasses a broad scope of variables to determine how much GDP per capita growth is attributed explicitly to infrastructure investment from 2015-2020 and produce recent results that can be applied moving forward.

Methodology

The goal of this study firstly is to isolate infrastructure investment from other variables that affect growth and then determine its statistical significance. Second, to determine which sectors of infrastructure investment are the most important. Due to time and information constraints, the data will cover 10 European nations that will provide a sample for the rest of the continent. Next, we will include the reasoning behind the inclusion of the chosen variables for the regression analysis and why they were chosen over other possible variables. Finally, the regression will be formatted in a manner that produces accurate and logical results.

To successfully analyze the statistical significance of infrastructure investment, this paper wants to look in a more recent timeframe so 2008-2019. The period is justified given that our goal is to study the impact on infrastructure investment recently, and any data from earlier periods would have too large of an effect on the data due to the presence of events such as the Marshall Plan, Cold War, etc. This makes the past 20 years or so the first opportunity to study the impacts of infrastructure investment on GDP per capita growth in Europe in a more normal climate. Although the goal is to fill a specific gap in the research from 2015-2020, the extension of the time frame to include data back until 2008 is necessary as the effects of infrastructure can't be constrained to one year (Mundell 1982). The consequences of infrastructure investment can continue for years, with the more substantial growth effects arguably occurring after the first year. Ideally, statistics would have been included for 2020; however, the severe impacts of COVID-19 make the year an outlier on the data.

To determine the relationship between GDP growth and infrastructure investment, an OLS multivariate regression is required. Utilizing a cross-sectional/longitudinal design through paneled data, 10 European nations will be used to test the hypothesis. The selection of control variables is attributed to the work of prior researchers as well as general economic theory.

Nation set: Croatia, France, Germany, Italy, Romania, Spain, the United Kingdom, Poland, and Hungary. This specific selection provides a diversity of culture, economic status, governing party, and spending habits that should sample as a representation for the rest of the continent.

Variable	Source	Measurement and definition
GDP per capita growth rate (Y1)(Dependent variable)	World Bank	GDP per capita growth has been chosen as our measurement for growth because it measures the size of the economy but also the economic prosperity of citizens.
Infrastructure investment X1	Eurostat and global infrastructure outlook	The variable which the study is interested in and focuses on
Education investment X2	Statista	A "productive" expenditure that we hypothesize to have a positive impact on growth. Control variable
Health investment X3	OECD and WHO	A "productive" expenditure that we hypothesize to have a positive impact on growth. Control variable
National deficit or surplus X4	Trading economics	Included due to the work of previous academic research. Has been shown to affect growth
Ex-Soviet state or Warsaw Pact member X5	Britannica	Dummy variable, developing Eastern European nations may have intrinsically more infrastructure investment to catch up to the West.
Military spending X6	Worldbank	A large part of many nation's spending affects various industries and regions. Has been shown to have impacts on economic activity.

Population change X7	Worldbank	Because we are using GDP per capita as the base metric for measurement of growth, we will include population change to absorb any effects
Average income tax rate X8	Tradingeconomics	Control variable, academic studies have shown tax rates to impact growth. To isolate purely for infrastructure this variable needs to be pulled out of the error term.

Hypothesis
Null hypothesis: H0=0; infrastructure does not have an effect on growth
Alternative Hypothesis: HA>0, one sided hypothesis as the goal is to prove a positive relationship

First generic regression equation
GDP/capita growth=b0+b1x1+b2x2+b3x3+b4x4+b5x5+b6x6+b7x7+b8+b8x8

Second regression equation
GDP/cap growth = plm(formula = GDPcapgr ~ infrainvest + Defenseinvest + Healthinvest + Warsawpact + Topincrate + Popgrrate + factor(Year) + Natdeficitsq, data = econproj, model = "within", index = c("Country"))

Theoretically, we expect higher rates of infrastructure spending to positively affect growth due to Keynesian economic theory (Keynes,1936). First a normal OLS regression is necessary just to get a baseline of where the results are. From there, there plan is to use a non-quadratic OLS to account for time and outlier effects. Fixed effects are expected, specifically The Great Recession of 2008 and 2009 and the European debt crisis for the years 2013 and 2014. National deficit is squared because it is likely that data on this point in the years following the 08 financial crisis are not linear due to the government spending on stimulus, unemployment, and bailouts. Additionally, the second regression utilizes the r tool “plm” which is created to deal with linear panel data as is present here.

The paper’s aim is to determine an exact figure for the growth attributed to infrastructure investment. Ideally, infrastructure would be split into three separate sections, similar in format to the structure used in the research of Fernandez and Gonzalez (2008); however, the specific data is not available for

2017-2019. Perhaps that data could be collected if given more time. In order to get the exact figures, it would likely be necessary to first examine each nations approved yearly budget and then a yearly summary to see the final amount spent. Clear cut definitions as to what each form is would also be required, as there is currently some vagueness about what can be categorized as infrastructure outside of the obvious transport, telecommunications, and energy parts.

Results

Regression 1

Variables	Estimated coefficients	Standard error	T value	P value
Intercept	3.9416215	2.5771653	1.529	0.1294
infrainvest	-0.2888974	0.3906691	-0.739	0.4614
Defenseinvest	1.1061493	0.8505163	1.301	0.1965
Healthinvest	-0.2079866	0.2240530	-0.928	0.3555
Warsawpact	0.4151492	0.2693324	1.541	0.1264
Topincrate	-0.0465571	0.0230509	-2.020	0.0461
Popgrrate	-2.0297403	0.9103115	-2.2.30	0.0280
Natdeficit	-0.0001484	0.0143391	-0.010	0.9918

Residual Standard error	*Degrees of freedom*	*Multiple R-Squared*	*Adj R-Squared*
2.739	*98*	*0.2269*	*0.1717*

First, a summary of the first regression results which was conducted through a simple OLS format. The T values for only two variables, top income rate, and population growth rate, were significant compared to the benchmark 95% significance level t-test of 1.660551. The primary focus variable, infrainvest, actually had a negative coefficient estimate which theoretically makes no sense given the expectation that an expansion in capital productivity and technological capacity should induce growth. Furthermore, the accuracy of the simple OLS function is cast into doubt given the very low R squared at just under 23%. The F stat also wasn't convincingly high, further weakening the model's accuracy. Overall, the results were not satisfying; therefore, running a second regression with different econometric tools was necessary. The results made more hypothetical sense and were supported by more robust statistical indicators. Furthermore, the presence of fixed effects is likely reducing the accuracy of the data and needs to be accounted for.

Regression 2

Variables	Estimate Coefficients	Standard Error	T value	P-value
infrainvest	1.26938455	0.42936744	2.9564	0.004102
Defenseinvest	3.55813134	1.39776940	2.5456	0.012856
Healthinvest	-0.53838829	0.33163655	-1.6234	0.108482
Warsawpact	-0.01655868	0.2010318	-0.0824	0.934562
Topincrate	-0.03080629	0.0188420	-1.6350	0.106031
Popgrrate	-0.3985846	1.0083286	-0.3953	0.693693
Natdeficitsq	0.0004522	0.0002085	2.1693	0.033064

Total Sum of Squares (TSS)	*Degrees of Freedom*	*R-Squared*	*Adj R-Squared*
751.37	*79*	*0.67131*	*0.56313*

The second run regression included econometric terms that dealt with fixed effects across time and country, along with Natdeficit squared. Clearly, these changes made significant differences in the accuracy of the model and the respective significant variables. Furthermore, the primary explanatory variable, infrastructure investment, was found to be statistically significant, confirming what numerous economists have previously found. Infrastructure investment had a significant p score at the 99% level while the national deficit and military expenditure had p values significant at 95%. All three variables passed t-tests at the 99% level as well. Therefore we can reject the proposed null hypothesis and conclude a statistically significant effect on GDP per capita growth from infrastructure investment in Europe from 2008-2019. Notably, Military expenditure also passed the t-test at 99% confidence level, so it is fair to say there is a 99% likelihood that the variable is having a statistically significant impact on GDP per capita from 2008-2019.

T test analysis for regression 2

Variable	*T value required to exceed at 99%*	*Value provided in T test(absolute value)*	*Reject Null Hypothesis?*
infrainvest	*2.36*	2.9564	Yes
Defenseinvest	*2.36*	2.5466	Yes
Healthinvest	*2.36*	-1.6234	No
Warsawpact	*2.36*	-0.0824	No
Topincrate	*2.36*	-1.635	No
Popgrrate	*2.36*	-0.3953	No
Natdeficitsq	*2.36*	2.1693	No (yes at 95%)

Furthermore, the *f*-stat which tests for the overall statistical significance of the model was found to reject the null hypothesis. Therefore, the model is statistically significant on the dependent variable adding to the accuracy of the regression.

F-stat test for regression 2

F-stat for regression	*Benchmark to compare F-stat to*	*Reject null hypothesis?*
8.96371	*1.437612*	*Yes*

Using the *T-test and F-stat* as evidence, we can firmly reject the null hypothesis for infrastructure investment at a 99% confidence level.

The resulting statistics point to a relatively high level of accuracy and applicability. Firstly, in running a variance inflation factor (VIF) test, each respective variable had scores below the standard 10, indicating little to no multicollinearity. Secondly, the R-squared is significantly higher compared to the first regression. It has gone from 23% variance explained up to 67% variance explained with an adjusted value of 56%. Although reasonably high, this suggests that there are still other variables that could better explain the data if they were included. Moving from regression 1 to regression 2 saw the coefficient of population growth rate drop from -2.050 to -0.39 along with a fall in the t value. For purposes of confidence, this is good because less of GDP per capita growth, which is inherently affected by the population, is having less of an effect on fluctuations in GDP growth. In addition, this change helps improve accuracy for the remaining variables as shifts in GDP per capita are being attributed to them rather than changes in the population. Overall, the increase in accuracy is likely due to the accounting for fixed effects, which showed some significant outliers along the basis of time and unit. Specifically, the year 2009 presented as a highly significant statistical outlier, as would be expected given the dramatic and abrupt effect of the great recession.

Variance inflation factor (VIF)

Variable	Infrainvest	Defenseinvest	Healthinvest	Warsawpact	Topincrat	Popgrrate	Natdeficitsq
Calculated VIF	3.50453	1.615490	2.685167	1.282260	1.484294	2.641247	1.692591
Multicollinear? (>10 indicates multicollinearity)	No	No	No	No	No	No	No

As the data measured examines multiple observations over 11 years, a test for serial correlation through an examination of the Durbin-Watson statistic is required. Based on these results it's fair to assume that there is some correlation between the variables over time. The statistical connections between the variables over time is logical as Infrastructure and other forms of investment are likely to have an impact beyond the year that they occur.

Durbin Watson test for autocorrelation

Calculated Durbin Watson Stat	Value needed to disprove the possibility of autocorrelation/serial correlation, exactly 2 or marginally +/-, yes or no?
1.60931	no

Discussion

Utilizing an OLS regression with accounts for year, nation, and drastic increases in the budget, the results prove that increased infrastructure investment leads to higher GDP per capita growth rates at the 99% significance level from 2008-2019. Specifically, a 1% increase in infrastructure investment results in a 1.27%

increase in GDP per capita. Furthermore, given the factoring for time, the given regression results allow for the inference that if the investment takes place in normal times, this is the result that will be yielded.

Surprisingly and essential to note for external validity purposes was the finding that military expenditure had a more significant percentage effect on GDP per capita than infrastructure investment. A finding that is not expected given previous research. Specifically, a 1 percent increase in military expenditure resulted in a 3.55% increase in GDP per capita. Military expenditure is not a form of spending that directly targets individuals among the population. However, it may be having an impact through indirect mechanisms. First, the defense industry is a substantial business, and increased spending on military resources could lead to more jobs. Second, more defense spending should hypothetically lead to a safe economy that is more conducive to a growth environment. The test for autocorrelation signals that infrastructure is having an impact in more than just the year where that initial investment is taken, this would be in line with academic research.

Concerning previous research that argued for the significant positive impact of infrastructure investment (Munnell, Argimon, Revoltella 2016), this assigned coefficient is less than would be expected. Furthermore, a common argument in the reviewed literature was that infrastructure investment would have a more significant impact than other forms of government spending. However, in these results for regression 2 it is clear that the estimated 1 unit increase in defense spending has a more significant effect than the 1 unit increase for infrastructure investment. Perhaps this comparative insignificance is related to the research of Ansar Fati and Bent Flyvbjerg (2009). Their respective research papers cited issues in the deployment and infrastructure as something that is reducing the positive effects of the investment. Therefore, although the impact of infrastructure investment is still significantly positive in the overall model, it is reasonable to assume that capital deployment inefficiencies and labor failures reduce the possible impact of infrastructure projects. For example, a 2017 study of infrastructure in Germany found that 73% of "major" projects were over budget, delayed, or both (Thehertieschool). It seems then that real-world inefficiencies are hampering the positive theoretical impacts of infrastructure investment in practice. Suppose this form of investment is to be successful. In that case, government officials will need to keep projects on time, on or under budget, and at max efficiency to have the positive impact that infrastructure investment should result in

The results of the two regressions point to another aspect of the characteristics of infrastructure investment, its cyclical nature. When Regression 1 was run, there was a low t-score, negative estimated coefficient, and infrastructure investment were not significant. However, compared to when the 2nd regression was run, a statistically positive result emerged. This data points to infrastructure investments' significance on growth in years only in more normal economic years. One of the primary motivations for researching this topic was to explore how policymakers can utilize this form of investment to boost economics that is still reeling from COVID. Therefore, it is reasonable to conclude that there is weak evidence for infrastructure being the excellent driver of growth that many current western policymakers say.

Although the results generated were precise, a few econometric issues could be reducing the accuracy of the regression. Firstly, there are effects on GDP per capita that should be included (education investment, for example). Unfortunately, the data is challenging to gather, and due to time and accessibility restraints, these variables weren't the study. Another possible econometric issue is the narrow scope of nations; although chosen to provide a diverse sample that modeled the entirety of Europe, perhaps a larger nation set would have yielded different results. Finally, the issue of 2009 is also worrying as the effects of the financial crisis could have reciprocating effects unseen in the variables that play a role in GDP per capita growth from 2010 onwards.

Conclusion

The overarching goal of this study was to investigate how infrastructure spending has impacted the GDP per capita growth rates of European nations in the past decade. As infrastructure takes a leading role in political-economic conversations, policymakers need the most up-to-date information possible regarding the relationship between infrastructure and growth. The results of the second regression run for this paper added to the body of work that infrastructure is positively related with GDP growth, and in this case those results hold true over the past decade. Statistical evidence that infrastructure investment growth has been having a positive impact on GDP per capita growth and therefore the overall living standards for the population of Europe. However, these results showed that while statistically significant, they were not as statistically significant as those derived by researchers in earlier time periods. The cause of this reduction is an area that is prime for research especially if policymakers hope to utilize infrastructure investment in their economies as effectively as possible along with research regarding what specific segments of infrastructure investment are the most impactful.

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