PUBLIC CAPITAL MAINTENANCE, DECENTRALIZATION, AND U.S. PRODUCTIVITY GROWTH

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Abstract: Data published by the U.S. Congressional Budget Office show that over the last fifty years expenditures for infrastructure's operations and maintenance (O&M) have roughly equalled those for new capital. We use this dataset to investigate the productive impact of public infrastructure spending taking into account its composition for each government level. We find that a rise (fall) in infrastructure expenditures by states and localities (the federal government) would enhance future productivity growth and that the rise in state and local spending should mainly come from additional O&M outlays in the transport sector.

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"*...urban planners and infrastructure experts say the deterioration of the area's roads is also the result of shortsighted policy decisions by state government officials who have often been more eager to build new highways than repair existing streets*."

(New York Times, 26 July 2009: *Many Failing Roads, Little Repair Money*)

1. Introduction

A number of recent policy reports have stressed the need for increased infrastructure spending in the U.S. in order to enhance long-run productivity growth. The Congressional Budget Office (CBO) has stated that an increased infrastructure investment of $184.8 billion would be 'economically justifiable' (CBO, 2008, Table 2). The National Surface Transportation Policy and Revenue Study Commission's (2008) report has recommended an investment of $225 billion to $340 billion annually across all modes of surface transportation to maintain and upgrade the system. Similarly, a study by the National Chamber Foundation (2005) has estimated that to maintain the current condition of the nation's pavements, bridges, and transit infrastructure, an expenditure by all levels of government of $222 billion ($125 billion in capital investment and $97 billion for operations and maintenance) was needed in 2005. Moreover, to improve highways and transit systems, an investment of $356 billion -expected to *"have a positive benefit/cost ratio and improve the productivity of the U.S. economy"*- is required by 2015.

The goal of the present paper is twofold. First, we aim at investigating the role of public infrastructure spending in U.S. private productivity growth by assessing the impact of capital versus operations and maintenance (O&M) outlays, with the latter broadly defined as the "*…employment of resources […] that preserve the operative state of capital*" (Bitros, 1976, p.919). Our paper therefore addresses a central and timely topic, left unexplored in existing studies on the determinants of U.S. productivity, namely whether the marginal dollar on public infrastructure should be spent for capital or O&M.

Moreover, given that in the U.S. the responsibility for providing public capital is shared across all levels of government, an important question is by whom this dollar should be spent. Conceptually, the rationale for why decentralization of infrastructure expenditures may affect productivity could be through the improvement of allocative efficiency, like better distribution of public services, or productive efficiency by providing infrastructure services at a lower cost. Standard public-finance theory suggests that local public goods, like many infrastructural projects, can be more efficiently provided at the regional level as a manifestation of the Tiebout hypothesis. As discussed in Estache and Sinha (1995), in various sectors of local economic activity, like urban transit, water supply and road maintenance, in which there is little scope for economies of scale, decentralization is the most effective way to deliver service.[1] In turn, a large empirical literature has explored the decentralization question, namely whether a reallocation of public spending from the central to lower levels of government would have a favorable effect on economic outcomes (see, among others, Davoodi and Zou, 1998; Zhang and Zou, 1998; Xie et al., 1999; Akai and Sakata, 2002; Iimi, 2005; Feltenstein and Iwata, 2005; Thornton, 2007). The second goal of the paper is therefore to assess the relative contribution of capital and O&M outlays by the federal government compared to those by states and localities.

Up to now, one of the main reasons for the lack of any systematic empirical investigation on the productive role of public capital maintenance by government level has been the non-availability of reliable and consistent data on the time pattern of O&M expenditures, as well as on their financing sources. Recently, a policy report by CBO (2007) has provided detailed time-series data for public spending on transportation and water infrastructure in the U.S.

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[1] We thank a referee for pointing out to us this paper.

since 1956 along with an extensive documentation. This unique dataset distinguishes between federal and state and local expenditures, and also between spending for capital and O&M. According to the evidence, the average size of total public-sector spending on infrastructure has been around 2.6 percent of GDP with the share of O&M expenditures amounting to 49 percent of total. The special emphasis of our study on the role of O&M spending can therefore be justified by the simple stylized fact that it has roughly equalled capital expenditures in the U.S. over the last fifty years. It is also of interest to note the heterogeneous allocation of these expenditures between the two government levels. Spending for infrastructure capital and related O&M by the federal government and states and localities has on average amounted to 0.7 percent of GDP and 1.9 percent of GDP, respectively, with only 25 percent of federal infrastructure spending directed towards O&M. In contrast, the corresponding share by states and localities has on average exceeded 58 percent.

Using this new dataset for the U.S. we are able to estimate the effects on future private productivity growth for both components of infrastructure spending and for each government level separately. It should be underscored at this point that the assessment of the productive impact of capital and O&M expenditures is conducted here at the aggregate, rather than say the industrial, level. This aggregation is important because of the associated economic and spatial synergies and spillovers generated by government interventions in areas like transportation and water. The *marginal* value of individual projects in these sectors is more likely to show up in national aggregates, like the private productivity growth rate.

The main findings of the paper can be summarized as follows. The U.S. private productivity growth rate would not be substantially affected at the margin by a change in total government spending for infrastructure capital and O&M or by a reallocation between these two components. Yet, a disaggregated inspection shows that a *ceteris paribus* increase in infrastructure outlays by the federal government would have a negative effect on future productivity growth. In contrast, a rise of spending by states and localities, and particularly of O&M outlays, would have a positive effect. Our results coincide with the views expressed by, among others, Hulten and Schwab (1997) who have stressed that state and local under-spending on infrastructure may occur if the presence of spillover benefits from one jurisdiction into another is ignored. The evidence presented here thus sheds some further light in the decentralization question by showing that decentralization of infrastructure spending, and mainly of its O&M component, contributes to future productivity growth. In particular, our findings extend those of Kalaitzidakis and Kalyvitis (2005), who have found that Canada overspends on total infrastructure and on maintenance, and Ghosh and Gregoriou (2008) who proxy O&M spending by the component of current expenditures labelled 'other purchases in goods and services' in World Bank data, and show in a panel of developing countries that these expenditures have exerted a positive impact on per capita growth. The current paper shares a similar methodology with these studies and finds that overall total spending on public infrastructure is about at the right level. Yet, our results also show that decentralizing infrastructure expenditures from the federal government to states and localities may increase productivity growth and that states and localities under-spend on O&M. Our sectoral analysis also indicates that state and local expenditures on transportation should increase and be directed towards O&M. The analysis is in line with the view that infrastructure maintenance is mainly a local task due to greater efficiency in identifying and dealing with maintenance requirements.

The rest of the paper is organized as follows. Section 2 describes briefly the U.S. data on public spending for infrastructure capital and related O&M. Section 3 outlines the empirical strategy and section 4 presents the estimation results. Section 5 provides empirical evidence for the transportation sector and, finally, section 6 offers some concluding remarks.

2. The CBO (2007) dataset on U.S. public infrastructure spending

The CBO (2007) report provides a detailed dataset that covers capital and O&M spending on U.S. transportation and water infrastructure at the federal level from 1956 to 2006 and at the state and local level from 1956 to 2004. Corresponding series come from the Office of Management and Budget and the Bureau of the Census, respectively, and are available at http://www.cbo.gov/publications/bysubject.cfm?cat=21. The data refer to highways and roads, mass transit, rail, aviation, water transportation, water resources, and water supply and wastewater treatment, which produce services under public funding and management that broadly facilitate private economic activity. These sectors have been typically examined by several studies, initiated by Aschauer (1989), that have attempted to estimate the productivity gains stemming from an increase in U.S. public infrastructure.[2] A second advantage of the present dataset is its budgetary nature, which circumvents several of the inherent difficulties associated with the measurement of public capital stocks, like ad hoc assumptions on the service life of public capital assets.[3]

Expenditures *"for the purchase, construction, rehabilitation, and improvement of physical infrastructure"* are defined as capital spending, while expenditures that are *"required to provide the services needed for infrastructure to function and are necessary for the repair and safe operation of*

[2] For a survey, see Romp and de Haan (2007).

[3] The figures provided here can therefore be considered as proxies for gross public capital formation, because they embed additions to the capital stock and replacement of depreciated capital brought about by wear and tear of used infrastructure. Still, the CBO (2007) report recognizes that these figures do not include expenses incurred through the depreciation of the infrastructure that is part of the cost of providing those services.

existing infrastructure" comprise O&M spending.[4] Federal capital outlays include all reported investment spending on physical infrastructure assets, such as construction and rehabilitation, purchase and sales of land and structures, and major equipment. The remaining investment spending in nonphysical infrastructure assets, such as research and development, education and training, and other noninvestment activities, comprises federal O&M spending. Turning to state and local spending, capital outlays cover construction, purchase of land, existing structures, and equipment, whereas O&M outlays cover current operations.[5]

Table 1 gives a synoptic presentation of the main statistics for capital and O&M expenditures by government level, taking account their allocation between transportation and water infrastructure over the period 1956-2004. The general picture shows that total government spending on infrastructure has fluctuated between 2.3 percent and 3.1 percent of GDP with the average O&M share covering around 49 percent. However, there are substantial differences between the two government levels. States and localities have accounted for roughly three-quarters of total government spending and have been devoting

[4] Only scant estimates on the magnitude of these expenditures exist in the literature. Yepes (2004) estimates that infrastructure maintenance in East Asian countries amounted to 2.2 percent of GDP over the period 1996-2005, covering roughly 30 percent of total capital expenditures. The only relevant long-run data source is the Canadian survey on 'Capital and Repair Expenditures' by Statistics Canada, which shows that total public capital maintenance and repair expenditures in Canada amounted on average to 1.5 percent of GDP for the period 1956-93 and comprised 21 percent of total public capital spending. However, the figures from the U.S. and the Canadian datasets are not comparable, because Statistics Canada simply reports expenditures by government-owned enterprises, government institutions-housing, and government departments, in which the government controls more than 50 percent of the voting rights; apart from 'pure' public services, such as departments or their equivalents, this definition also covers other organizations, which operate more independently. The Canadian survey does not classify these expenditures by sector of economic activity and hence is not informative regarding the productive nature of these outlays.

[5] The determination of each of these categories is given in the Bureau of the Census, *Government Finance and Employment Classification Manual* For a detailed description of the distinction between capital and O&M expenditures, see also Appendix B, Web Supplement to Trends in Public Spending on Transportation and Water Infrastructure, 1956 to 2004 (available at

the largest portion of this spending (close to 60 percent) to O&M. In contrast, the vast majority of federal outlays (close to 75 percent) have been targeted at providing new capital (see also Figures 3 to 5 in CBO, 2007). Table 2 summarizes the correlation coefficients between the main components of aggregate public capital and O&M spending by government level.

We close this section by noting that, as pointed out by Holtz-Eakin (1993), during the post-war period the federal government provided strong incentives for new investment via matching grants, which is likely to have resulted in maintenance under-spending by states and localities. Yet, it is often hard to disentangle the financing sources of infrastructure, as several projects in the U.S. states and communities are funded by federal grants with a requirement for matching funds. Co-financing of infrastructure projects by higher and lower tiers of authorities has been usually justified as a means of internalising spillover effects (see e.g. Oates, 1999). For example, the Interstate Highway System was co-financed by the FHWA (90 percent) and matching state funds via the Department of Transportation (10 percent). Yet, as pointed out by several case studies, after the completion of the Interstate Highway System in the 70s transportation issues have increasingly become local in nature. [6]

3. Empirical strategy

A large number of empirical papers on the policy determinants of economic activity have examined the role of government activities for the improvement of long-term economic performance and its key engine, productivity growth.[7] Following this line of research, a strand of the literature has focused on the decomposition of public expenditures in order to

www.cbo.gov/ftpdocs/85xx/doc8517/WebAppendix.pdf).

[6] For a fiscal-federalism approach to infrastructure policy in the U.S., see Hulten and Schwab (1997).

identify the impacts of individual categories on productivity growth. In particular, Devarajan et al. (1996), Kneller et al. (1999), and Bleaney et al. (2001) have classified public investment expenditures into 'productive' and 'unproductive' expenditures based on the sectoral activity involved, and have confirmed that their impact differs dramatically with 'productive' expenditures exerting a positive influence on growth, whereas 'unproductive' ones have virtually no impact.

Up to now, there has not been a systematic attempt to empirically investigate the productive impact of O&M expenditures on public infrastructure, despite the intuitive consensus on their crucial weight and the apparent trade-off with outlays aiming at public capital formation.[8] In this paper, based on Kalaitzidakis and Kalyvitis (2005) and Ghosh and Gregoriou (2008), we develop a time-series framework that relates the capital and O&M components of infrastructure spending to U.S. private productivity growth. More specifically, we aim at examining the links between public infrastructure expenditures as a share of GDP, the corresponding O&M share in these expenditures, and future productivity growth. For instance, a positive (negative) impact of capital and O&M expenditures scaled to GDP on productivity growth indicates that a rise (fall) of these expenditures as a share of GDP would *ceteris paribus* enhance (reduce) future private productivity growth. In a similar vein, a positive effect of the O&M spending share on productivity growth would imply that a reallocation of government expenditures towards O&M would increase future productivity growth. The estimated equation takes the general parametric form:

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[7] See Gramlich (1994) and Gemmel and Kneller (2001) for extensive surveys.

[8] Rioja (2003), Kalaitzidakis and Kalyvitis (2004), and Dioikitopoulos and Kalyvitis (2008) have developed theoretical models that investigate the positive externalities of these expenditures arising through endogenous public capital depreciation and the associated implications for growth. The impact of maintenance expenditures on public capital is usually assessed in the context of cost-benefit analysis and is primarily concerned with road damage and optimal user charges, which rely on

$$productivity\ growth^{US_f} = g(\cdot) + f\left(\frac{G+OM}{Y}, \frac{OM}{G+OM}\right) \quad (1)$$

where $productivity\ growth^{US_f}$ denotes the measure of future private productivity growth (see below for a more detailed discussion), $g(\cdot)$ is a set of controls, *G* and *OM* respectively denote capital and O&M spending on public infrastructure, and *Y* denotes output. Hence, $\frac{G+OM}{Y}$ refers to capital and O&M expenditures as a share of GDP, and $\frac{OM}{G+OM}$ refers to the share of O&M spending in these expenditures. Given the heterogeneous allocation of capital and O&M expenditures between the two government levels, equation (1) is estimated both for total government expenditures and for federal and state and local spending separately in order to assess potential differences in the productive impacts.

We use as the dependent variable the five-year forward moving average of the productivity growth rate, in order to avoid potential endogeneity problems (Devarajan et al., 1996; Kalyvitis and Kalaitzidakis, 2005; Ghosh and Gregoriou, 2008); this definition captures the impact of lagged public expenditures and dampens down the business-cycle effect on productivity growth.[9] To account for the presence of overlapping observations and the associated serial correlation of the residuals, which renders estimation methods like OLS inappropriate, estimation is carried via an asymptotically efficient Generalized Method of Moments estimator that is robust to autocorrelation, with a correction for fourth-order moving-average autocorrelation in the weighting matrix.

In turn, we employ two alternative measures of long-run U.S. private productivity

required repairs and their timing; see Newberry (1988).

[9] We experimented with the percentage change between t+5 and t+1 growth rate and the three-year forward moving average, but the main results were not affected.

provided for the non-farm private business sector by the Bureau of Labor Statistics (BLS). The first measure utilizes the traditional aspect of labor productivity, namely output per hour, whereas the second measure covers multifactor productivity, which also accounts for the role of capital growth in output growth. We include two main variables to control for other effects on the U.S. private productivity growth rate. First, a technology index, based on Fernald (2010), is used to account for changes in technology and variable factor utilization along the business cycle (hoarding) following Basu et al. (2006). This effect becomes more important in the present setup, since capital hoarding is likely to affect the magnitude of O&M expenditures as well as their productive impact. Second, the GDP share of total government revenues is included as a measure of the domestic fiscal stance, which is likely to influence the productivity impact of infrastructure expenditures.[10]

4. Estimation results

4.1. Primal findings

Table 3 presents the results for our first set of regressions that estimate *linear* effects of infrastructure expenditures (capital and O&M) on future U.S. private productivity growth separately for total government, federal government, and states and localities.[11] With respect to the control variables, the technology index enters with a negative sign that is generally statistically significant, whereas the coefficient on revenues is positive and statistically

[10] See the Data Appendix for further details on the explanatory variables. Other potential explanatory variables routinely included in aggregate productivity studies are the levels of R&D expenditures, human capital and trade openness. However, none of these variables entered with a significant coefficient in the estimated regressions, probably due to the relatively short horizon (5-year) measure of future productivity utilized here.

[11] Standard Dickey-Fuller and Phillips-Perron unit root tests were performed for all the variables at hand. The optimal lag was found to be of second or third order in all regressions and the results (available upon request) indicated that all variables are stationary.

significant. Turning to the variables of interest, we observe that they are not significant in the regressions with expenditures by total government. Re-estimating the specifications with expenditures by the federal government only, we find statistically significant negative effects at the 1% level for both variables of interest. According to the estimated coefficients, a fall of federal *capital and O&M expenditures* as a share of output by one percentage point would raise the productivity growth rate by roughly 0.02 percentage points. Similarly, a reallocation of federal spending towards capital spending by increasing its share by ten percentage points (say from 50% to 60% of total spending) would *ceteris paribus* raise productivity growth by roughly 0.009 percentage points. The picture turns opposite when it comes to estimating the effects of state and local spending, as we get positive and significant coefficients at the 1% level for *capital and O&M expenditures* and insignificant coefficients for the *O&M share* in both specifications. The productivity gains are here much larger: a rise of state and local spending in *capital and O&M expenditures* as a share of output by one percentage point would raise the productivity growth rate by roughly 0.04 percentage points

Next, we further investigate the above results by including in our regressions second-order effects of the two main explanatory variables, as in Kalaitzidakis and Kalyvitis (2005), to account for potential nonlinearities in the relationship under investigation.[12] Table 4 reports the results for this second set of regressions, again for each government level separately. The general picture with respect to the control variables remains unaltered. Focusing on the two main explanatory variables, first in the case of total government

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[12] Potential nonlinearities are taken into account for two reasons. First, at relatively low levels of spending the marginal productivity-growth effects of total expenditures are likely to be positive, but the relationship may become negative, when they get relatively large as a manifestation of the Barro (1990) standard inverse U-shaped effect. Second, O&M expenditures are expected to operate by affecting mainly the service life and, consequently, the depreciation rate of public infrastructure. This relationship is likely to be nonlinear in the presence of a standard convex depreciation technology. We also considered including multiplicative terms or higher-order effects of two main variables in our

spending the regression results are improved, since for *capital and O&M expenditures* the first- and second-order effects become highly significant. The same holds for the *O&M share*, for which the first- and second-order effects (negative and positive signs, respectively) are as well significant. These results indicate that the relationships under investigation are nonlinear. To assess the marginal impacts of the two variables of interest, the corresponding derivatives are calculated at the means of the variables and a standard Wald test is performed. The results, summarized in the lower part of Table 4, suggest again that additional total government expenditures on infrastructure, as well as a reallocation between their capital and O&M components, would not affect future productivity growth (zero marginal effects). This finding may well be related to the broad definition of total government expenditures covered here, which include both federal and state and local spending that could be operating in opposite directions regarding their effects on productivity growth.

To further explore this issue we turn to the evidence from regressions with federal or state and local spending. The coefficients on *capital and O&M expenditures* and its square term turn out insignificant, whereas the first- and second-order effects for the *O&M share* are found to be negative and positive respectively, and statistically significant in specifications with federal spending. Interestingly, the marginal effects of *capital and O&M expenditures* and the *O&M share* are now found to be negative and statistically significant at the federal level. In fact, the marginal effects are close and slightly higher relatively to those obtained by the linear regressions. In contrast, the marginal effects for *capital and O&M expenditures* in the case of states and localities are found to be significantly positive and again close to those obtained from the linear regressions. These results suggest that for the period under

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regressions, but they turned out statistically insignificant.

consideration U.S. productivity growth would benefit (a) from a *ceteris paribus* fall in federal government's total spending on infrastructure and from a rise in total expenditures by states and localities, and (b) from a rise in capital expenditures (or, equivalently, from a fall of spending on O&M) by the federal government.

These results naturally raise the question whether a reallocation of infrastructure spending between the federal government and states and localities would have been desirable. Hulten and Schwab (1997) have linked the possibility of state and local under-spending on infrastructure with the presence of spillover benefits from one jurisdiction into another: *"In cases where these spillovers are significant, it is quite possible that state and local governments will under-invest in infrastructure because they fail to recognize benefits realized by people who live elsewhere."* Indeed, Bania et al. (2007) have found that the average state under-invests in productive expenditures, and Cohen and Paul (2004) have found that significant beneficial productive effects exist from interstate spillovers of public infrastructure. We investigate these issues in the next subsection

4.2. Testing the fiscal decentralization hypothesis

The "fiscal decentralization hypothesis" involves the devolution of responsibilities for public spending and revenue collection from the central to lower levels of government. Focusing on the expenditure side, the main theoretical prediction is that decentralization of spending increases efficiency and promotes economic development because local governments have better local information and hence can better match policies with the citizens' preferences (Samuelson, 1954; Oates, 1972, 1993). The literature has emphasized that decentralization of fiscal expenditures may increase the efficiency of local public good delivery, particularly in large countries in which local governments are in a better position than the central government to assess local preferences.

Our approach is similar in spirit to that of Xie et al. (1999), who have introduced theoretically public spending by different government levels in the production function. The authors have shown in a time-series framework that the spending shares by states and localities were consistent with growth maximization over the period 1948-1994 and have claimed that any reallocation between government levels might harm U.S. growth. We follow Xie et al. (1999) and include as a main variable in our regressions the share of state and local spending in total government's capital and O&M expenditures in order to test the fiscal decentralization hypothesis. A rise in state and local governments' share indicates a higher degree of fiscal decentralization.[13] We also run the regressions with the state and local shares in the capital and O&M components of total government spending to reveal any differential impacts between them.

Table 5 displays the estimation results for the impact of expenditure decentralization, in the context of infrastructure, on future U.S. private productivity growth. Consistent with our previous evidence, we find a positive and statistically significant impact of this share on both measures of future productivity growth utilized here. Moreover, examining separately the state and local shares for capital and O&M expenditures, we find that the impact of capital spending by states and localities is insignificant, whereas there is O&M spending has a positive and statistically significant effect. Importantly, these results hold irrespective of whether state and local spending is measured net of federal grants or not (see last row of Table 5).[14] These findings imply that decentralization of infrastructure spending, and mainly

[13] Since spending shares for the federal government and states and localities add up to unity, the state and local share is only included in the regressions.

[14] When expenditure by lower-levels government is partly financed by grants from higher-levels government, the share of expenditure in the total budget does not necessarily reflect the level of

of its O&M component, contributes to future productivity growth.

These results suggest that a rise in the share of state and local expenditures as well as a reallocation of O&M spending towards states and localities would positively affect future productivity growth. This may well indicate that infrastructure's maintenance is mainly a local task due to greater efficiency in identifying and dealing with maintenance requirements. Hulten and Schwab (1997) have also stressed that the federal government has always been more willing to subsidize public capital expenditures than expenditures for maintenance and have suggested that the political economy literature might offer some insights into this; for instance, according to Tullock (1983), given imperfect information, politicians will choose methods of redistribution (e.g. transfer wealth to road builders and bus manufacturers) that are difficult to detect, even if they are inefficient. Finally, a possible explanation for the observed contrast with the current results of Xie et al. (1999) is that the authors consider total spending and do not focus on 'productive' expenditures like infrastructure spending.

5. Transportation sectoral analysis

In this section we focus on the role of the transport sector, since it has been one of the largest areas of public-sector investment and its good condition is considered to be crucial in enhancing productivity.[15] For instance, highways and roads, which in their vast majority are

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authority allocated to a lower-level government because, to some extent, its grant relates to expenditure authorized by a higher-level government. As Oates (1972) suggests, when the grantor directs in some detail the purposes for which the funds are to be used, the grants should be attributed to the level of government that collects the revenues. By contrast, lump-sum or unconditional grants should be attributed to the level of government that undertakes the expenditure.

[15] ASCE (2009) reports that poor road conditions cost U.S. motorists $67 billion a year in repairs and operating costs, while limited capacity causes Americans to spend 4.2 billion hours a year stuck in traffic at a cost of $78.2 billion a year to the economy. In a similar vein, a report by the American Association of State Highway and Transportation Officials (2009) states that extra vehicle operating

state or locally owned, are seen as the quintessential transportation infrastructure and have been studied extensively in the literature (see e.g. Chandra and Thompson, 2000; Cohen and Paul, 2004; Fraumeni, 2009). As shown in Table 1, irrespective of government level, the GDP share of spending on transportation has been more than double compared with spending on water infrastructure. Using a more detailed breakdown, CBO (2007) reports that the bulk of federal outlays has been dominated by capital spending on highways and roads (60 percent of total), whereas those for O&M have been concentrated on aviation. While federal O&M spending on highways and roads is relatively small, both capital and O&M expenditures on highways and roads comprise the largest share of spending for states and localities.[16]

The upper panel of Table 6 displays the summarized evidence on the marginal non-linear effects of federal and state and local spending on transportation infrastructure. Highly-significant effects for both variables of interest are obtained and are again of opposite sign with respect to the two government levels: negative in the case of federal expenditures and positive in the case of state and local expenditures.

The lower panel of Table 6 presents the corresponding effects for the transportation infrastructure components. The basic result on the negative marginal effects of federal spending is further clarified here, as additional expenditures by the federal government on *mass transit*, *rail* and *aviation* would exert a negative effect on future private productivity growth. Also, the negative marginal effect of the *O&M share* seems to be mainly driven by

costs due to rough roads in urban areas can be, for the average driver, as high as $746 annually, whereas every $1 spent in maintaining the good condition of a road precludes spending $6-$14 to rebuild one that has deteriorated. Mattoon (2004) corroborates these assessments by stating that the return on maintenance of U.S. highways was as high as 35 percent, while the return on related investments was just 5 percent.

[16] Contrary to federal infrastructure spending series, data are not available for state and local spending on water resources and freight rail (passenger rail spending is combined with expenditures on mass transit). Notice also that state and local spending on infrastructure is net of federal grants and loan subsidies, which are included in federal spending and comprise its largest portion.

the *mass transit* component. The main finding obtained in the case of spending by states and localities relates to the positive impact of spending on highways and roads, and the associated *O&M share*, which form their largest spending category. The policy conclusion derived from the estimated positive marginal effects is that expenditures on highways and roads should increase and be directed towards O&M. However, given the partial nature of our findings we delegate this issue to future research.

6. Concluding remarks

The present paper aimed at extending the empirical literature on the impact of productive government spending by identifying the attractive, yet unresolved, role of various types of public infrastructure expenditures in U.S. productivity growth. The primary question formulated was twofold: what have been the impacts of capital and O&M outlays on U.S. private productivity growth and to what extent can these effects be attributed to different government levels? According to our findings, a reduction of federal infrastructure spending or a rise of state and local expenditures ("decentralization of infrastructure spending"), mainly in the form of additional O&M outlays in the transport sector, would enhance future private productivity growth. The evidence presented here therefore contributes to the literature on the U.S. productivity - infrastructure link by showing that the impacts differ substantially by level of government and, consequently, this distinction should be taken into consideration in future studies. An additional by-product of our study is therefore that the functional classification of public outlays into capital and O&M matters for the assessment of their effects.

The paper thus hopefully makes a persuasive case for some strong policy implications for infrastructure expenditures in the context of private productivity. As already emphasized, many recent policy reports have thoroughly acknowledged the need for increased public spending to upgrade America's infrastructure system, which is believed to play a key role in the nation's economic performance. In this direction, the American Recovery and Reinvestment Act of 2009 is expected to provide an important funding boost in some areas, although a number of systemic challenges, such as under-investment, inadequate revenue, and strategic planning and coordination, should still be addressed. Our study confirms some of these challenges by, for instance, providing evidence of state and local under-spending during the period under consideration. Also, in light of the tight budgetary constraints often faced by the authorities under fiscal distress, especially during periods of economic crisis like the current one, the relative impacts of federal and regional spending for infrastructure capital and related O&M presented here can provide a useful operational policy guideline for the efficient management of these resources at the macroeconomic level.

Finally, our results open some new avenues for further research in the area. Further work could certainly focus on regional aspects. Several types of infrastructure projects often involve small-scale interventions (like O&M outlays for public schools or hospitals) that are largely effective at the local level, but whose impact may not appear equally powerful at the national level. On the other hand, state and local O&M expenditures on transportation could have network benefits that are possibly stronger nationwide than at the regional level. It would therefore be of interest to policymakers to know if, and in which sectors, O&M activities affect primarily the local economy or display out-of-state spillover effects on productivity. Also, this study has not examined the role of granting tax credits and exemptions to state and local governments, typically used by the federal government to encourage investment in infrastructure. During the period examined, the tax law has substantially supported spending on public capital by excluding, for instance, from the taxable income the interest paid on bonds issued by states and localities for infrastructure financing, thus reducing their effective interest rate (see Hulten and Schwab, 1997). However, similar tax incentives have not been adopted for financing infrastructure's O&M through bonds. Future research could therefore investigate the extent to which the existing tax incentives have shifted the allocation of resources away from O&M spending and the implications for productivity growth.

Data Appendix

For a description and details on the source of the main variables on public spending, see Section 2. The following variables were used in the estimated regressions.

Growth of Output per Hour: output measured net of price change and inter-industry transactions and compared to labor input, measured as hours at work (source: http://www.bls.gov/lpc/tfp.php).

Growth of Multifactor Productivity: output measured net of price changes and inter-industry transactions, with the input measured as an aggregate of hours at work and capital service flows to account for the role of capital growth in output growth (source: http://www.bls.gov/mfp).

Technology Index: Business sector TFP, given by output growth less the contribution of capital and labor, and the utilization of capital and labor following Basu et al. (2006) estimates (source: http://www.frbsf.org/csip/tfp.php).

Revenues: Budget of the U.S. Government, Historical Tables, Section 15.1 (source: http://www.gpoaccess.gov/usbudget/fy12/hist.html).

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TABLE 1.
Basic statistics of capital and O&M expenditures on public infrastructure: US, 1956-2004.

	Mean	Std. Dev.	Minimum	Maximum
TOTAL GOVERNMENT				
Capital and O&M expenditures (% of GDP)	2.6	0.2	2.3	3.1
O&M expenditures (% of capital and O&M expenditures)	48.8	7.2	36.9	57.0
Capital and O&M expenditures on transport (% of GDP)	1.8	0.2	1.6	2.2
O&M expenditures on transport (% of capital and O&M expenditures on transport)	47.9	6.7	35.7	56.0
Capital and O&M expenditures on water (% of GDP)	0.8	0.1	0.7	0.9
O&M expenditures on water (% of capital and O&M expenditures on water)	50.9	9.3	37.2	65.0
FEDERAL GOVERNMENT				
Capital and O&M expenditures (% of GDP)	0.7	0.2	0.4	1.0
O&M expenditures (% of capital and O&M expenditures)	25.0	3.8	16.8	33.3
Capital and O&M expenditures on transport (% of GDP)	0.5	0.1	0.2	0.7
O&M expenditures on transport (% of capital and O&M expenditures on transport)	23.8	6.0	11.9	39.0
Capital and O&M expenditures on water (% of GDP)	0.2	0.1	0.1	0.4
O&M expenditures on water (% of capital and O&M expenditures on water)	30.0	10.1	16.2	59.0
STATES AND LOCALITIES				
Capital and O&M expenditures (% of GDP)	1.9	0.2	1.5	2.3
O&M expenditures (% of capital and O&M expenditures)	58.4	8.9	41.1	69.6
Capital and O&M expenditures on transport (% of GDP)	1.3	0.2	1.0	1.7
O&M expenditures on transport (% of capital and O&M expenditures on transport)	58.1	8.7	40.5	70.2
Capital and O&M expenditures on water (% of GDP)	0.6	0.1	0.5	0.7
O&M expenditures on water (% of capital and O&M expenditures on water)	59.0	9.7	42.6	71.6

Source: Congressional Budget Office (2007) and authors' calculations.
Note: Data series on federal expenditures extend to 2006.

TABLE 2.

Cross correlations of total capital and O&M expenditures (% of GDP) and O&M share by government level: US, 1956-2004.

	Capital and O&M expenditures (total)	*Capital and O&M expenditures (federal)*	*Capital and O&M expenditures (S&L)*	*O&M expenditures (total)*	*O&M expenditures (federal)*	*O&M expenditures (S&L)*
Capital and O&M expenditures (total)	1.00					
Capital and O&M expenditures (federal)	0.63	1.00				
Capital and O&M expenditures (S&L)	0.62	- 0.21	1.00			
O&M expenditures (total)	-0.89	-0.40	-0.71	1.00		
O&M expenditures (federal)	-0.65	-0.21	-0.61	0.69	1.00	
O&M expenditures (S&L)	-0.79	-0.17	-0.83	0.96	0.63	1.00

Note: Capital and O&M expenditures are expressed as % of GDP. O&M expenditures are expressed as a share of capital and O&M expenditures. S&L denotes spending by states and localities, respectively. See also Table 1.

TABLE 3.

Linear effects of government expenditures for infrastructure capital and O&M on future U.S. private productivity growth rate

	Total Government		Federal Government		States & Localities	
Independent variable	O.p.H.	MFP	O.p.H.	MFP	O.p.H.	MFP
Constant	-0.01 (0.06)	-0.03 (0.06)	0.01 (0.02)	0.01 (0.02)	-0.16*** (0.04)	-0.15*** (0.04)
Technology index	-0.04** (0.02)	-0.04* (0.02)	-0.04*** (0.01)	-0.04*** (0.01)	-0.03** (0.01)	-0.03** (0.01)
Revenues	0.42** (0.17)	0.34** (0.17)	0.45*** (0.12)	0.36*** (0.13)	0.49*** (0.13)	0.38*** (0.12)
Capital and O&M expenditures	-0.49 (1.38)	0.61 (1.34)	-2.28*** (0.68)	-1.85*** (0.67)	4.69*** (1.23)	4.64*** (1.08)
O&M share	-0.01 (0.06)	0.01 (0.06)	-0.09*** (0.03)	-0.09*** (0.03)	0.04 (0.03)	0.04 (0.03)
R^2-adjusted	0.23	0.31	0.57	0.55	0.56	0.62
Observations	46	46	46	46	46	46

Notes:
a) The dependent variable is a five-year forward moving average of the measure of private productivity growth. O.p.H. and MFP denote the growth rates of Output per Hour and Multifactor Productivity respectively, as provided by the BLS. See Data Appendix for the list of explanatory variables. 'Capital and O&M expenditures' is expressed as GDP percent and 'O&M share' denotes the share of O&M spending in total (i.e. capital and O&M) expenditures).
*b) Estimation method is GMM with correction for fourth-order autocorrelation. Standard errors are in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% levels respectively.*

TABLE 4.
Non-linear effects of government expenditures for infrastructure capital and O&M on future U.S. private productivity growth

	Total Government		Federal Government		States & Localities	
Independent variable	O.p.H.	MFP	O.p.H.	MFP	O.p.H.	MFP
Constant	0.65***	0.54***	0.10***	0.06	-0.18	-0.32***
	(0.11)	(0.16)	(0.03)	(0.04)	(0.12)	(0.12)
Technology index	-0.03***	-0.03***	-0.03***	-0.04***	-0.03**	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Revenues	0.48***	0.38***	0.44***	0.36***	0.51***	0.41***
	(0.08)	(0.02)	(0.09)	(0.10)	(0.12)	(0.11)
Capital and O&M expenditures	-29.38***	-27.72*	-3.48	6.18	21.51	24.38*
	(11.44)	(15.39)	(4.61)	(5.13)	(13.76)	(12.88)
(Capital and O&M expenditures)^2	560.45***	538.01*	-54.39	-558.79	-458.72	-517.09
	(209.80)	(282.51)	(306.44)	(340.97)	(362.07)	(339.09)
O&M share	-1.32***	-0.98**	-0.92***	-0.77***	-0.44	-0.01
	(0.33)	(0.45)	(0.22)	(0.24)	(0.35)	(0.32)
(O&M share)^2	1.35***	1.01**	1.69***	1.41***	0.41	0.06
	(0.35)	(0.47)	(0.45)	(0.49)	(0.29)	(0.27)
R^2-adjusted	0.76	0.69	0.66	0.63	0.58	0.64
Observations	46	46	46	46	46	46
			Marginal effects			
Capital and O&M expenditures	Zero	Zero	-2.66***	-2.29***	4.36***	5.05***
O&M share	Zero	Zero	-0.07***	-0.06**	Zero	0.06*

Notes: The statistical tests marginal effects are estimated from a Wald statistic based on the partial derivatives (see Section 3 in text). See Table 3 for further details.

TABLE 5.
Effects of decentralization of capital and O&M spending on future U.S. private productivity growth

	Federal Grants Excluded from S&L Spending				Federal Grants Included in S&L Spending			
Independent variable	O.p.H.	MFP	O.p.H.	MFP	O.p.H.	MFP	O.p.H.	MFP
Constant	-0.07** (0.03)	-0.05* (0.03)	-0.17*** (0.03)	-0.13*** (0.03)	-0.22*** (0.05)	-0.18*** (0.05)	-0.17*** (0.05)	-0.15*** (0.06)
Technology index	-0.04*** (0.01)	-0.04*** (0.01)	-0.05** (0.01)	-0.05*** (0.01)	-0.05 (0.01)	-0.05*** (0.01)	-0.05*** (0.01)	-0.05*** (0.01)
Revenues	0.40*** (0.14)	0.31** (0.14)	0.55*** (0.11)	0.41*** (0.12)	0.47*** (0.13)	0.37*** (0.13)	0.53*** (0.11)	0.41*** (0.12)
S&L share of capital and O&M expenditures	0.07*** (0.02)	0.06*** (0.02)	-	-	0.23*** (0.06)	0.20*** (0.06)	-	-
S&L share of capital expenditures	-	-	-0.01 (0.02)	-0.01 (0.02)	-	-	0.01 (0.06)	0.04 (0.07)
S&L share of O&M expenditures	-	-	0.17*** (0.04)	0.13*** (0.04)	-	-	0.16*** (0.04)	0.12*** (0.04)
R^2-adjusted	0.50	0.47	0.63	0.58	0.56	0.54	0.60	0.54
Observations	46	46	46	46	46	46	46	46

Notes: 'S&L share of capital and O&M expenditures', 'S&L share of capital expenditures', and 'S&L share of O&M expenditures' respectively denote the fraction of capital and O&M spending, of capital spending, and of O&M spending by total government that are conducted by states and localities. See Table 3 for further details.

TABLE 6.
Summarized marginal effects of government expenditures for transport capital and O&M on future U.S. private productivity growth

	FEDERAL GOVERNMENT		STATES AND LOCALITIES	
Independent variable	O.p.H.	MFP	O.p.H.	MFP
	Transport (Aggregated)			
Capital and O&M expenditures	-2.01**	-2.42**	7.83***	10.96***
O&M share	-0.09***	-0.08***	0.09*	0.14***
	Transport (Disaggregated)			
	Highways and Roads			
Capital and O&M expenditures	Zero	Zero	Zero	6.58***
O&M share	Zero	Zero	Zero	0.14***
	Mass Transit			
Capital and O&M expenditures	-31.75***	Zero	Zero	12.74
O&M share	0.01***	Zero	Zero	Zero
	Rail			
Capital and O&M expenditures	Zero	-31.26**	n.a.	n.a.
O&M share	Zero	Zero	n.a.	n.a.
	Aviation			
Capital and O&M expenditures	-15.49*	Zero	Zero	Zero
O&M share	Zero	Zero	Zero	Zero

Notes: n.a. denotes non-available data. The non-linear effects are estimated from a regression including a constant, the technology index, and tax revenues as % share of GDP. See Table 4 for further details.