Could Long-Term Investments in Infrastructure Reduce Inequality?*

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Abstract

By reviewing US state-level panel data on infrastructure spending and on per capita income inequality over a 60-year period, from 1950 to 2010, this paper sets out to test whether there is an empirical link between infrastructure and inequality. Our main results, obtained from panel regressions with both state and time fixed effects, show that highways and higher education spending growth in a given decade correlates negatively with Gini indices at the end of the decade, suggesting a causal effect from growth in infrastructure spending to a reduction in inequality. This relationship is stronger with inequality at the bottom 40% of the income distribution and also for highways spending. A counterfactual experiment reveals which states ended up with a significantly higher bottom Gini coefficient in 2010 due to underinvestment in infrastructure in the 2000s. A second related goal of this paper, from a policy making perspective, is to highlight innovations in finance for infrastructure investments, for the US, other mature markets and also for developing economies.

JEL Classification Numbers: C23, D31, H72, I24, O51

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1 Introduction

Long-term investments in infrastructure are now at the center of many policy initiatives worldwide. In particular, many global institutions are now betting on the development of infrastructure to pave the way for future growth. In developed countries, the hope is to reverse a much feared "secular stagnation" by better maintenance of existing public goods and more importantly by investing in infrastructure that fosters innovation while at the same time protecting the environment. In developing countries, on the other hand, electrification as well as hospitals and railways construction are central during election campaigns, most prominently in Africa. Additionally, investment in infrastructure is needed to ensure that economic improvement continues in the many countries that have benefitted from a significant reduction in violent conflicts. To list of few of the many initiatives that have received a lot of attention from the public media and are widely discussed among policy circles figures prominently the launch of the Asian Infrastructure Investment Bank (AIIB) under the leadership of China. In Europe, the Juncker Plan as well as several actions that have been undertaken by the European Investment Bank (EIB) and by the European Bank for Reconstruction and Development (EBRD) to promote infrastructure investment can be seen as a vehicle to resuscitate the European Union project. In addition, the World Bank, through its Global Infrastructure Facility (GIF), has designed a platform to channel funds to mature as well as developing countries, while numerous global investment banks such as Goldman Sachs and J.P. Morgan now have set up infrastructure investment divisions within their operations. Last but not least, infrastructure financing surfaced as a major topic in the recent US election, with explicit infrastructure plans proposed by both the Clinton and Trump camp.

While there is growing belief about the potential benefits of public infrastructure, which include highways, bridges, ports, transportation networks, telecommunications systems and community colleges, one is struck by the lack of empirical evidence. More specifically, little is known about the ability of infrastructure to ensure that the proceeds from enhanced growth, if any, are distributed among society in a fair way. The literature about the empirical link between inequality and growth is well developed, however the existence in the data of a possible relationship between infrastructure and income distribution is negligible or obsolete in the discourse. This research gap is felt most acutely in the US context, where the damaging impact of rising inequality has become a major policy issue. In addition, physical infrastructure in the US is admittedly in urgent need of maintenance and upgrading. The burgeoning literature on the subject suggests that the growing deterioration of infrastructure is having an adverse effect on per capita GDP and GDP growth, and possibly also on physical quality of life and well-being. However, very little is known about whether a lack of infrastructure spending affects inequality. The latter question is the main focus of our inquiry.

In short, the inequality-growth nexus has turned out to be a hard empirical nut to crack. While the bulk of the literature which flourished during the early 1990s, surveyed by Bénabou (1996), tends to support the view that higher inequality typically slows down growth, more recent studies by Forbes (2000) and Li and Zou (1998) challenge this view. Atkinson and Bourguignon (2015) for example argue that important nuances are missing by relying extensively on aggregate data to study the relationship between economic growth and inequality. The current trend therefore has been to focus instead on disaggregated data across different deciles of the distributions. A departure from the previous path can be seen in Thomas Piketty's Capital in the 21st Century (2014), generating enormous public interest on the subject of inequality and growth at a global level. Milanovic (2016) uses global survey data, while van der Weide and Milanovic (2014) employ micro-census data from US states to show that high levels of inequality reduce the income growth of the poor but help

the growth of the rich. One of the main policy solutions put forward to address the problem of rising inequality, particularly by Piketty, is to increase the income tax, especially at the top end of the income and wealth distribution to make it more progressive. The belief is that raising income tax among the wealthiest segments of society, at a global level, would enable governments to both increase in-kind and monetary transfers and also invest more on public goods for the majority of the population. While the literature on the impact of transfers on inequality is gaining a lot of visibility, research about the extent to which infrastructure investments may effect inequality, however, is glaringly sparse.

This paper has two main objectives. The first is to empirically test whether there is any correlation between infrastructure investments and income inequality, and more specifically to evaluate the extent to which infrastructure investments may have a differential effect on top and bottom inequality. The focus of earlier studies has been on highlighting the negative relationship between inequality and growth produced by the wealthiest segment of the income distribution opting out from the financing of public infrastructure projects. In spite of its intuitive appeal, such a postulation has not been put to empirical scrutiny. On the other hand, how inequality at the bottom end of the income distribution correlates with infrastructure appears to be ambiguous on a priori grounds. This is due to the fact that while more bottom inequality could be explained by lack of public services such as education, it also calls for more redistributive transfers that could possibly crowd out spending on long-term investment in infrastructure. More importantly, while the literature has emphasized causality running for inequality to infrastructure, it is equally plausible that investment in infrastructure improves geographical mobility and inequality. Here again, data should help clarify whether or not, and when one of these two effects dominates.

Our aim here is to try to address these pressing issues by reviewing and analyzing US state-level panel data. The main motivation for selecting US states, apart from having easier access to reliable data, is that there are significant differences in how both inequality and infrastructure spending vary over time across US states. Such variations offer the possibility to uncover any robust relationship between infrastructure and inequality. In addition, the data allow us to test for such a relationship by taking different types of infrastructure into account such as transportation, education, health related areas, judicial, cultural and legal. Our data on overall, bottom and top Gini indices on income distribution are derived from van der Weide and Milanovic (2014), who use six waves of the Integrated Public Use Microdata Series (IPUMS), for 1960, 1970, 1980, 1990, 2000 and 2010. For infrastructure spending, we have constructed real growth rates by relying on data from the US Census Bureau, that provide an annual survey of state and local government finances from 1951 to 2008. By using US state-level data on both infrastructure spending and per capita income inequality over a 60 year period, from 1950 to 2010, this paper sets out to test if there is an empirically verifiable link between infrastructure and inequality. Our main finding, obtained from panel regressions with state and time fixed effects, is that highways and higher education spending growth in a given decade correlates significantly and negatively with Gini indices at the end of the decade, suggesting a causal effect from growth in infrastructure spending to inequality. We find that this relationship is stronger with inequality at the bottom 40% of the income distribution and also for highways spending. Our tentative explanation of the latter feature comes from the observation that spending on highways has declined in many states over the 1950-2010 period, thus worsening income inequality because of more difficult access to job opportunities and education. In contrast, higher education spending has grown faster and has almost never declined in any state. The data and empirical strategy are described in Section 3, while Section 4 offers a discussion on our main empirical results, including a counterfactual exercise that helps identify the states which experience

larger income inequality because of underinvestment in infrastructure.[1]

It is important to stress that the negative correlation that we document - between Ginis in year t and growth rates of spending on infrastructure in the decade preceding year t - arguably suggests a causal effect from growth in infrastructure spending to inequality. In other words, US states with high growth rates of spending on highways or higher education enjoy lower inequality a decade down the road. Causality, however, is shown to go in the opposite direction, in the existing debate and literature on inequality and growth. The idea being put forward there is that states with high inequality (especially bottom inequality) have lower growth rates of infrastructure spending, either because the richest segment of the income distribution plays no major role in financing of infrastructure or because larger inequality triggers more transfers that crowd out infrastructure investments. In order to test that assumption, we run regressions of growth rates on infrastructure spending on lagged Ginis, together with state and year fixed effects, and we find that coefficients on lagged Ginis are not significant. Hence the data we use neither reject a causal effect from infrastructure to inequality, nor support a reverse pattern. In consequence, our results accord with the notion that investments in infrastructure contribute to enlarge geographical mobility and hence to reduce inequality.

The second key objective of our paper is to present a set of possible solutions to alleviate the many obstacles to fund infrastructure investments in developing as well as developed countries. The negative - and highly significant - relationship between infrastructure spending and inequality that we document in the first part of this paper suggests that boosting public investment could help ameliorate the US income distribution. However, the US, like many other countries, has accumulated high levels of government deficit and public debt, and that may put a tight limit on the scale of any plan to enhance infrastructure. In Section 5, we offer a discussion of four key pillars that could help mitigate the barriers to fund infrastructure. We first draw attention to the growing reliance on Public Private Partnerships (PPPs). Secondly, we focus on the important role that sovereign wealth funds (SWFs) and other long term investors such as insurance companies, pension funds could play to finance infrastructure. Thirdly, we provide a set of strategies and incentives for global corporations in partnership with governments to redirect corporate tax revenues into infrastructure spending, that would otherwise be evaded or avoided. Finally, we critically review the positive impact Multilateral Developement Banks and infrastructure investment platforms may have for both investors as well as host governments to obtain higher returns on investment, finance environmentally sound infrastructure projects and to potentially reduce inequality, specially for the bottom decile.

The paper is organized as follows. Section 2.2 offers some stylized facts regarding the infrastructure funding gap in the US. Section 3 describes the data and empirical strategy that we employ, while Section 4 reports our main results about the relationship between income inequality and infrastructure spending growth. Section 5 discusses key policy proposals about how to fund infrastructure investment, that relate to our main empirical results. Finally Section 6 is dedicated towards making some concluding remarks and offering suggestions for future research.

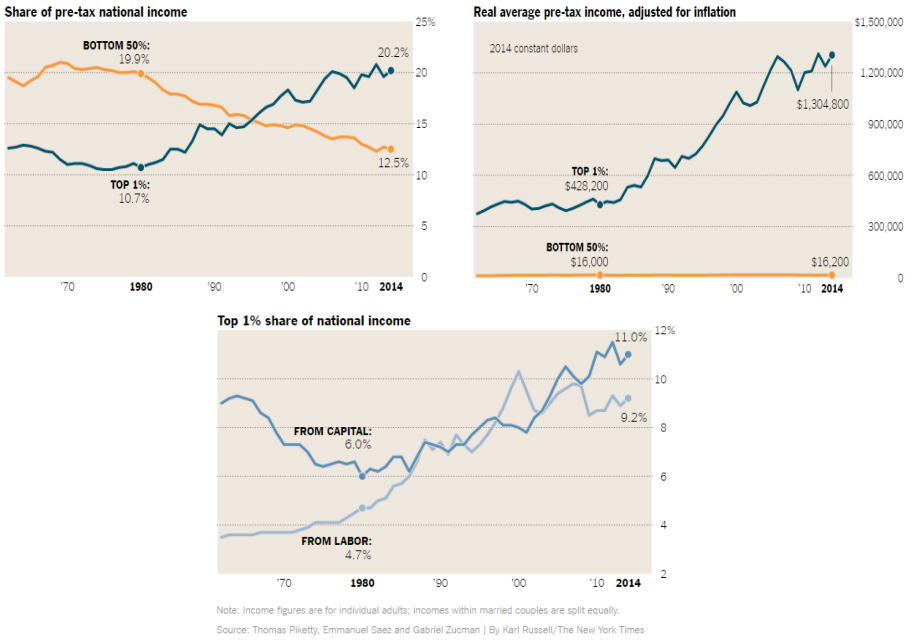
[1] A few papers study the empirical relationship between infrastructure and inequality, typically by pooling aggregate data from both developed and developing countries. See Calderón and Servén (2014) for a survey. However, Wolff and Zacharias (2007) is the only paper - we know of - that looks at US household-level data to uncover such a link. The major difference with our work is that Wolff and Zacharias (2007) focus on two years, 1989 and 2000, and on public consumption while our study covers a longer period and uses data on capital outlays. They find that public consumption is very progressive and that total government expenditures, including on education and on highways, are far more potent in their inequality-reducing effect than taxes.

2 Issues at Stake in the United States

2.1 Rising Inequality

Rising global inequality, especially over the past 20 years, is arguably having the most damaging effect on economic growth, political and social stability in poor, transition, as well as in industrially advanced economies. The results of the 2016 US elections, Brexit, the political instability in Venezuela and the growing migrant crisis in Europe could all be viewed as manifestations of inequality reaching breaking point. The widening gap between the rich and poor is increasingly fueling major social unrest that could have long-term implications not just on a national and regional level scale, but also a global level. Stiglitz (2012) points out that the US economy has grown over the past three decades, but the incomes of the middle class have remained stagnant, while the incomes of 1 percent of the population has steadily risen, even during the peak of the 2007-08 global economic recession. Piketty, Saez and Zuckman (2016) also show that the share of total income in the US has risen by two fold for 1 percent of top earners during 1980-2014, while the bottom 50 percent has experienced no increase in three and half decades (see Figure 1).

Figure 1: Rising Inequality in the US



The widening gap between the very rich and the lowest income earners produce different types of social and political strains on countries, as well as regions and states within countries. d'Hombres et al. (2012) argue that, inequality can result in political apathy and reduce voter participation amongst the lowest income earners, often representing the largest percentage of the population. As a consequence, redistributive measures and efforts to reduce income disparities undertaken by policy makers are ascribed very low priority or left off the political agenda altogether. Income inequality also raises criminal activity within the poorest segments of society when comparing their living standards with the wealthiest 1-10 percent of the population.

"The relevance of the widening of income has not only caught the political and scholarly attention but is heavily discussed nowadays on the streets, with most prominent

manifestation of such protests being the 'Occupy Wall Street'- movement. This movement and its widely-cited slogan "We are the 99%" (see for instance the reporting of the movement by the New York Times, 2011, and also the web blog "We are the 99 percent", 2012) refers specifically to a growing unequal distribution of wealth" (ibid; 2012).

Inequality in access to education also has an adverse affect on income earning potential. The positive effect of education on growth is no longer a mere conjecture but is well supported by empirical evidence. Gary Becker's theory on human capital (1964) shows that education gains can lead to increases in the competencies of individuals and thus enhance their ability to contribute to productivity growth. Given that higher productivity tends to lead to higher wages, the argument is that a more educated society would contribute substantially to higher overall economic growth and also reduce income inequality.

The concept of inequality is relatively easy to grasp, but the real challenge lies in being able to implement appropriate policy measures and to empirically test its impact on long sustainable economic growth, or to determine whether causation runs in the opposite direction. This section provides a brief summary of the main debates on inequality and sets out to link the discussion to the possible relationship between infrastructure and inequality across US states over the past 50 years, given that is the main focus of our research.

The relationship between inequality and economic growth continues to be a contentious issue. The early work by Simon Kuznets (1955), for example, claims that income inequality increases during early stages of economic development, generated by industrialization and that this process declines at later stages. Kaldor (1960) too argues that countries are confronted with a tradeoff between achieving economic and reducing inequality. This was the widely held view amongst economists five decades ago (cited in Bahety et al, 2012). Fields (2001) however argues that the inverted "U" shaped Kuznets curve is not backed up by empirical data. Instead, he maintains that the type of economic growth is what determines whether inequality increases or declines over time, as apposed to stages of industrial development. In sum, Kanbur and Stiglitz (2015), argue that the earlier Kuznets and Kaldor models are outdated in the current context of the global economy. "The new models need to drop competitive marginal productivity theories of factor returns in favour of rent-generating mechanism and wealth inequality by focusing on the rules of the game."

The prevailing view at present (see Bourguignon; 1996, Kanbur and Lustig, 1999, Stern, 1991 and Atkinson, 1997) is that a more equitable initial distribution of income and assets determine long-term economic growth, and that redistribution, albeit without any guarantee, could make an important contribution to facilitate sustainable economic growth. Both Bourgignon (2000) and Piketty (2014) propose progressive increases in the taxation of incomes of the 1 percent of the highest earners to redistribute wealth and reduce inequality as well as to achieve long-term growth (see latter section of the paper on corporate tax avoidance and evasion). Based on more recent literature, the direction of causation is shown to run in the opposite direction as put forward by the Kuznets Curve, from inequality reduction to growth. A further extension of this argument is highlighted in the discussion on financial market imperfections having an adverse effect on initial distribution of wealth and long-term rate of economic growth (see, Aghion and Bolton, 1992 and 1997; Banerjee and Newman, 1993; Galor and Zeira, 1993 and Piketty, 1997). According to adherents of this view, the practice of credit rationing is made on the basis of initial wealth endowment of individual agents who invest in human and physical capital. The problem is that there are enormous differences in the initial endowment of wealth among individuals (inherited from parents) and this heterogeneity is said to shape their investment opportunities (cited in Ehrhart, 2009).

A case study which measures the impact of infrastructure investments on inequality at a regional level in India by Bajar and Rajeev (2015) shows that certain elements of infrastructure such as power and roads tend to exacerbate inequality rather than reduce it. This is due to the fact that public goods are allocated at a flat, albeit subsidized rate across the board, which helps those who are already better endowed with higher incomes and own expensive cars and durable goods such as fridges and televisions. The newly built or improved roads merely enable the more economically well off in rural regions of India to gain easier access to markets. The poorest groups also benefit from the access to improved or new roads, but much less in comparative terms. All farmers, for example are charged a flat rate for electricity, mainly used for pumping water, but this tends to benefit large land owners more than small scale farmers. Leakages as well as poorly designed policy measures are the main barriers to mitigate inequality at a regional level in India through infrastructure investments. A study by Lee et al. (2016) on rural electrification projects in Kenya also reveals similar leakages and the costs of such government programs to outweigh the benefits.

Ashauer's (1989) groundbreaking paper meanwhile reveals that public infrastructure increases total factor productivity in the US. Subsequently, several empirical research papers at a country level have emerged showing that infrastructure positively affects economic growth (see Bom and Ligthart, 2008, and Romp and De Haan, 2007). Cross-country comparative research by Calderon and Serven (2004) and Calderon and Chong (2004) concur with such findings, and argue that infrastructure can at least partially help reduce inequality (cited in Gibson and Roja, 2014). These mixed results stress the need for greater empirical scrutiny to determine the nature of the relationship between infrastructure and inequality. They also impress the challenges involved in trying to establish a general pattern in infrastructure spending for reducing inequality across all countries, regions or states within countries.

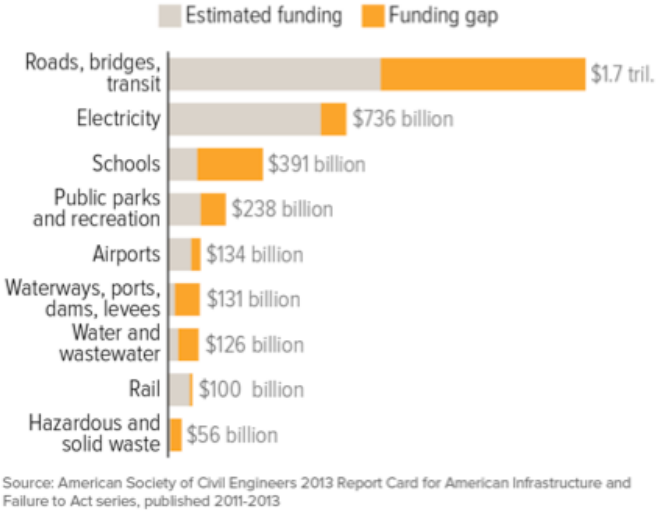
2.2 The Infrastructure Funding Gap

The American Society of Civil Engineers, in its 2013 Report Card for America's Infrastructure, estimates the cost of bringing US infrastructure from a poor grade to a state of good repair (from D+ to B) to be about $3.6tr, of which only 56% is funded. Figure 2 shows that surface transportation and school infrastructure are the items with the largest funding gap ($846bn and $271bn, respectively). Combined together, surface transportation and schools infrastructure account for 69% of the US funding gap estimated to be about $1.6tr (ibid ASCE, 2013).

State and Local governments own the vast majority of public capital (about 96% in 2014 according to the Bureau of Economic Analysis) and account for nearly 75% of total spending designed to maintaining and improving public infrastructure in 2004 (Congressional Budget Office). Schools and surface transportation represent about two thirds of capital spending by state and local governments. While most of the public funding is provided by state and local governmental institutions, it does not mean that the federal government does not play any role in funding infrastructure. For example, it has been well documented that when states received a federal highways grant from the 2009 American Recovery and Reinvestment Act (ARRA), they increased highways spending from 2009 to 2011 by more than dollar-for-dollar with the grant they received (Leduc and Wilson, 2013). Such "flypaper effect" suggests that federal funding has a multiplier effect on state funding and, hence, the federal government could stimulate and foster major infrastructure projects.[2] However, most of this and other related episodes seem to be associated with stimulus plans that aim at boosting

[2]Dupor and Mehkari (2015) show that the education component of the ARRA increased expenditures on public schools at the district level and that 70% of the increase in expenditures came in the form of capital outlays.

Figure 2: Infrastructure needs, funded and unfunded from 2013 to 2020



economic activity in recession times. This pattern of federal funding would suggest that they would likely dry up during periods of economic recovery and expansion. In Section 5, we further discuss how financial innovation can spur long-term commitments to fund infrastructure, over and above counter-cyclical fiscal policy at the federal level.

If one takes a longer-term perspective, two features stand out. First, federal infrastructure spending has fallen from 1 percent to 0.5 percent of GDP over the last 35 years. Second, a similar downward trend has also been noted at the state level, which shows that state and local spending on infrastructure is at a 30-year low and went down from about 3% of GDP at the end of the 1960s to below 2% of GDP in 2014, according to BEA data.

3 Data and Empirical Strategy

The purpose of this section is to examine how inequality may be related to infrastructure spending, using US state-level data. More specifically, the aim is to test whether more inequality in year t is associated with a decline in infrastructure spending growth over the decade prior to year t.

As for our dependent variable, we use the data provided by van der Weide and Milanovic (2014) on state-level Gini coefficients of income inequality, which are constructed using six waves of the Integrated Public Use Microdata Series (IPUMS, see Ruggles *et alii*, 2015), 1960, 1970, 1980, 1990, 2000 and 2010. The main advantage of their data is that it breaks down the overall Gini into a bottom Gini (lower 40% end of the income distribution) and a top Gini (top 40%). This allows detecting possible differential effects of infrastructure spending on inequality at the bottom and top ends of the income distribution.

Our state-level data on infrastructure have been obtained from the US Census Bureau, which provides an Annual Survey of State and Local Government Finances from 1951 to 2008. We compute the annualized real growth rates of expenditures on infrastructure for each of the six decades. The Census Bureau data contain different categories of infrastructure spending on roads, education, health, utilities, correction and judicial facilities. We focus on two categories, highways and higher education. The former includes data on the construction, maintenance, and operation of highways,

streets, toll highways, bridges, tunnels, ferries, street lighting, and snow and ice removal. For this category, we use the capital outlays of direct expenditure on infrastructure, which take into account the construction of buildings, roads, purchase of equipment, as well as improvements of existing structures. The second item refers to operations of local public schools, construction of school buildings, and purchase of school buses. For both items, we compute annualized growth rates in real terms, by subtracting the inflation rate calculated from BEA data (by using the price index of state government investment goods from the US Economic Accounts; see Table 3.9.4. Price Indexes for Government Consumption Expenditures and Gross Investment, at http://www.bea.gov/) from the growth rate of nominal spending.

Table 1 provides some summary statistics for our main variables and Figures 3-4 provide a simplified graphic illustration of the data.

Table 1: Data Summary Statistics

Variable	**N**	**Mean**	**St.Dev.**	**Min.**	**25%**	**Med.**	**75%**	**Max.**
Overall Gini	306	0.42	0.04	0.35	0.39	0.42	0.45	0.57
Bottom 40% Gini	306	0.25	0.03	0.19	0.23	0.25	0.27	0.36
Top 40% Gini	306	0.26	0.03	0.22	0.24	0.26	0.28	0.37
Highways Growth Rate	306	0.04	0.07	-0.44	0.00	0.03	0.08	0.28
Higher Edu. Growth Rate	306	0.07	0.11	-0.89	0.05	0.07	0.09	1.44

van der Weide and Milanovic (2014) provide further description of the Gini data, which we draw the attention to. It is worth pointing out that there is a notable difference in state level government expenditures for highways and higher education. While Figure 4 reveals only a couple of points with *negative* growth rates for higher education spending, Figure 3 shows that in contrast it is much more common for US states to reduce real spending on highways. To support our observation that there is in fact a mismatch in the capital outlay for higher education and highways, we note that while Table 1 reports a larger standard deviation for higher education growth than for highways growth, it also shows that the 25% quantile is zero for highways growth but 5% for higher education spending. In other words, almost all states increased their spending on higher education in real terms, over the period 1950-2010. In contrast, many state budgets saw episodes with decreasing highways spending. In fact, negative real growth rates between -5% and -10% were not uncommon patterns.[3] In Appendix 7.2, we report more summary statistics at the state level.

In addition to our data on growth rates of infrastructure spending, we also add four state-level controls that are potential determinants of income inequality and that have been used by van der Weide and Milanovic (2014). The first two relate to the fraction of household members that are either too young (under age 15) or too old (over 65) to work. The third is the education shortfall for individuals between 15 and 18, while the last measures the fraction of household members with at least four years in college. Like the Gini indices, those four controls are obtained from the IPUMS for 1960, 1970, 1980, 1990, 2000 and 2010.

Our methodological approach involves carrying out a panel regression of overall Ginis, bottom Ginis and top Ginis in year t on real growth rates in infrastructure spending over the decade prior to t, all at the state level, adding the four controls defined above, as well as year and state fixed-effects so as to limit endogeneity biases due to omitted variables. Our goal is to determine whether or not

[3] Alaska in the 1950-60 decade accounts for the most negative growth rates of highways and higher education, that is, -43.9% and -89.4% respectively. On the other hand, the growth rates of highways and higher education in the District of Columbia were -24.4% and 144.1% respectively in the same decade.

Figure 3: Highways Spending Growth Rate and Gini Indices

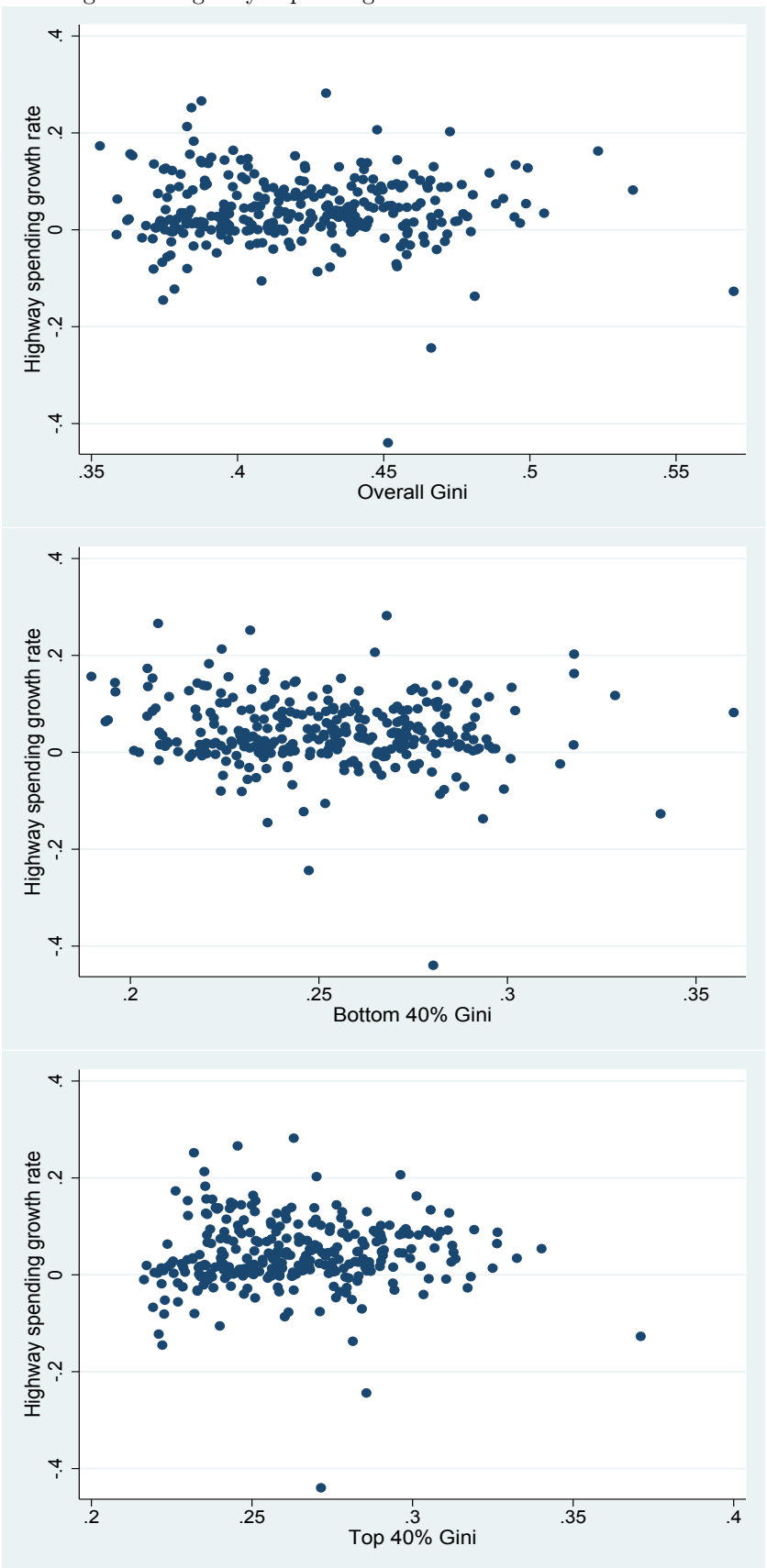
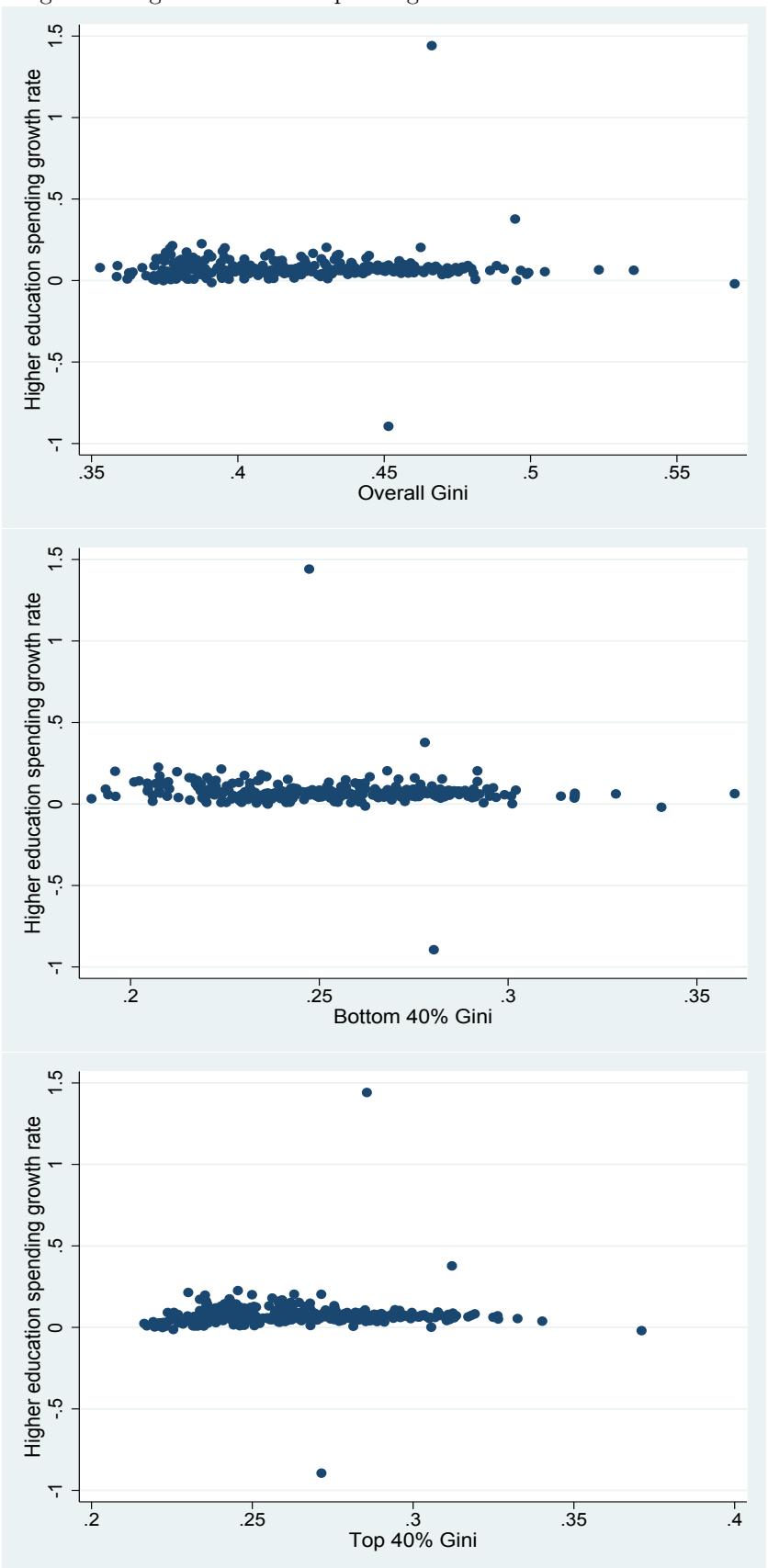


Figure 4: Higher Education Spending Growth Rate and Gini Indices



Ginis correlate with *past* infrastructure spending, and if they do, to determine what the direction of such a relationship would be. More formally, the panel regression is based on the following equation:

$$G_{it} = X_{it}\beta + \alpha_i + \gamma_t + u_{it} \text{ for } t = 1, ..., 6 \text{ and } i = 1, ..., 51 \quad (1)$$

where t refers to a particular year (1960, 1970, 1980, 1990, 2000 or 2010) and i refers to a particular state (from all US states and Washington D.C.). For example, G_{it} is the Gini index for state i in year t. Similarly, included in vector X_{it} are the four controls that come from the IPUMS (fractions of household members that are under age 15 and over 65, education shortfall for individuals between 15 and 18, fraction of household members with at least four years in college) for state i and year t. In contrast, the last variable included in vector X_{it} is the average annual growth rate of infrastructure spending on either highways or higher education (or both) in the decade preceding year t in state i. The variable α_i captures state fixed effects while γ_t captures time fixed effects - that is, the influence of aggregate trends. In most tables, coefficients for year dummies - not reported - turn out to be statistically significant.

4 Causal Link in US State-Level Spending on Infrastructure and Income Inequality

4.1 Panel Regression Results

The main results are presented in Tables 2 to 4. Tables 2 and 3 examine the effects of highways and higher education separately, while Table 4 provides results with both variables included in equation (1). All three tables show that the overall Gini index correlates negatively with infrastructure spending, both for highways and for higher education. In other words, states which have financed high growth rates of spending on either highways or higher education - or both - over a decade turn out to experience lower inequality at the end of the decade. Also, all tables report positive coefficients for the four controls, which indicates that more inequality - especially at the bottom - is observed. This is especially notable in states with a larger fraction of household members that are under age 15 or over 65, with a larger education shortfall for individuals between 15 and 18, or with a larger proportion of household members with at least four years in college.

Disaggregation of the Gini index between bottom Gini and top Gini in Tables 2 and 3 shows a larger effect of highways and higher education spending for bottom inequality than for top inequality. In addition, while coefficients on the four controls are not very different across both tables, the coefficients on highways and higher education do reveal variances: Tables 2 and 3 suggest an even stronger relationship between inequality and highways spending than between inequality and higher education spending. This result, as shown in Table 4, remains valid if both types of infrastructure are added as explanatory variables into equation (1), on top of our four controls and state and time fixed effects. The main insight is that inequality is much lower in states with strong highways spending growth, compared to states with strong higher education spending growth. One possible explanation is the observation, discussed above when commenting on Table 1, that many states have experienced episodes where highways spending has declined in real terms, whereas negative growth rates for higher education spending is very rare. Those episodes featured by a decline in highways spending have been associated with larger increases in inequality, compared to the ubiquitous episodes of decelerating but always positive growth of higher education spending.

It is important to stress that the negative correlation that we document - between Ginis in year t and growth rates of spending on infrastructure in the decade preceding year t - arguably suggests a causal effect from growth in infrastructure spending to inequality. In other words, US states with high growth rates of spending on highways or higher education enjoy lower inequality a decade down the road.[4] Causality, however, has been thought to be possibly running in the opposite direction, as suggested by the earlier literature on inequality and growth. The idea being put forward is that states with high inequality (especially bottom inequality) have lower growth rates of infrastructure spending, either because the richest segment of the income distribution opts out from the financing of infrastructure or because larger inequality triggers more transfers that crowd out infrastructure investments. In order to test that assumption, we have run regressions of growth rates on infrastructure spending on lagged Ginis, together with state and year fixed effects. Unreported results show that the obtained coefficients of lagged Ginis are not significant, even at 10%. Hence the data we use neither reject a causal effect from infrastructure to inequality, nor support a reverse pattern.

Table 2: Effect of Highways Spending on Inequality - State & Year Fixed Effects

	(1)	(2)	(3)
	Total Gini	Bottom Gini	Top Gini
Highways	-0.031***	-0.030**	-0.020***
	(0.008)	(0.011)	(0.006)
Under Age 15	0.759***	0.439***	0.488***
	(0.115)	(0.100)	(0.076)
Over Age 65	0.428***	0.370***	0.249***
	(0.113)	(0.114)	(0.087)
Education Shortfall	0.044***	0.054***	0.012
	(0.016)	(0.017)	(0.008)
College	0.396***	0.519***	0.137**
	(0.082)	(0.086)	(0.058)
Constant	0.067	-0.000	0.052*
	(0.043)	(0.037)	(0.030)
Observations	306	306	306
R^2	0.823	0.633	0.896
State fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As robustness checks, we also report additional results in Appendix 7.1. Most importantly, Tables 5-7 show that our results are essentially unchanged if we add in our regressions the *levels* of infrastructure spending (averaged over decades) on top of the growth rates: the coefficients on

[4] Our interpretation in terms of causality from infrastructure to inequality is reinforced by the fact that lagged growth rates - that is, from years $t-20$ to $t-10$ - of infrastructure spending turn out to be also significant, implying dynamic effects of infrastructure on inequality that last longer than a decade, especially for spending on highways.

Table 3: Effect of Higher Education Spending on Inequality - State & Year Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Higher Education	-0.016**	-0.019***	-0.015*
	(0.008)	(0.004)	(0.007)
Under Age 15	0.743***	0.422***	0.475***
	(0.114)	(0.093)	(0.076)
Over Age 65	0.386***	0.322***	0.213**
	(0.117)	(0.114)	(0.090)
Education Shortfall	0.043***	0.052***	0.011
	(0.016)	(0.018)	(0.008)
College	0.355***	0.474***	0.104*
	(0.083)	(0.079)	(0.061)
Constant	0.077*	0.012	0.062*
	(0.045)	(0.036)	(0.031)
Observations	306	306	306
R^2	0.821	0.631	0.897
State fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

levels are very small (smaller than 10^{-6}) while the coefficients on growth rates are very close to those in Tables 2 to 4 and turn out to be more precisely estimated. This clearly indicates that, according to the data we are using, inequality is affected by the growth rate - not the level - of spending on infrastructure, both for highways and higher education. Second, Appendix 7.1 show results from regressions with state fixed effects but no year fixed effects. From Tables 8-10, we conclude that highways and higher education spending growth only affects bottom inequality, with a negative coefficient, when year fixed effects are dropped. In addition, the resulting R^2s are lower when year fixed effects are not added. We also report in Appendix 7.1 the results from standard OLS regressions in Tables 11-13, which show that coefficients for highways or higher education come with a positive sign now, whenever significant, suggesting that only aggregate time-series trends are captured. Another indication that standard OLS regressions without any fixed effects are misleading are the poor R^2s, compared to the outcome with state and year fixed effects. Such a robustness exercise, we conclude, clearly supports our main results in Tables 2 to 4: with both state and year fixed effects, infrastructure spending on highways and higher education correlates negatively with income inequality in the US from 1950 to 2010.[5]

The panel regression results that we report are far from being economically insignificant. Table 4

[5]We have also run our panel regressions excluding Alaska and DC, which account for all state-year pairs that might appear as "outliers" in Figures 3-4 as already remarked. Our main results turn out to be robust to that change. For example, coefficients for highways and higher education in the regressions of bottom Gini become larger when Alaska and DC are excluded.

Table 4: Effect of Higher Education and Highways on Inequality - State & Year Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Higher Education	-0.012***	-0.016**	-0.013***
	(0.004)	(0.008)	(0.004)
Highways	-0.027**	-0.026*	-0.017**
	(0.010)	(0.014)	(0.007)
Under Age 15	0.751***	0.429***	0.480***
	(0.111)	(0.091)	(0.073)
Over Age 65	0.402***	0.337***	0.222**
	(0.117)	(0.112)	(0.090)
Education Shortfall	0.042***	0.051***	0.010
	(0.015)	(0.018)	(0.007)
College	0.374***	0.491***	0.115*
	(0.086)	(0.083)	(0.062)
Constant	0.076*	0.010	0.061**
	(0.044)	(0.035)	(0.030)
Observations	306	306	306
R^2	0.825	0.638	0.899
State fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes

Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

implies that a one standard deviation increase in the growth rate of spending on highways and higher education would be associated with a fall in the overall Gini of about ($0.07 \times -0.027 + 0.11 \times -.012 =$) -0.003 on average. Such a reduction in the overall Gini over the next 10 years would undo the increase observed between 2000 to 2010, from 0.461 to 0.464. Of course, this implies sizeable increases in spending growth rates, of about 11pp for higher education and 7pp for highways, but such magnitudes have not been unfrequent over the last 60 years. For example, the state of Connecticut increased its growth rate on higher education spending from 3.2% in 1950-60 to 13.6% in 1960-70. The same state increased its growth rate on highways spending from -5.6% in 1970-80 to an astonishingly high 16.4% in 1980-90, hence an increase of about 20pp. Unfortunately, Connecticut has since experienced much smaller growth rates of higher education spending (between 2.8% and 7.7% since 1970) and even negative growth rates for highways spending (between -4.1% and -2.7% since 1990). This state belonged in 2008 to the top 25% quantile of the US states inequality distribution. Similarly, from Table 4 we derive that increasing highways and higher education spending growth rate by one standard deviation would go hand in hand with a fall in the bottom Gini of about ($0.07 \times -0.026 + 0.11 \times -.016 =$) -0.0036 on average. Such a fall in the bottom Gini index would more than undo its increase observed between 1990 and 2000, when it went from 0.260 to 0.262. In other words, a one standard deviation increase in the real growth rate of spending on

highways and higher education would reduce the bottom Gini by 20% more than the overall Gini.

As noticed before, the US Census Bureau data on infrastructure spending contains several categories. We have estimated equation (1) using growth rates of spending on other types of infrastructure. While the resulting infrastructure coefficients are not significant, we still think it is informative to point out that those items correlate negatively with inequality. The growth rates of capital outlays on judicial and legal, public building, and total education (including elementary and secondary) correlate negatively with overall, bottom and top Ginis. The growth rate of capital outlays on air transportation also correlates negatively with inequality, but only for overall and bottom Ginis. Finally, the growth rates of capital outlays on hospitals and health are negatively related to the bottom Gini.[6]

Although the results presented in this paper help us to better understand the relationship between infrastructure and inequality, they are not void of shortfalls. There are several limitations to the data that we have employed. Survey waves are 10 years apart and the size of the micro-census varies between 1% and 5% depending on the survey period. While the overall size of the dataset is an advantage, the variation in size over time may pose concerns.

Even though it may not come as a surprise that our results show that inequality correlates negatively with higher education, the fact that it still correlates negatively but more signficantly with highways spending deserves more attention. Such a pattern is in accordance with the notion that transportation infrastructure improves social mobility because of better access to a large number of employment opportunities and schools. For example, Chetty and Hendren (2015) assert that the geographical location, more specifically neighborhoods in the US where children reside all the way up to early adulthood (to age 20), has a clear impact on social mobility. This could include access later in life to admission to higher educational institutions, employment opportunities, and particularly to filling skilled labor positions. Poor neighborhoods are often characterized by poor quality of teaching in schools, as well as poor transportation access. Approximately 50 percent of the variation in intergenerational mobility in the US, based on their empirical research, is attributed to the causal effects from the exposure of children to residing in a given neighborhood over the first two decades of their lives. While their research does not make any sort of clear linkage to the impact of infrastructure (highways and other means of surface transportation) in neighborhoods within the US on social mobility, implicitly this factor cannot be overlooked. While our results do not establish causal link between infrastructure expenditure and social mobility, they do not contradict the view that infrastructure spending may help reduce inequality through enhancing social mobility.[7]

4.2 Regional Implications: A Counterfactual Exercise

In this section we would like to stress some regional implications of our empirical results. More specifically, a counterfactual exercise has enabled us to determine which states may deemed to be losers and winners in terms of bottom income inequality, because of infrastructure spending growth from 2000 to 2010. We undertake this exercise in two stages. We first group states into four quartiles, based on the distribution of infrastructure growth rates over the decade mentioned above, both for

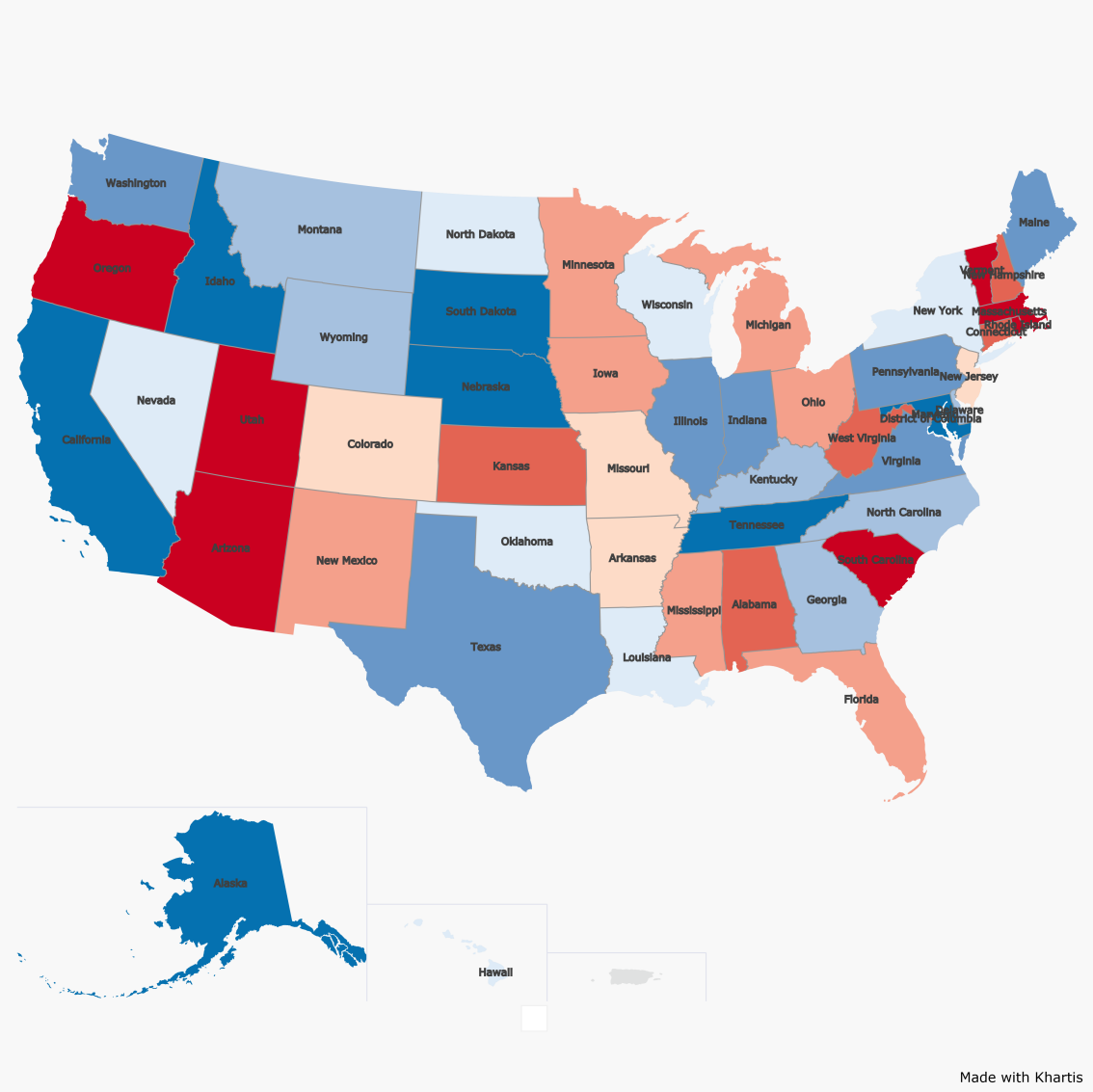
[6] Unfortunately, Census Bureau data on water, electric, gas, and transit utilities are available only since 1977. With fewer data points, a similar analysis is still feasible but is left for future research.

[7] A recent ruling by State Superior Court judge Moukawsher in Connecticut highlights the urgent need for the state to entirely rethink its policy on school funding, which is thought not to be driven by rational motives. See http://www.nytimes.com/2016/09/12/nyregion/in-connecticut-a-wealth-gap-divides-neighboring-schools.html?mwrsm=Email.

higher education as well as for highways. The idea here is that we are willing to group states with similar abilities to fund infrastructure spending. We compute the median infrastructure growth rates for each group and then subtract the actual growth rate from 2000 to 2010. Of course, some states end up with a positive difference because they underinvested in infrastructure, compared to the median state in their group. In the second step, we multiply the counterfactual growth rate deficit/surplus by the regression coefficient of bottom Ginis on highways and higher education, respectively from Tables 2-3. The outcome of this procedure is that we get counterfactual bottom Gini variations for each state in 2010, which gives a sense of the extent to which inequality would have been lower or higher, *ceteris paribus*, had the state experienced the median growth rate of infrastructure spending. The resulting counterfactual bottom Gini variations are reported in two maps, in Figure 5 for highways and Figure 6 for higher education. More details about the grouping in quartiles are reported in Appendix 7.3, for each state in each of the four quartiles. To put it differently, in Figures 5-6, those states with negative variations in their bottom Gini - represented in red - would have enjoyed lower bottom inequality had they invested like the median state in their quartile, while above-median states with positive variations - represented in blue - would have seen higher bottom inequality materialize had they invested like the median state in their group. The magnitudes in Figures 5-6 are not trivial. For example, the inequality losses for Massachusetts and Rhode Island due to underinvestment in highways - see Figure 5 - account for about 5% of the increase in bottom inequality observed from 2000 to 2010. In fact, if Massachusetts and Rhode Island had invested in highways as California in that decade, their level of bottom Gini in 2010 would have been reduced by respectively 25% and 23%.

There are several lessons that one can draw from Figures 5-6 (and Figures 10 to 13 in Appendix 7.3). First, the counterfactual variations in bottom inequality due to highways over/underinvestment are larger than those related to higher education. This observed pattern is in line with what was noted earlier that both that highways growth is more volatile than higher education and that regression coefficients of Ginis on infrastructure growth rate are larger for highways than for higher education. Second, for both items, positive and negative variations in quartiles 1 and 4 exceed those of quartiles 2 and 3. For example, in Figure 5 and in red, Rhode Island - which belongs to the first quartile - would have gained three times more than New Hampshire (second quartile), in terms of reducing bottom inequality, if both states had invested at the median level from 2000 to 2010. On the winner side (in blue), California (fourth quartile) has avoided a rise in bottom inequality twice the size of Idaho (third quartile), compared to what would have happened had both invested like the median state within their respective quartile. Similarly, variations in inequality due to higher education growth deficit/surplus are larger in the first and fourth quartiles than in quartiles 2 and 3. An important limitation is that we are not able to identify the very reason why discrepancies between quartiles arise. This may partly be due to not fully understanding the various determinants of infrastructure growth. Obviously, credit constraints at the state level could explain why underinvesting is more costly in terms of inequality in the lowest quartile. Moreover, increased credit access does not garantee increased spending on infrastructure. Political economy reasons, including short-termism, or lobbying by firms for government subsidies could also lessen the will to invest in infrastructure. A third factor could also be the limited awareness, resulting in part from the lack of documented and convincing evidence, that neglecting infrastructure investment can exacerbate inequality. Lastly, inequality losses due to underinvestment relative to the median state are in the lowest 3 quartiles typically larger than inequality gains in above-median states. This is true for both highways and higher education. This suggests that there is some asymmetry in the sense that infrastructure underinvestment (again relative to the median) is more costly in terms of

Figure 5: Counterfactual Bottom Gini Variations (in ten thousandth) when States are Given the Median Highways Spending Growth Rate in the 2000s. States with Negative (Positive) Gini Variation in Red (Blue).

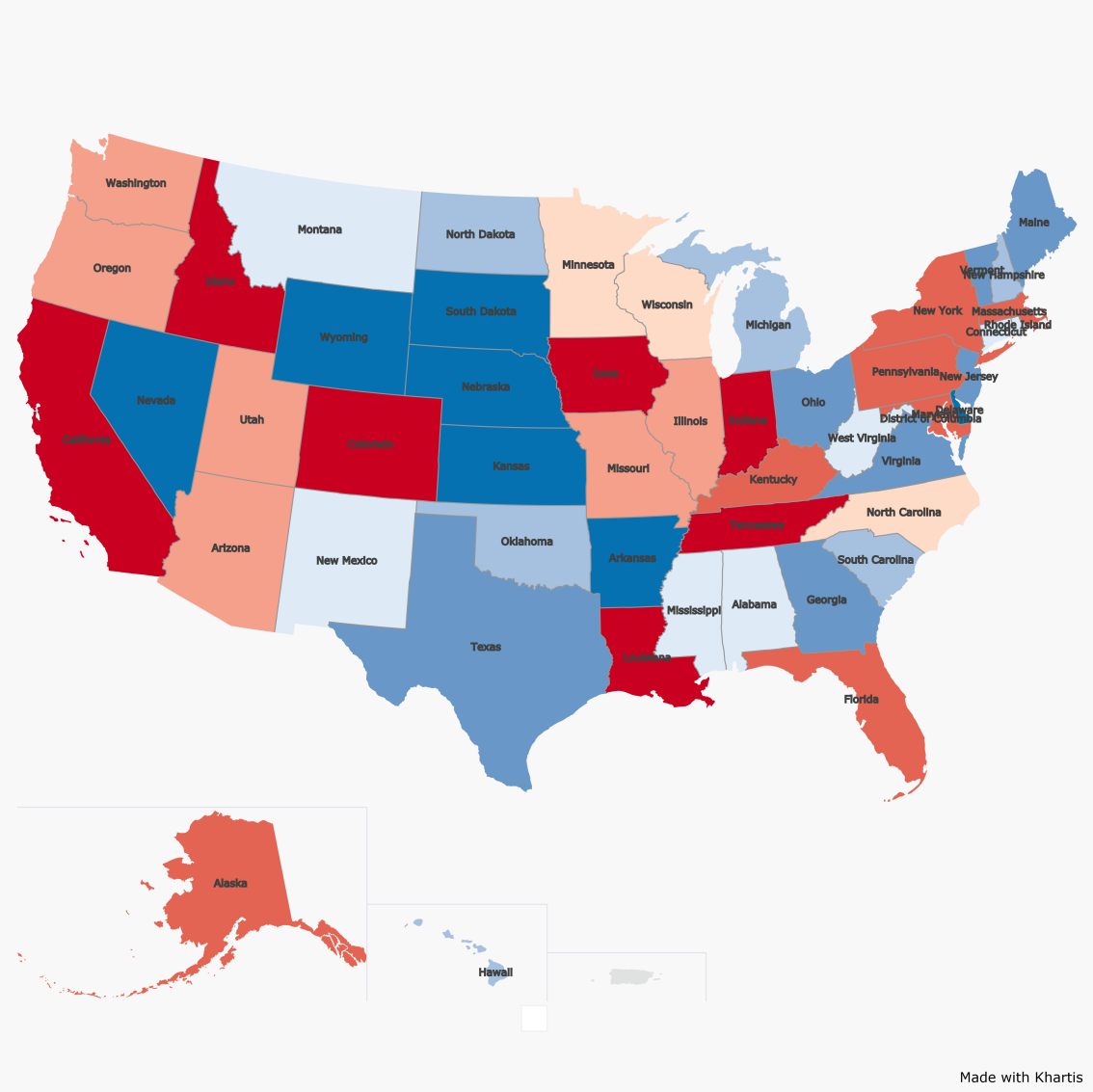


inequality when the level of infrastructure growth rate is lower, except in the highest quartile.

5 Alternative Sources to Public Funding for Infrastructure

Our empirical results suggest that increasing infrastructure investments can be enormously effective as a strategic policy measure to mitigate inequality of various forms, but it is important to recognize that they do not guarantee that this outcome will automatically occur. India's major infrastructure initiative known as the "Golden Quadrilateral Network", for example, which sought to connect the four regions of the country with a modern highways system, has had negligible or no impact on reducing inequality. The main users of this transportation network are large firms to address supply chain and logistical challenges. The other main beneficiaries have been those individ-

Figure 6: Counterfactual Bottom Gini Variations (in ten thousandth) when States are Given the Median Higher Education Spending Growth Rate in the 2000s. States with Negative (Positive) Gini Variation in Red (Blue).



uals who make up the top decile of the population in per capita income terms. The bottom decile has experienced no change. Infrastructure investments by development banks and international development organizations in Palestine has produced similar adverse results (Salamanca, 2014). Besides the effectiveness of infrastructure to generate growth and reduce inequality, a major concern is how to fund new projects. In this section, we review key proposals that help identify solutions to this problem.

5.1 Investing in Infrastructure Through Public-Private Partnerships

We now turn to our analysis of public-private partnerships. We begin by relating how the growth in PPPs is closely connected to the privatization wave of the 1980s and the re-conceptualization at that time of the role of the state in the economy. Second, we highlight how the economics literature

on PPPs is almost entirely framed around incentive issues that were prominent when privatizations were initiated, and is almost entirely silent on the financing issues that are more relevant today. Third, we point to the critical role of a third actor in the PPP relation, the development banks. They are a unique repository of technical expertise and government long-term relations, which make them essential facilitators for the origination of greenfield-investments as well as the financing of infrastructure projects.[8]

Privatization and the Genesis of PPPs

The 1980s and 1990s ushered in a world-wide wave of privatizations and a retrenchment of the role of the public sector in the economy. This was true of developed countries (Western Europe, Japan, Australia, Canada), developing countries (Latin America, Turkey, Malaysia), as well as most transition economies (Eastern Europe, China). Widespread evidence of inefficient management of state-owned enterprises, fiscal and debt crises in many countries, together with new economic thinking on incentives, competition, regulation and the monitoring role of capital markets (see Vickers and Yarrow, 1991) underpinned the new economic consensus emerging in this period around a model of development led by private sector investment and market liberalization. This wave of privatizations inevitably brought about a reduced role of the public sector in infrastructure and opened up the gates for a surge in infrastructure investments funded and operated through public-private-partnerships. In all a total of over 2700 projects were initiated in developing countries between 1990 and 2003 (see Hammami, Ruhashyankiko, and Yehoue, 2006). However, it is now increasingly apparent that the early aspirations of a new investment and development boom have largely been disappointing. Not only has the flow of new PPP infrastructure projects been disappointing, but also the touted greater efficiency of PPPs has not always materialized. The cost of capital of PPPs relative to public funding, and assumption of risk, has proved to be significantly higher than initially estimated. Although risk transfer to the private sector inevitably requires compensation increases in the cost of capital sometimes incorporated more than just compensation for risk. This in turn has driven user costs up disproportionately, which has led to adverse public opinion around PPPs. The bad reputation of some PPP projects has been further exacerbated when the quality of service delivery of some PPPs deteriorated due to budget cuts or other constraints. These reasons partly explain why PPP deal flow has not been as large as some hoped. In raising the broader issue of the role of the state in infrastructure, Estache and Fay (2007) have concluded: "The vision did not play out as expected. Almost 20 years after privatization began to be touted as the solution to infrastructure woes, the role of the large scale private sector in the delivery of infrastructure services in energy, water or transport is far from being as widespread as many had hoped for, at least in developing countries." [Estache and Fay, 2007, page 1].

As a result, while aging infrastructure facilities deteriorate, population continues to grow, and urbanization trends endure, massive and growing infrastructure needs remain unfulfilled. The reality is that the global privatization experiment of the past three decades has held back the supply of new large-scale infrastructure projects in many parts of the world. Moreover, private sector funding of infrastructure will not be forthcoming in sufficient quantity under the current PPP models to meet the future global infrastructure needs. The current private funding levels only meet a fraction of the huge $57tr of global infrastructure needs. Indeed, the global annual volume of infrastructure investments must be multiplied by four or five from current levels, starting immediately, to be able to reach the total investment amounts estimated by the McKinsey Global Institute by 2030. Just as when the "Washington Consensus" emerged as a possible new template for development thirty years

[8]Much of this section is drawn from a forthcoming paper by Arezki, Bolton, Peters, Samama, and Stiglitz, 2016.

ago following the collapse of the central planning development model of previous decades, the world today is at a new cross-roads. Similarly, new institutional innovations are required in the current era that can channel the vast pools of long-term savings parked in low- yielding assets towards higher-return long-term infrastructure assets. Before outlining how a re-conceptualization of PPPs and the role of development banks can remove an important obstacle in the deployment of private long-term savings towards infrastructure assets, we briefly discuss the key economic rationales for PPPs that have been proposed in the existing academic literature.

The Microeconomics of PPPs and the emphasis on Incentive Issues

Most of the economics literature on PPPs is cast in a dynamic bilateral Principal-Agent framework (see Iossa and Martimort, 2015 for an overview).[9] The Principal is the government and the Agent is the infrastructure provider. The early contributions to this literature are motivated by the privatization experience in the UK in the 1980s and the subsequent proliferation of infrastructure service provision under PPP arrangements. The record of publicly provided infrastructure services in the UK prior to the privatization wave of the 1980s was rife with inefficiencies and underinvestment in maintenance and technological upgrades. In light of this evidence, economists not surprisingly pointed to the lack of incentives for the public infrastructure service providers to minimize cost, increase quality, and maintain the infrastructure facility. A basic observation of incentive theory (Mirrlees 1999, Holmstrom 1979) is that the agent providing a service will have stronger incentives to perform if her compensation is tied to performance. Given that public infrastructure service providers were not compensated based on performance it was not surprising that public infrastructure service provision, whether in transport, energy, water, health, education or telecommunication was deficient. A major advantage of privatization, and of the private provision of infrastructure services, is that the provider is compensated based on performance, as measured by profit. However, a major "inconvenience", well recognized by the early proponents of privatization, is that maximization of profit by a monopoly infrastructure service provider exploiting its market pricing power is generally not a desirable social objective. If private provision of infrastructure services can deliver desirable incentives for cost and quality performance, it also introduces undesirable monopoly distortions. Therefore, private provision of infrastructure services has to be accompanied at a minimum by rate and standards regulation, setting up a first unavoidable long-term link between the private service provider and the public regulator. But the PPP economics literature is more specific than that. First, as Donahue (1989) has noted, the benefits of privatization are highest when private providers are also subjected to competition. When horizontal competition is not feasible because the service provider is a natural monopoly, some discipline may be introduced through vertical competition and by periodically organizing an auction for the license to provide the service. Accordingly, the UK and many other countries have introduced fixed term concession contracts that are up for competitive bidding or contract renegotiation when the private service-provision contract expires. An important policy question is then how broad a scope and how long a term to specify in the concession contract. A central insight of the economics literature on PPPs regarding this question is that it is generally incentive-efficient to structure the concession contract by bundling construction and service-provision together with a single private operator. In practice PPPs can take several different forms: there are PPPs that combine building, owning and operating (BOO), building, owning and transferring (BOT), building, rehabilitating, owning and transferring (BROT), rehabilitate, operate and transfer (ROT), and build, lease, own (BLO). According to Hammami, Ruhashyankiko, and Yehoue (2006), from 1990 to 2003 a total of 690 BOO, 317 BOT, 234 BROT,

[9]For a more complete list of theoretical and empirical papers on PPPs and infrastructure finance we refer the reader to: http://www.people.hbs.edu/besty/proj_nportal/articles.htm.

108 ROT, and five BLO PPPs have been initiated. A striking result in the economics literature on PPPs is that whenever there are positive spillovers between construction and operation of an infrastructure facility it is optimal to design the PPP in the form of a BOO or BLO (see Hart, 2003, Bennett and Iossa, 2006, Martimort and Pouyet, 2008, and Iossa and Martimort, 2012 and 2015). In simple and general terms the reason why bundling is efficient is that by assigning construction and operation to the same provider, the latter has strong incentives to construct the facility so as to minimize future operating costs.[10] One drawback of structuring the PPP by bundling construction and operation, however, is that this generally involves a very long-term contract, lasting over 25 to 40 years. Moreover, under such a contract the operator faces significant risk, both during the construction phase and in the operating phase.[11] It is generally not efficient to expose the operator to the entire risk of the project. Again, a central lesson from agency theory is that the optimal contract between a principal and an agent involves trading off risk- sharing and incentives. To the extent that the government is better able to absorb risk it makes sense to provide some insurance to the PPP operator, even if this comes at the expense of incentives to deliver services.

How much insurance should be offered, and what types of risk should be insured is not clear from the existing economics literature on PPPs. With the exception of a few studies (in particular Engel, Fisher and Galetovic, 2008) this topic has not been studied systematically. The main argument in the economics literature against any form of insurance is that investors in PPPs are diversified investors and as such are best able to hold the risk, provided of course that it is properly priced. The argument in favor of insurance is that the government has a greater ability to raise funds through taxation (see Holmstrom and Tirole, 1996) and therefore should take on as much as of the funding cost as is compatible with maintaining incentives for service provision by the PPP operator. Neither of these arguments is fully compelling nor is it always relevant to the constraints faced on the ground by the contracting parties in specific PPPs. It is striking how little attention the economics literature has devoted to the fundamental question of how to structure financing of investments under PPPs, how much should come from private sources and in what form and how much should come from public sources. An equally striking observation is that almost all the economics literature on PPPs frames the contract as a bilateral contract between a private provider and a government agency. One important exception is Dewatripont and Legros, 2005, who emphasize the important role a third party can play as a monitor to improve the efficiency of contract enforcement. In most developing countries the obvious third party is a multilateral development bank, which can play not only a key monitoring role of both the service provider and the government agency, but also a fundamental role in structuring financing efficiently and providing optimal insurance or guarantees to private investors in PPPs.

Origination and Financing: The New Economics and Finance of PPPs

As little as the economics literature has explored the issue of financing of PPPs, the most important concern of private operators and investors in practice is how to structure financing and minimize the cost of capital of PPP projects. Structuring financing of PPPs is not just a technical question; it is what supports the delicate balance between the interests and comparative advantages of the different partners in the PPP. It is not just a question of optimally allocating the different

[10] A survey by Standard and Poor's (2007) suggests that the successful delivery of PPPs remains dependent on a number of critical prerequisites. The survey indicates that, absent these prerequisites, the construction-phase performance differential between PPPs and conventional procurement methods can narrow considerably.

[11] During the operating phase some PPP concession-holders may be subject to significant volume risk such as toll road operators. On the other hand, hospitals, prisons, and other such PPP operations are less subject to such demand risk during the operating phase.

risks involved in an infrastructure project, but also a question of setting up the right governance structure to ensure the sustainability of the project. Given the public goods nature of most PPP projects a fundamental difficulty is to find a way to internalize the positive externalities produced by the project without excessively excluding all the potential beneficiaries of the project. This is, of course, not a new problem; what is new is the institutional context that evolves over time and technological advances. Before we discuss the new institutional context and how it shapes new approaches to the financing of PPPs it is worth mentioning a particularly instructive old model of PPPs from the Middle-Ages in Europe and to contrast it with a successful modern equivalent: "The Bridges were always the weakest links in the road network and the most difficult for occasional labour to maintain. In the course of the twelfth century local efforts began to be supplanted by a more powerful organization of resources, often of a charitable nature." [pp 176] "It was an extremely expensive enterprise to maintain... It was normal for a toll to be levied from those using such a bridge, and sometimes as at the Pont St Esprit, from those using the river under it, to help pay for its upkeep and repair. However, tolls by themselves were not adequate to maintain a bridge. Those who planned to build one did not simply have to look for enough funds to build it in the first place, but for an adequate permanent endowment in land. The first years' rents from the bridge's lands paid for the initial building. The fact that the Pont St Esprit and its associated works took forty years to complete was not because medieval masons could not work any faster, but because it needed forty years' income to pay them. The endowment was then intended to pay for the maintenance of the fabric, of the brotherhood and of their chapel." [From "Power and Profit: The Merchant in Medieval Europe" (2002), Peter Spufford, Thames and Hudson, New York pp 177-178.] A modern equivalent of the medieval "bridge financing" model is the striking example of "value capture" implemented by Hong Kong's mass transit rail corporation (MTR), a private operator with a majority stake held by the Hong Kong government. Just as medieval bridge operators had endowments of land to establish a sustainable revenue source the MTR owns properties in Hong Kong whose value appreciates as a result of the extension of the transit network (see Cervero and Murakami, 2009). As a result MTR is hugely profitable unlike most mass transit systems in the world even though ticket prices are relatively low. In 2013, for example, MTR realized an operating profit of HK $16.3bn (or US $2.10bn) of which revenues from property development, rental and management, and station commercial businesses represented over 50% of the profit (www.mtr.com.hk). This example illustrates how a well-designed PPP can better exploit the comparative advantages of the different partners in capturing revenue to finance infrastructure construction and operation. In MTR's case it was better placed as a private operator to combine property development with transit extension than the Hong Kong government. A well-known problem that all too many heavily-indebted poor countries (HIPC) have faced is that their public finances are just too stretched to be able to support large infrastructure investments that are nevertheless sorely needed. Often the only way for these countries to be able to build an infrastructure facility is to rely on private financing through a PPP. It is most likely the reason why Hammami, Ruhashyankiko, and Yehoue (2006) have found that PPPs are most prevalent in HIPC. In these countries what drives the way the financing of the PPP is structured is basically a very tight government financial constraint. The private funding of an infrastructure project generally comes against a concession contract which assigns future toll revenues to the provider. But this is only the beginning of the PPP financial-structure problem. Two other major issues are: First, how senior the claims of the private investors should be: should private investors be senior secured lenders, subordinated bond-holders or common equity holders? If they are debt-holders, to what extent should this debt be guaranteed and by whom? Second, what are the control rights of private investors and what are their protections against the hold-up

risk by host governments?[12] The reality of infrastructure assets as an investment class is that most investors are only comfortable holding debt instruments, preferably guaranteed, in relatively safe infrastructure assets.[13] This generally means that private infrastructure investors crowd into the relatively safe brownfield infrastructure-asset class (that is, projects that are already built and operating), in which yields are no longer that attractive. Far fewer investors venture into greenfield infrastructure-projects (that is, projects that are still under development), which expose them to construction, regulatory, and demand risk and involve much longer payback periods. For routine transport and energy infrastructure the construction risk is limited, but demand and regulatory risks may not be. For more unusual infrastructure investments, such as nuclear reactors, long tunnels, or major urban redevelopment projects construction risk is much more of a concern. Another consideration in the greenfield space is that most private investors only want to hold senior, secured, and if possible, guaranteed debt. Far fewer private investors venture into holdings of common equity stakes in greenfield projects because the perception of high risks, especially for investors with limited expertise in infrastructure project finance, who are most exposed to adverse selection. One notable example of a long-term investor taking equity positions in greenfield projects is the private equity firm Meridiam (http://www.meridiam.com). Remarkably, Meridiam imposes on its long-term limited partners lock-up periods of up to 20 or 25 years, more than double the typical length for a lock-up period in private equity funds. Also noteworthy is the fact that on a risk adjusted basis the returns offered by Meridiam are actually higher than the average return for brownfield investments. Meridiam typically engages in greenfield projects that have delivered double digit returns for their investors, while a pure brownfield long-term investments yielded only single digit returns. The reason behind the superior performance of Meridiam has to do, essentially, with the different business model it has adopted from the typical leveraged buy-out model in the private equity industry. Under the dominant business model in the industry most of the attention is devoted to privatization of existing infrastructure assets, instead of the origination of long-term investments in infrastructure projects.[14]

We next turn to a discussion of a specific, cutting-edge, example of one of the largest PPP projects ever to be envisaged, currently in the final pre-construction stage in the UK, the Hinkley Point C nuclear power EPR plants project involving the French electric utility company EDF as the private provider, a strategic partnership with China's General Power Corporation (GPC), and the UK government.[15] Early consultations on the project began in October 2008 and the project is now reaching the point when construction is about to begin.[16] Currently, the estimated time for construction of the new EPR plant is eight years, the expected operational lifetime is sixty years, and the total capital commitment for the two reactors is expected to be around Euros43bn.[17] EDF and GPC will respectively own 66.6% and 33.5% of the capital, and the UK government will provide a Pounds20bn loan guarantee.[18] Under this structure most of the construction risk is taken

[12] Toll revenues in developing countries are not well accepted by users, which reinforces the risk of hold-up and expropriation by the Government. In addition, toll revenues are subject to currency risk and the lack of long- term currency hedging mechanisms is a major concern for investors.

[13] Guarantees are rarely available and therefore seldom sought by investors (non-recourse debt remains the norm).

[14] To sustain its rather uncommon business model, Meridiam has invested time and resources in building an in-house multi-disciplinary team with public sector, industrial, and finance expertise.

[15] Nuclear power plants are a very special type of infrastructure, from which private investors shy away due to the enormous construction or operational risks. Outside investors are only willing to step in as liquidity providers under the condition that the totality of risk is assumed by another stakeholder (State or other entity).

[16] See: http://www.edfenergy.com/energy/nuclear-new-build-projects/hinkley-point-c/about.

[17] See the European Commission Press Release IP/14/1093 on 8 October 2014.

[18] Under a previous financing structure which received support from the European Commission, construction costs were estimated at around Euros31bn with debt financing of about Euros22bn covered by the State guarantee.

on by the equity owners in the PPP, and credit risk is transferred to the UK government, who is a stronger counterparty than any private default protection seller. Moreover, a particularly innovative feature of the PPP is the so-called contract for difference provision that locks in and front-loads the future prices for the Hinkley Point C electricity sold by EDF to the national grid. This provision, in effect, allows the private provider and the UK Government to share operating risk, and thus lower the cost of financing of the project.[19] It is worth mentioning that the guarantee fee has been significantly raised by the European Commission in order to "reduce the subsidy" by the UK Government, although the subsidy had been authorized by the Commission on the grounds that the "UK authorities demonstrated that the support would address a genuine market failure". The impact of the project on EDF's balance sheet and risk profile is so large that EDF has decided for risk management purposes to increase its liquidity holdings by selling Euros10bn of assets over the next five years.[20] This example is remarkable not just for the sophistication of its financial structure and risk allocation, but also for its sheer size and the particularly long-term commitments that may be involved in infrastructure projects: more than seven years from the first consultations to the beginning of construction, eight years of construction, and sixty years of operating income. Such an investment asset is obviously only well suited for long-term investors, which besides the operating companies include pension funds, insurance and re-insurance companies, and sovereign wealth funds. The example is also noteworthy for its reliance on guarantees to lower the cost of debt financing. The UK Government is, of course, in a position of being able to extend such a guarantee, and thus to significantly lower the cost of capital for such projects. A simple back-of-the-envelope calculation gives the following ball-park number: assuming that the required interest payment on a thirty year AAA bond is 3%, and the required interest payment of a thirty year bond without the guarantee is 5%, the yearly interest savings to service the AAA bond versus the non-guaranteed bond for a total issue of 17 billion pounds is approximately $850 - 510 = 340$ million pounds. It should be noted, however, that extending a guarantee is not costless, and the present value costs of such government guarantees is generally underestimated, as Lucas (2014) has shown, since these guarantees are typically not priced under private sector, fair-value, accounting rules, which take into account compensation for risk and therefore yield cost estimates that are significantly higher. Obviously, proper risk management should identify the limits beyond which governments or MDBs can no longer efficiently extend guarantees. Development banks and foundations can play a critical in fostering infrastructure investment especially by alleviating governments' financial constraints and risk sharing. Development banks and foundations are however also constrained. In the aftermath of the global financial crisis of 2008, central banks around the world have been called to the rescue and have expanded their balance sheet in order to help ease financial conditions especially through private bank credit channel. That led to an extraordinary expansion of central banks' balance sheets which effectiveness has been put into question considering that the anemic credit recovery of private banks. At a time when the debate in the US in particular is switching toward how to unwind the balance sheets of central banks, it is perhaps time to think about whether and how development banks can take the lead and act on the more "structural" margin including through alleviating infrastructure bottlenecks. For that to happen, development banks and foundations would need to increase the leverage their own capital tapping into available vast pools of long-term savings or allow for greater and innovative co- financing of projects including through allowing private investors. The Bill and Melinda Gates Foundation has over the years been a very pragmatic and innovative partner in solving global and regional challenges mainly in the health

[19] See the European Commission Decision of 08.10.2014 on the Aid Measure, which the United Kingdom is planning to implement for Support to the Hinkley Point C Nuclear Power Station, SA.34947.

[20] See: http://www.ft.com/intl/cms/s/0/fcd6a462-7578-11e5-a95a-27d368e1ddf7.html.

sector, offering guarantees or concessional loans alongside development banks. Further involvement of development banks and foundations can help scale up global infrastructure investment not just through alleviating governments' financial constraints. Most PPPs are too small in scale for large long-term institutional investors, such as pension funds, reserve funds, and sovereign wealth funds, who do not always have dedicated infrastructure experts in their management teams. Considering the breadth and depth of development banks' expertise in infrastructure, development banks can facilitate the origination and the development of large scale projects and reduce political risk associated with the project. For that development banks need not only respond to the needs of governments around the world but also follow to the leads of private investors whom may also help identify viable projects. Considering the opportunity presented by the large pools of long-term savings, the provision of expertise in origination, guarantees and an improved institutional framework by development banks can be a catalyst for more private sector involvement and in turn scaling up the volume of PPPs. The scaling up on infrastructure can lead to the densification of networks both domestically and regionally. Indeed, the degree of "bankability" of individual infrastructure projects rests on the whole infrastructure network. Development banks can help governments and private actors internalize those externalities and further alleviate financial constraints.

Multilateral and Regional Development Banks and Infrastructure Platforms

Before we describe the various existing infrastructure investment platforms it is useful to discuss in broad terms the mandate and role played by multilateral development banks (MDBs). Figure 7 presents some existing examples. As initially envisioned, the broad mandate of MDBs was to provide financial support to investments in human and physical capital that promote development, and that otherwise would not able to attract private funding (see Buiter and Fries, 2002 and Levy Yeyati, Micco and Panizza, 2004). Most of the early investments of development banks went to funding public sector projects, but the interpretation of their mandate evolved as many developing economies transitioned away from large public sectors towards more market-based models.[21] With the growth of the private sector, and the shift towards privatization of infrastructure, MDBs increasingly participated as co-investors along with other private sector investors. However, MDBs remain different from ordinary commercial banks in a number of respects. First, the mandate of MDBs remains to stay away from commercially viable investments, so as to avoid inefficient crowding out of private lenders. Second, the criteria they apply for investment involve an important assessment of the social and economic development impact of the project, possibly including inequality measures. Third, MDB debt is senior to other commercial creditors according to existing conventions. Fourth, as repeat players and essential partners in infrastructure investments, MDBs are in a stronger position to be able to enforce repayment on their debt. MDBs can thus play a critical disciplining role, without which private lenders would not be willing to invest. MDBs could further leverage this disciplining role, as we shall argue, and act more as catalysts stimulating private investment in projects that are currently perceived as too risky, with too few protections for private investors. To fully play that role, however, MDBs must venture further in the direction of extending guarantees to private investors, so as to bring in more private capital.

[21] The European Bank for Reconstruction and Development and the International Finance Corporation, in particular, have reoriented their loans mostly to the private sector.

Figure 7: Development Bank Investment Platforms for Potential Infrastructure Investments

	EIB	EBRD	WB	AIIB	NDB
Official purpose	Bring about European integration and social cohesion	Using investment as a tool to help build market economies	Reduction of worldwide poverty	Provide finance to infrastructure projects in the Asia Pacific region	Mobilize resources for infrastructure and sustainable development in BRICS and other emerging economies
Shareholders	EU member states	64 countries and 2 EU institutions. USA is the largest shareholder	188 member countries. Top 5 countries by voting power are USA, Japan, China, Germany, and France. Thus, dominated by American, European and Japanese interests	22 Asian countries. China holds the major stake	The "BRICS" countries: Brazil, Russia, India, China, and South Africa
Inception and initial mission	Nonprofit long-term lending institution established in 1958 under the Treaty of Rome	Founded in April 1991 during the dissolution of the Soviet Union. Support countries of the former Eastern Bloc in the process of establishing their private sectors	One of the key Bretton Woods institutions founded in 1944 to increase cooperation on an international scale	Founded in 2014 as China was frustrated with the slow pace of reforms and governance of the American, European and Japanese members	The idea for setting up the bank was first proposed in 2012 at the 4th BRICS summit; The agreement on provision of legal basis was signed in July 2014, and was entered into force in July 2015. The NDB was formerly known as the BRICS Development Bank

5.2 Sovereign Wealth Funds and Long-Term Investments in Infrastructure

Sovereign wealth funds (SWFs) managed $7.1tn in 2014, an amount that has more than doubled since 2007 (SWF Institute 2015, see http://www.swfinstitute.org/). If just 10% of the SWF assets were to be earmarked for infrastructure development, these needs would be easier to meet and the impact on global GDP growth, inequality and poverty reduction could be bigger than other sources of large-scale private investments. This mismatch is particularly puzzling because the savings, highly concentrated among SWFs, insurance companies, as well as pension funds, and the required investments share similarly long-term investment objectives. Having matching time horizons between the investors and the projects reduces the need for financial intermediation,[22] which removes another layer of complexity and cost in project financing. So what's stopping those trillions of dollars from finding these strong investment opportunities, such as in infrastructure? There are numerous obstacles that prevent the efficient flow of capital from the countries with high savings to the countries with strong investment opportunities in infrastructure. Inadequate institutions, information asymmetries, adverse incentives, and poor governance are just a few examples. In many developing countries - especially commodity-exporting and agriculture-based economies in Africa - political risks, poor governance, corruption, and conflict present even higher hurdles to infrastructure investment. Although the objectives of all SWFs are not typically short-term oriented,

[22] Pension funds typically match their liabilities to investment assets to minimize reinvestment risk. However very long life-span assets have limited supply. Through financial intermediation, short-term assets can be linked together to synthetically create long-dated assets. Pension funds incur additional cost for the financial institutions to assume the reinvestment risk in this maturity transformation process.

the main strategic focus of certain types of SWFs require ready access to liquid assets to address foreseen or unforeseen market disruptions. For example, SWFs from commodity-driven economies such as Chile (a major exporter of copper) function as a stabilization fund in case of a commodity price crash. SWFs that function primarily as a stabilization fund are reluctant to seek riskier investments, such as equity stakes in private companies or real estate, let alone invest in long-term infrastructure projects, especially in countries that appear risky for the reasons listed above. Even if such investments yield higher returns on average, the lack of access to liquidity of such investments is an obstacle, as they may pose a problem of obtaining immediate access to financial resources when urgently required. Other types of SWFs, including monetary reserve investment funds and savings funds share similar liquidity concerns, but to a much lesser degree (see Peters, 2016).

The concern about access to liquid assets is very legitimate; however the mismatch in savings and need for investment could be nonetheless still be addressed if SWFs were to earmark even a relatively small percentage of their total assets under management to infrastructure investments. Because of the anticipated growth in SWF assets, an investment size of as little as 5% would be a meaningful step in bridging the savings to the investments and to national economic growth, global GDP growth and to transforming the lives of hundreds of millions of peoples, particularly across developing countries. Apart from the problem of liquidity that deters long-term investors such as SWFs to invest in infrastructure, some of the main obstacles to infrastructure investments listed earlier are also gradually disappearing. In general terms, the obstacles posed by infrastructure investments are shrinking and there is a growing awareness among fund managers that traditional patterns of safe investment strategies by SWFs are inadequate due to very low, if not negative, real yields as a result of global central banks' interest rate policy and quantitative easing programs. The mindless "search for yield", while exposing SWFs to considerable risk, has proven to be even more counterproductive due to a lack of consistent investment strategy. Moreover, investing in conservative instruments such as treasury bills to avoid liquidity risk and commodity boom and bust cycles is not particularly effective in the long term: SWFs can only stabilize their wealth if financial assets are held in counter-cyclical investments (countercyclical, that is, to the underlying asset, e.g. the price of copper) which these are not. Otherwise, in a prolonged commodity price decline, the assets under management can experience significant drawdown. On the other hand, large-scale infrastructure investments offer advantages of stable long-term real returns that have low correlation with other asset classes (Inderst 2010).[23]

Because large infrastructure initiatives can be a part of the government stimulus programs during a downturn when the private sectors are scaling back, infrastructure investment may exhibit countercyclical patterns that carry significant diversification effects. This type of countercyclical investment initiative has been unfolding in China since early 2015; to combat declining economic growth, the Chinese government has been accelerating 300 infrastructure projects valued at $1.1tr in order to spur economic growth, according to Bloomberg News. Private sector funding would meaningfully benefit from government support during periods of economic slump. Though it is has long been recognized that the long term returns to equity exceed those to debt by more than an amount that can be justified by risk aversion (the equity premium puzzle), only a small - if growing - number of SWFs have started to allocate a larger share of their assets to equity investments. Beyond these two broad asset classes, however, there has been relatively little exploration into other very large asset classes, such as real estate or infrastructure. These asset classes, however, are natural

[23]Of course, the overall return to such investments will typically depend on the overall economic performance of the country.

targets for SWFs, given their long-term orientation.[24]

5.3 Corporate Tax Revenues from Repatriated Profits

New large sources of funding for infrastructure are required, beyond those linked to sovereign wealth funds, pension funds, regional development banks and by institutional investors. The world needs to increase its investment in infrastructure by nearly 60 percent until 2030. To reach those aggregate targets, investment in infrastructure will have to increase from $36tr over the past 18 years to $57tr over the next 18 years. One strategy certainly worthy of consideration is to earmark corporate tax revenues on repatriated profits earned by foreign multinational in developing countries, and also in mature markets, to finance infrastructure development in the host country. This amount could be sizeable: The Securities and Exchange Commission filings from the 500 largest American corporations, estimated that these companies hold at least $2.1tr in accumulated profits offshore. This could generate $620bn in US taxes if they repatriated the funds (cf http://www.uspirg.org/sites/pirg/files/reports/USP%20ShellGames%20Oct15%201.3.pdf).

Tax revenues from repatriated profits could be earmarked for specific infrastructure investments while companies repatriating profits could be minority investors in such long-term infrastructure projects. If even half of the $2.1tr were repatriated, the resulting $310bn could go a long way in rebuilding the crumbling US infrastructure as well as investing in infrastructure in developing countries. Sources for infrastructure funding within the euro-zone and in developing countries could be generated similarly. Developing country governments could also incentivize up-front tax payments on estimated corporate profits. Thus far, most multinational corporations have been making use of public infrastructure at zero cost. Creating partnerships between corporate investors and host governments could provide urgently needed funds to finance infrastructure. Due to the recent media attention generated by public scandals such as the Swiss Leaks, Luxembourg Leaks, and more recently, the Panama Papers, and the ensuing mandate by the G20 to the OECD to reform international tax standards, MNEs are under heavy scrutiny to provide full disclosure on earnings, transfer pricing, profits, adhere to regulations and comply with local and international laws. The positive publicity derived from corporate social responsibility by investing in infrastructure in poor countries could substantially compensate MNEs for the diversion of tax payments to an infrastructure fund. In addition, this option would allow private corporations to use infrastructure investments as an important savings vehicle.

To avert risk of corrupt host country governments usurping the funds, regional development banks could guide such funds via an infrastructure investment platform. RDBs could play a more active role to monitor, enhance transparency, improve governance, serve as guarantor in the event of default and to fulfill an advisory function in such areas as project preparation in private, public partnerships in infrastructure. The European Investment Bank and the World Bank's Global Infrastructure Facility can serve as useful examples, in addition to the newly created Asian Infrastructure Investment Bank, led by China. Skeptics to this novel approach of generating financial resources through new tax policy measures would argue that it would be operationally non-viable to get global MNEs to finance infrastructure investments as a more palatable way to reduce corporate tax evasion and tax avoidance. Paradoxically, most policy makers and leading economists would be fully in favor of

[24] Part of the reason for this failure is institutional: most of the funds have relatively small teams of managers, who mostly have expertise in managing portfolios of liquid, publicly traded securities. They lack expertise in less liquid markets, such as real estate and infrastructure - and may be more reluctant or even unable to assess when these markets have become less risky. This paper focuses on an alternative explanation.

carbon tax as an important instrument to control global climate change, in spite of the laudable achievement of the signing of the Paris Global Climate Change Accord by G20 countries in 2016.

6 Conclusion

The state of US infrastructure is in urgent need of maintenance and upgrading. In view of the large empirical literature supporting the view that investments in infrastructure are key to ensure high levels of standards of living and economic growth, large-scale plans to enhance infrastructure should be given high priority. Our empirical analysis using US state-level data from 1950 to 2010 further shows, perhaps more fundamentally, that future infrastructure investments are expected to lower income inequality as well. While we acknowledge that there are certain limitations to our data and analyses, we still hope that this paper offers a first step to better understand the relationship between infrastructure and inequality. In particular, it is beyond the scope of this paper to address more directly the issue of causality, for example using instrumental variables techniques. Such an important extension is left for future research but we have already undertaken a few steps in that direction. Preliminary results using inequality data set up by Frank (2009), based on annual state-level tax data, turn out to be broadly in line with those of this paper. This suggests that a potentially fruitful way forward is to experiment with the instrument used by Aghion et al. (2009), which relies on data about decisions made by the US senate appropriation committees.[25] We are currently exploring along those lines. Our analyses could also potentially be extended to other data-rich countries from the European Union, Japan, Australia, and to other dimensions of inequality, such as wealth, consumption and also subjective well-being. Perhaps at first glance one expects developing countries to be less amenable to similar panel regressions, due to lack of reliable data. It remains to be seen, however, whether poverty indices and other aspects of inequality, such as limited access to health care, that are increasingly being measured in the South, could also be relied upon to assess the benefits and costs of infrastructure that are strongly needed there. We argue that escalating migration flows are also closely linked to infrastructure, both in relation to the fact that public goods are abundant in the North and lacking in the South.[26]

In view of the many obstacles to generate financial resources needed for infrastructure, especially in the current context of the most recent global economic crisis, where many countries continue to face high levels of government deficit and public debt, this paper puts forward various financial and policy innovations. Such innovations, as those involving the redirection of corporate tax revenues from multinational companies towards infrastructure spending, PPPs, augmented by greater involvement of multilateral development banks (MDBs) and global investment platforms that match long-term investors with long-term infrastructure projects, are going to need further refinements. Therefore these themes that revolve around financing require further scholarly research in order to determine whether or not they could play an even more important role to bridge the ever increasing infrastructure funding gap in both developing as well as developed countries.

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[25] We thank very much Philippe Aghion for suggesting this to us.

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7 Appendix

7.1 Robustness of Regression Results

In this section, we report additional results, first from regressions with both level and growth rate of infrastructure spending (Tables 5-7), second from regressions with state fixed effects but no year fixed effects (Tables 8-10), and finally from standard OLS regressions without any fixed effects (Tables 11-13).

7.2 State-Level Summary Statistics

Figures 8 and 9 report the average annual real growth rates for highways and higher education, respectively, state by state and over the six time periods, where the year indicated at the top of each column is the end year of the decade. For example, the average real growth rate of higher education in Alabama from 1950 to 1960 was 5.1% in Figure 9.

7.3 Counterfactual Exercise: Quartiles

Figures 10 to 13 report the details of the counterfactual analysis, in terms of quartiles.

Table 5: Effect of Highways Spending Growth Rate and Level on Inequality - State and & Year Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Highways Growth Rate	-0.032***	-0.027**	-0.022***
	(0.008)	(0.010)	(0.005)
Highways Level	0.000	-0.000**	0.000**
	(0.000)	(0.000)	(0.000)
Under Age 15	0.739***	0.494***	0.444***
	(0.113)	(0.103)	(0.076)
Over Age 65	0.434***	0.352***	0.263***
	(0.113)	(0.110)	(0.086)
Education Shortfall	0.045***	0.051***	0.015*
	(0.015)	(0.017)	(0.008)
College	0.398***	0.512***	0.142**
	(0.083)	(0.085)	(0.058)
Constant	0.072*	-0.013	0.063**
	(0.043)	(0.038)	(0.029)
Observations	306	306	306
R^2	0.824	0.641	0.900
State fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes

Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Effect of Higher Education Spending Growth Rate and Level on Inequality - State and & Year Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Higher Ed. Growth Rate	-0.015***	-0.019***	-0.014**
	(0.006)	(0.004)	(0.006)
Higher Ed. Level	0.000***	-0.000	0.000***
	(0.000)	(0.000)	(0.000)
Under Age 15	0.648***	0.436***	0.399***
	(0.108)	(0.104)	(0.073)
Over Age 65	0.397***	0.320***	0.222**
	(0.114)	(0.114)	(0.087)
Education Shortfall	0.047***	0.052***	0.014*
	(0.015)	(0.018)	(0.007)
College	0.367***	0.472***	0.113*
	(0.087)	(0.079)	(0.064)
Constant	0.104**	0.008	0.083***
	(0.044)	(0.038)	(0.031)
Observations	306	306	306
R^2	0.831	0.632	0.904
State fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes

Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Effect of Highways and Higher Education Spending Growth Rate and Level on Inequality - State and & Year Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Higher Ed. Growth Rate	-0.012***	-0.017**	-0.012***
	(0.004)	(0.006)	(0.003)
Highways Growth Rate	-0.028***	-0.022*	-0.019***
	(0.010)	(0.013)	(0.007)
Higher Ed. Level	0.000***	0.000	0.000***
	(0.000)	(0.000)	(0.000)
Highways Level	-0.000***	-0.000***	-0.000
	(0.000)	(0.000)	(0.000)
Under Age 15	0.667***	0.460***	0.403***
	(0.102)	(0.099)	(0.069)
Over Age 65	0.398***	0.312***	0.232***
	(0.114)	(0.110)	(0.086)
Education Shortfall	0.045***	0.048***	0.014*
	(0.015)	(0.017)	(0.007)
College	0.386***	0.487***	0.126*
	(0.093)	(0.087)	(0.066)
Constant	0.103**	0.006	0.083***
	(0.042)	(0.037)	(0.029)
Observations	306	306	306
R^2	0.839	0.650	0.907
State fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes

Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Effect of Highways Spending on Inequality - No Year Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Highways	-0.012	-0.037***	0.015
	(0.017)	(0.010)	(0.019)
Under Age 15	0.763***	0.387***	0.584***
	(0.061)	(0.052)	(0.065)
Over Age 65	0.876***	0.295***	0.898***
	(0.152)	(0.103)	(0.165)
Education Shortfall	0.045***	0.038***	0.034***
	(0.013)	(0.013)	(0.010)
College	0.870***	0.593***	0.602***
	(0.073)	(0.052)	(0.072)
Constant	0.001	0.032	-0.079**
	(0.032)	(0.026)	(0.035)
Observations	306	306	306
R^2	0.685	0.559	0.537
State fixed effects	Yes	Yes	Yes
Time fixed effects	No	No	No

Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Effect of Higher Education Spending on Inequality - No Year Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Highways	0.009	-0.021***	0.019
	(0.015)	(0.006)	(0.012)
Under Age 15	0.742***	0.341***	0.598***
	(0.061)	(0.047)	(0.059)
Over Age 65	0.867***	0.255**	0.916***
	(0.148)	(0.107)	(0.160)
Education Shortfall	0.047***	0.033**	0.040***
	(0.014)	(0.014)	(0.010)
College	0.867***	0.550***	0.626***
	(0.071)	(0.047)	(0.064)
Constant	0.005	0.056**	-0.091***
	(0.030)	(0.026)	(0.032)
Observations	306	306	306
R^2	0.685	0.553	0.542
State fixed effects	Yes	Yes	Yes
Time fixed effects	No	No	No

Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Effect of Highways and Higher Education Spending on Inequality - No Year Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Higher Education	0.010	-0.017***	0.018
	(0.013)	(0.006)	(0.014)
Highways	-0.014	-0.033**	0.011
	(0.018)	(0.012)	(0.019)
Under Age 15	0.762***	0.388***	0.583***
	(0.061)	(0.056)	(0.067)
Over Age 65	0.881***	0.287**	0.906***
	(0.155)	(0.110)	(0.170)
Education Shortfall	0.048***	0.034**	0.039***
	(0.014)	(0.013)	(0.011)
College	0.879***	0.578***	0.617***
	(0.065)	(0.052)	(0.060)
Constant	-0.003	0.038	-0.086**
	(0.032)	(0.029)	(0.037)
Observations	306	306	306
R^2	0.686	0.566	0.542
State fixed effects	Yes	Yes	Yes
Time fixed effects	No	No	No

Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Effect of Highways Spending on Inequality - No Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Highways	0.015	-0.013	0.031*
	(0.025)	(0.020)	(0.018)
Under Age 15	0.237***	-0.003	0.258***
	(0.089)	(0.072)	(0.065)
Over Age 65	0.399***	0.158*	0.471***
	(0.114)	(0.093)	(0.084)
Education Shortfall	0.119***	0.102***	0.064***
	(0.014)	(0.011)	(0.010)
College	0.654***	0.363***	0.470***
	(0.067)	(0.054)	(0.049)
Constant	0.167***	0.132***	0.050
	(0.041)	(0.034)	(0.030)
Observations	306	306	306
R^2	0.355	0.299	0.348
State fixed effects	No	No	No
Time fixed effects	No	No	No

Standard errors in parentheses.
OLS estimation without any fixed effects.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Effect of Higher Education Spending on Inequality - No Fixed Effects

	(1) Total Gini	(2) Bottom Gini	(3) Top Gini
Higher Education	0.028*	-0.009	0.023**
	(0.016)	(0.013)	(0.012)
Under Age 15	0.245***	-0.014	0.283***
	(0.085)	(0.069)	(0.063)
Over Age 65	0.409***	0.149	0.494***
	(0.112)	(0.092)	(0.083)
Education Shortfall	0.121***	0.102***	0.065***
	(0.014)	(0.011)	(0.010)
College	0.663***	0.357***	0.484***
	(0.066)	(0.054)	(0.049)
Constant	0.161***	0.137***	0.038
	(0.040)	(0.033)	(0.030)
Observations	306	306	306
R^2	0.361	0.299	0.350
State fixed effects	No	No	No
Time fixed effects	No	No	No

Standard errors in parentheses.
OLS estimation without any fixed effects.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Effect of Highways and Higher Education Spending on Inequality - No Fixed Effects

	(1)	(2)	(3)
	Total Gini	Bottom Gini	Top Gini
Higher Education	0.027*	-0.008	0.021*
	(0.016)	(0.013)	(0.012)
Highways	0.010	-0.011	0.028
	(0.025)	(0.020)	(0.018)
Under Age 15	0.234***	-0.003	0.256***
	(0.088)	(0.072)	(0.065)
Over Age 65	0.400***	0.158*	0.471***
	(0.114)	(0.093)	(0.084)
Education Shortfall	0.121***	0.101***	0.065***
	(0.014)	(0.011)	(0.010)
College	0.659***	0.361***	0.474***
	(0.067)	(0.055)	(0.049)
Constant	0.164***	0.133***	0.048
	(0.041)	(0.034)	(0.030)
Observations	306	306	306
R^2	0.361	0.300	0.355
State fixed effects	No	No	No
Time fixed effects	No	No	No

Standard errors in parentheses.
OLS estimation without any fixed effects.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

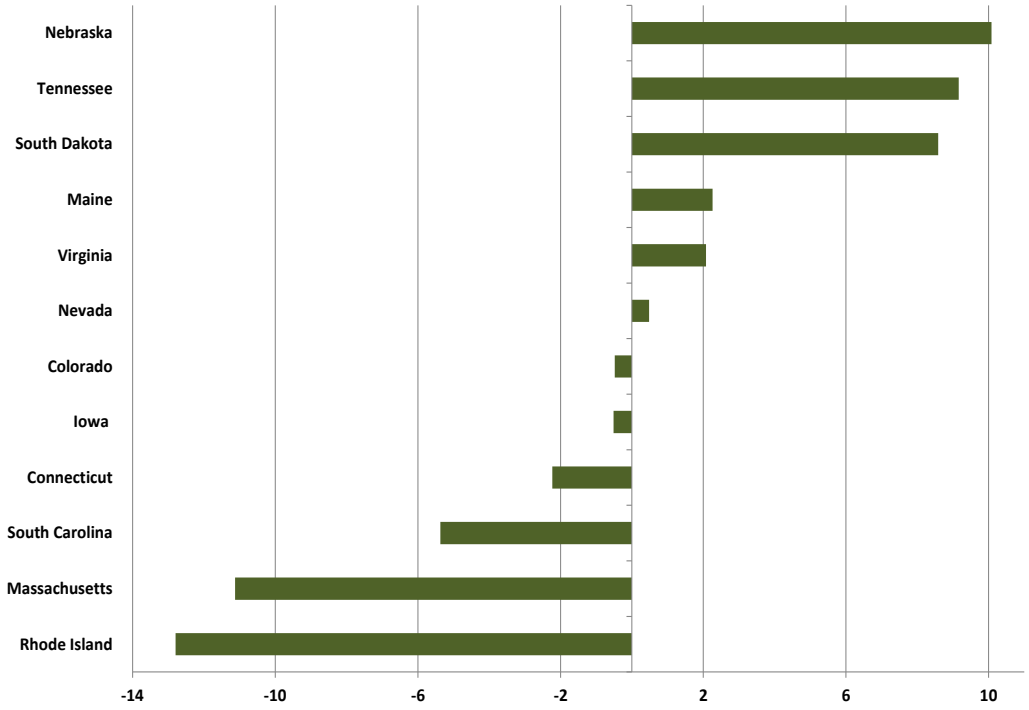
Figure 8: Average Real Growth Rate of Spending on Highways

State	1960	1970	1980	1990	2000	2008
Alabama	0.203	0.020	-0.023	0.040	0.055	0.026
Alaska	-0.440	0.282	0.003	0.011	0.074	0.107
Arizona	0.127	0.053	0.018	0.138	-0.009	0.018
Arkansas	0.072	0.011	0.067	-0.047	0.092	0.014
California	0.137	0.069	-0.106	0.050	0.034	0.128
Colorado	0.089	0.045	0.006	0.037	0.085	-0.035
Connecticut	0.157	0.019	-0.056	0.164	-0.027	-0.041
Delaware	-0.048	0.013	-0.003	0.094	0.048	0.045
Florida	0.130	0.006	0.049	0.020	0.088	0.089
Georgia	0.102	0.026	0.069	0.024	0.061	0.017
Hawaii	0.144	0.122	-0.011	0.033	-0.007	0.041
Idaho	0.085	0.035	-0.007	0.058	0.018	0.057
Illinois	0.252	0.000	0.028	0.019	-0.008	0.102
Indiana	0.156	0.016	0.005	0.003	0.077	0.054
Iowa	0.109	0.013	-0.025	0.024	0.087	-0.035
Kansas	0.113	0.004	0.032	-0.002	0.085	0.003
Kentucky	0.086	0.040	0.065	-0.077	0.095	0.046
Louisiana	0.130	0.007	0.008	0.015	0.033	0.091
Maine	0.125	0.000	0.009	-0.007	0.068	-0.026
Maryland	0.024	0.053	0.017	0.049	-0.038	0.125
Massachusetts	0.063	0.021	-0.052	0.028	0.207	-0.070
Michigan	0.183	-0.004	0.003	-0.007	0.040	0.011
Minnesota	0.104	0.041	-0.018	0.040	0.022	0.039
Mississippi	0.163	0.027	0.017	-0.013	0.093	0.033
Missouri	0.153	0.061	-0.032	-0.003	0.090	0.013
Montana	0.102	0.071	-0.034	0.005	0.061	0.047
New Hampshire	0.173	0.004	-0.010	0.022	0.046	0.002
New York	0.143	0.013	-0.040	0.048	0.054	0.014
Nebraska	0.130	0.009	0.035	0.014	0.070	0.001
Nevada	0.082	0.091	0.031	0.049	0.079	-0.032
New Jersey	-0.017	0.127	-0.122	0.144	-0.017	0.090
New Mexico	0.078	0.046	0.007	0.048	-0.004	0.088
North Carolina	-0.024	0.071	-0.002	0.033	0.084	0.016
North Dakota	0.147	-0.032	0.015	-0.002	0.084	0.015
Ohio	0.213	0.020	-0.067	0.032	0.080	0.008
Oklahoma	0.030	0.075	-0.028	0.032	0.092	0.016
Oregon	0.115	0.017	0.023	0.000	0.028	0.062
Pennsylvania	0.003	0.089	-0.145	0.116	0.045	0.104
Rhode Island	0.153	0.012	-0.081	0.150	0.007	-0.076
South Carolina	0.117	0.005	-0.027	0.074	0.083	-0.051
South Dakota	0.132	0.001	-0.021	0.022	0.084	-0.004
Tennessee	0.115	0.025	0.002	0.042	0.046	-0.003
Texas	0.144	0.031	0.034	0.008	0.064	0.054
Utah	0.136	0.075	0.001	-0.003	0.102	0.026
Vermont	0.266	0.042	-0.080	0.016	0.027	0.067
Virginia	0.050	0.100	0.010	0.033	0.034	-0.026
Washington D.C.	-0.244	0.027	-0.137	0.134	-0.127	0.082
Washington	0.067	0.074	0.014	-0.002	0.045	0.105
West Virginia	0.139	0.087	0.019	-0.087	0.087	0.032
Wisconsin	0.138	-0.003	0.019	0.012	0.099	0.014
Wyoming	0.139	0.017	0.015	-0.001	0.051	0.018

Figure 9: Average Real Growth Rate of Spending on Higher Education

State	1960	1970	1980	1990	2000	2008
Alabama	0.051	0.153	0.050	0.056	0.061	0.077
Alaska	-0.894	0.204	0.092	0.010	0.042	0.073
Arizona	0.108	0.148	0.042	0.087	0.042	0.054
Arkansas	0.044	0.111	0.048	0.061	0.080	0.062
California	0.163	0.059	0.052	0.095	0.054	0.049
Colorado	0.091	0.132	0.035	0.056	0.074	0.044
Connecticut	0.032	0.136	0.028	0.059	0.065	0.077
Delaware	0.070	0.180	0.048	0.056	0.055	0.062
Florida	0.062	0.133	0.050	0.107	0.051	0.073
Georgia	0.203	0.160	0.016	0.072	0.088	0.080
Hawaii	0.201	0.214	0.027	0.044	0.056	0.059
Idaho	0.017	0.130	0.045	0.056	0.074	0.082
Illinois	0.067	0.146	-0.013	0.059	0.055	0.074
Indiana	0.081	0.120	0.003	0.054	0.075	0.046
Iowa	0.051	0.120	0.021	0.057	0.044	0.045
Kansas	0.052	0.110	0.010	0.061	0.058	0.072
Kentucky	0.085	0.153	0.046	0.045	0.069	0.084
Louisiana	0.079	0.099	0.041	0.036	0.072	0.081
Maine	0.047	0.141	0.030	0.082	0.036	0.070
Maryland	0.064	0.144	0.036	0.073	0.071	0.084
Massachusetts	0.091	0.198	0.006	0.080	0.063	0.083
Michigan	0.091	0.108	0.009	0.054	0.075	0.058
Minnesota	0.054	0.122	0.010	0.048	0.068	0.066
Mississippi	0.066	0.092	0.055	0.049	0.083	0.068
Missouri	0.067	0.151	0.013	0.049	0.075	0.065
Montana	0.073	0.081	0.008	0.034	0.107	0.089
New Hampshire	0.079	0.135	0.024	0.047	0.071	0.079
New York	0.106	0.168	0.013	0.088	0.038	0.062
Nebraska	0.067	0.129	0.024	0.054	0.071	0.062
Nevada	0.143	0.126	0.070	0.068	0.094	0.108
New Jersey	0.079	0.162	0.027	0.093	0.057	0.071
New Mexico	0.052	0.121	0.025	0.066	0.074	0.078
North Carolina	0.048	0.124	0.044	0.087	0.065	0.076
North Dakota	0.070	0.094	0.031	0.053	0.043	0.068
Ohio	0.062	0.145	0.035	0.055	0.053	0.062
Oklahoma	0.012	0.121	0.043	0.038	0.066	0.090
Oregon	0.093	0.127	0.031	0.032	0.077	0.075
Pennsylvania	0.080	0.123	-0.001	0.075	0.104	0.063
Rhode Island	0.052	0.175	0.029	0.048	0.043	0.057
South Carolina	0.062	0.138	0.093	0.057	0.061	0.078
South Dakota	0.087	0.095	0.009	0.011	0.055	0.072
Tennessee	0.048	0.167	0.039	0.068	0.059	0.046
Texas	0.081	0.129	0.062	0.061	0.071	0.091
Utah	0.091	0.128	0.040	0.055	0.085	0.086
Vermont	0.226	0.172	0.009	0.066	0.041	0.092
Virginia	0.062	0.129	0.065	0.071	0.054	0.091
Washington D.C.	1.441	0.378	0.007	0.001	-0.020	0.063
Washington	0.057	0.145	0.029	0.046	0.072	0.076
West Virginia	0.048	0.123	0.014	0.036	0.062	0.077
Wisconsin	0.069	0.159	0.010	0.039	0.052	0.067
Wyoming	0.029	0.103	0.038	0.048	0.034	0.099

Figure 10: Counterfactual Bottom Gini Variations (in ten thousandth) when States are Given the Median Highways Spending Growth Rate in the 2000s. Upper Panel: Quartile 1. Lower Panel: Quartile 2.



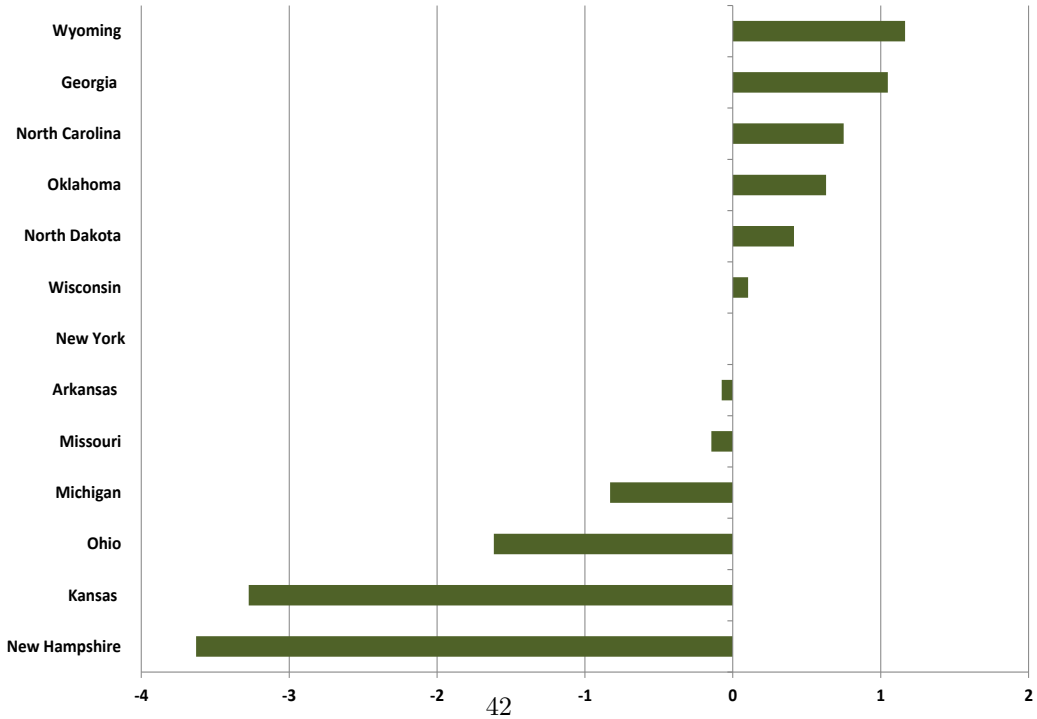
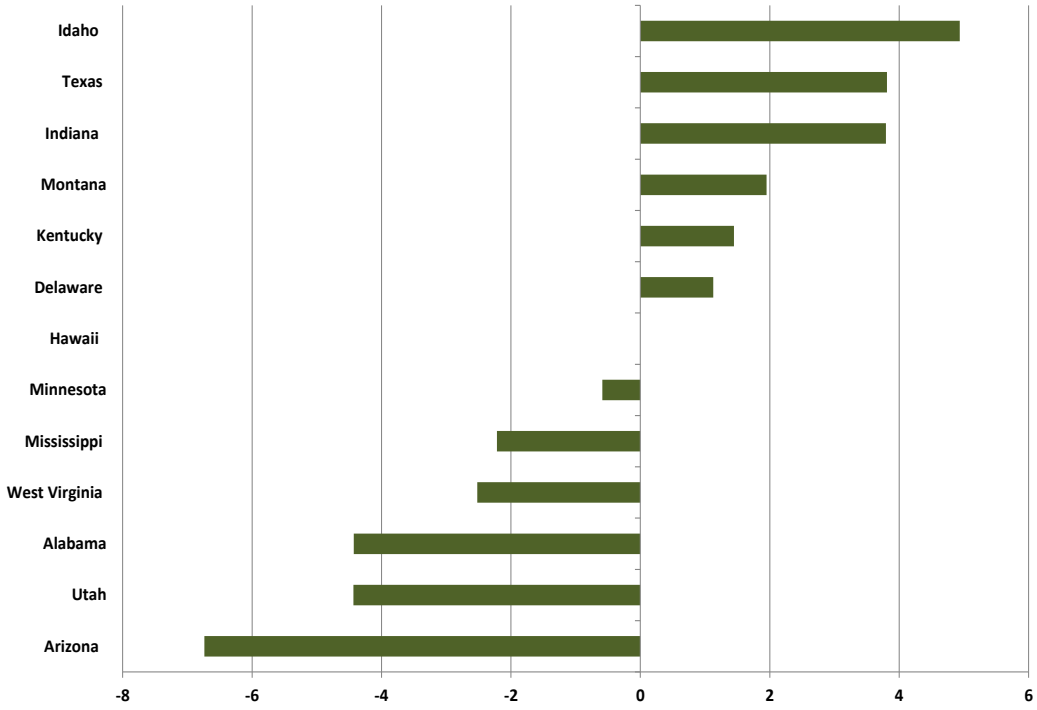


Figure 11: Counterfactual Bottom Gini Variations (in ten thousandth) when States are Given the Median Highways Spending Growth Rate in the 2000s. Upper Panel: Quartile 3. Lower Panel: Quartile 4.



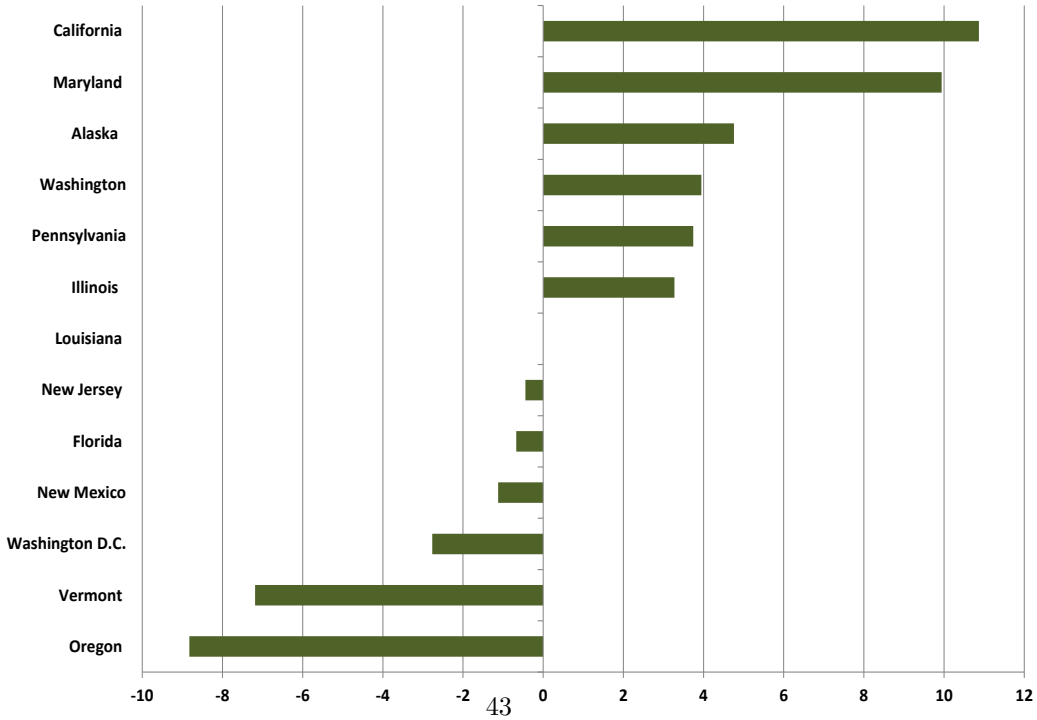
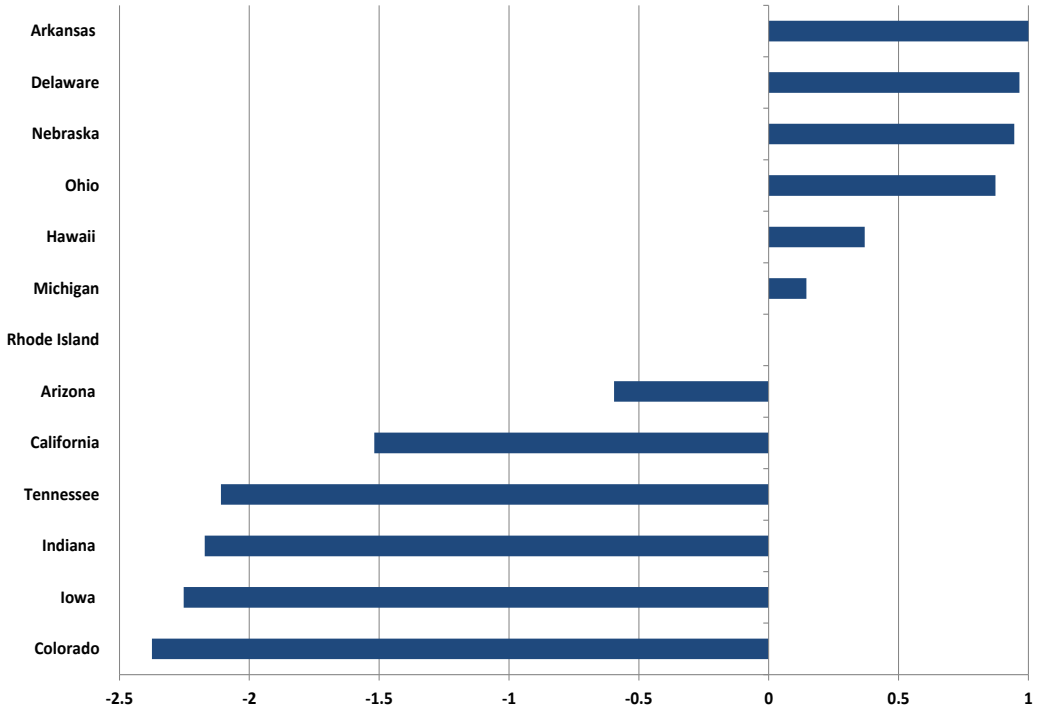


Figure 12: Counterfactual Bottom Gini Variations (in ten thousandth) when States are Given the Median Higher Education Spending Growth Rate in the 2000s. Upper Panel: Quartile 1. Lower Panel: Quartile 2.



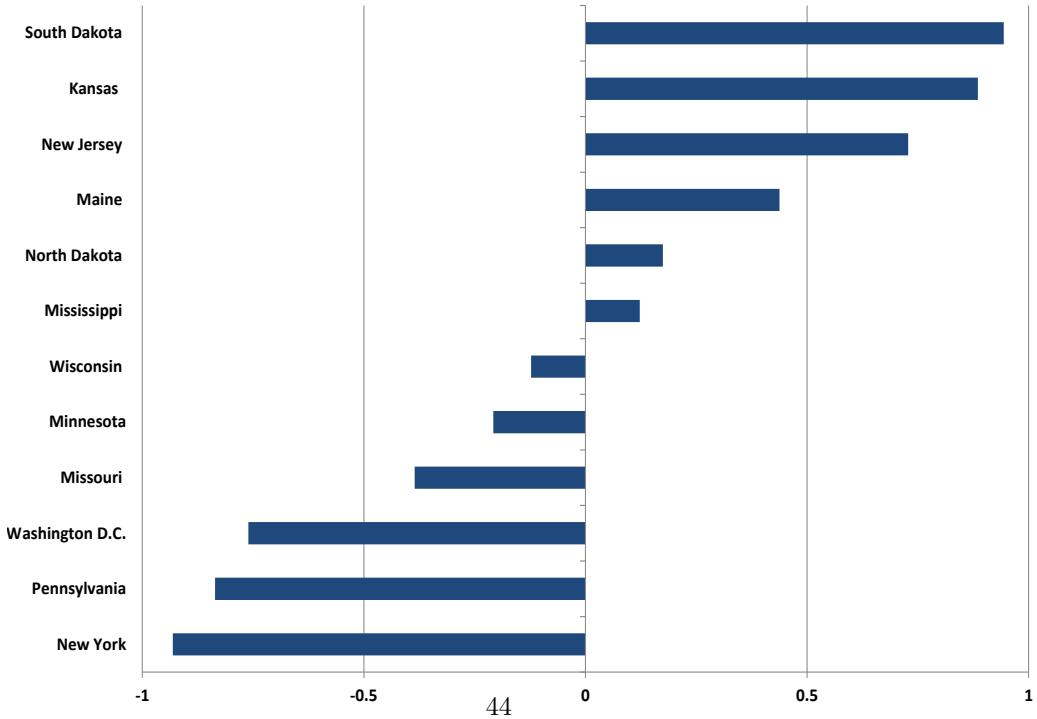


Figure 13: Counterfactual Bottom Gini Variations (in ten thousandth) when States are Given the Median Higher Education Spending Growth Rate in the 2000s. Upper Panel: Quartile 3. Lower Panel: Quartile 4.