Real Estate & Planning

HENLEY
UNIVERSITY OF READING

Working Papers in Real Estate & Planning 11/11

Does Regional Infrastructure Investment Stimulate Extra Housing and Commercial Building Supply? Long-Run Evidence across the English Regions[1]

Michael Ball*[2] and Anupam Nanda[3]

School of Real Estate & Planning
University of Reading
Reading, RG6 6UD, UK

Draft: June 9, 2011

[1] The authors would like to acknowledge financial support from the University of Reading, School of Real Estate and Planning, UK. All remaining errors are ours.
[2] *Corresponding Author: m.ball@henley.reading.ac.uk, Tel: +44 118 378 6336, Fax: +44 118 378 8172.
[3] a.nanda@reading.ac.uk, Tel: +44 118 378 6339, Fax: +44 118 378 8172.

Abstract

This paper uses long-term regional construction data to investigate whether increases infrastructure investment in the English regions leads to subsequent rises in housebuilding and new commercial property, using time series modeling. Both physical (roads and harbours) and social infrastructure (education and health) impacts are investigated across nine regions in England. Significant effects for physical infrastructure are found across most regions and, also, some evidence of a social infrastructure effect. The results are not consistent across regions, which may be due to geographical differences and to network and diversionary effects. However, the results do suggest that infrastructure does have some impact but follows differential lag structures. These results provide a test of the hypothesis of the economic benefits of infrastructure investment in an approach that has not been used before.

Keywords: Regional Variation, Infrastructure, Spill-over, Structural Break
JEL Classifications: R11, R58, C32, H73.

1. Introduction

In the aftermath of recent global economic contraction, many countries have used infrastructure spending to boost the domestic economies. The fundamental premise behind such policies is based on the economic principle of the classic short-run demand ‘multiplier’ effect. The spending in infrastructure works through the real sector of the economy and thus helps create jobs in the short-run, though the precise size of such multipliers is variable and controversial, particularly at the regional level where leakage effects can be substantial (McCann, 2001). The other potential route for benefits of infrastructure is more fundamental and long-term via its impact on the productive capabilities and economic competiveness. Again, the role of infrastructure investment is controversial, particularly at the regional level. As a recent survey put it: “… it is a fairly well-established finding that infrastructure investment is a necessary, but not a sufficient, condition for regional prosperity.” (European Commission, 2004, p4-25).

These conclusions highlight that the precise transition mechanisms for the effects of infrastructure expenditure remain uncertain and controversial in the literature. This problem cannot be adequately resolved by micro-studies of the consequences of specific infrastructure investments because there is also a likelihood of a within-region diversionary effect that is hard to identify at the individual project level. Infrastructure projects may lead to an area with improved infrastructure attracting economic activity away from elsewhere in the region, especially from localities with poorer facilities and generally less attractive locations. The result is that there is little or no net effect on aggregate regional activity. This suggests that a regional level approach may have relevance, but measurement of direct infrastructure impacts on aggregate regional economies faces substantial problems of simultaneity in which other variables may be more important than infrastructure itself. In consequence, the problems of isolating the real regional impact of better infrastructure remain fraught.

Here, we posit a potential straightforward impact whereby additional infrastructure expenditure improves the attractiveness of private investment and leads to the building of additional housing and commercial property at the regional level. Lags matter in this analysis, given the long gestation periods for building projects. If the impact is relatively fast, this may be because of a simple demand multiplier effect, whereby additional public expenditure helps to sustain private projects already in the pipeline; whereas longer lags may indicate more permanent consequences, with improvements in residential accommodation raising the quality of life and labour mobility, on the one hand, and new commercial buildings leading to greater productive capacity, on the other hand, especially in service-dominated economies. The results of such a study are especially pertinent as structures investment is the largest component of physical investment in regional as well as national economies.

This study presents time series modeling of the impact of new infrastructure provision on investment residential and commercial property, utilising a long time-series of national and regional data for England over past four decades and a model of investment in built structures that includes infrastructure. It distinguishes physical (e.g. roads, harbours, etc.) and social infrastructure (schools, universities, health services, etc.). The long-run time-series data (1966 - 2009) also provide an opportunity to study the structural breaks in structures investment in England and its regions. The modeling approach and data have not been used in relation to regional economic analysis before but they do suggest that a direct impact of infrastructure stimulating additional building projects can often be identified, although this is not always the case.

The paper is organized as follows. A brief survey of literature is presented, along with the main research objectives in Section 2. Section 3 describes the data and summary statistics. The empirical framework and analysis are reported in section 4. A final section provides a summary of the findings and concluding remarks.

2. Related Literature and Research Objectives

2.1. Previous evidence on infrastructure using national data

In his seminal studies, Aschauer (1989a, 1989b) concluded that public building investment had crucial impact on economic growth. This work stimulated a substantial debate, with many supporting this conclusion but others questioning it.[4]

[4] See Munnell (1992) and Gramlich (1994) for a survey of the literature.

The national evidence comes from a cross-section of countries: for example, Evans and Karras (1994), Pereira and Andraz (2004) for US, Ezcurra et al. (2005) for Spain, Pereira and Andraz (2006) for Portugal. Munnel (1990a) finds that a 1 percent increase in the stock of public capital would increase output by 0.34 per cent using US data. Canning and Fay (1993) use panel data to estimate the marginal product of transport infrastructures for 96 countries and they find that transportation infrastructure yields "normal" rates of return in developed countries, extraordinarily high rates of return in industrializing countries, and moderate rates of return in underdeveloped countries. They conclude that "… the effect of infrastructure has little short run impact on output but leads to a higher growth rate and higher output in the long run".

Using US data, Lynde and Richmond (1991) find estimates indicating a positive marginal product of public capital and suggest that private and public capital are complements in production, rather than substitutes. Berndt and Hansson (1992), using a dual cost function approach with Swedish data, find that increases in public infrastructure capital, ceteris paribus, reduce private sector costs. Shah (1992) provides evidence of economic significance of public infrastructure investment on private sector profitability using data on Mexican manufacturing industries. Nadiri and Mamuneas (1994) examine the effects of public infrastructure and R&D capitals on the cost structure and productivity of US manufacturing industries and find significant positive effects of these investments. Seitz (1994) uses a panel of West German manufacturing industries to argue that the provision of public capital has a stabilizing but steadily decreasing impact on private input demand. Ball and Wood (1996) analyze long-run UK aggregate data and report evidence of strong co-integrating relationships between equipment and structures investment and aggregate productivity.

In contrast, several studies have also found weak or insignificant relationships. Tatom (1991) presents no evidence of statistically significant effect from a rise in public capital spending on private sector output, productivity and private capital formation. Using a panel of seven countries, Evans and Karras (1993) also find no significant evidence that the government capital is productive. These papers argue that the relationship may be spurious in the level data and thus, the analysis should be conducted with first-differenced data to eliminate common trends. Therefore, a consensus on the national effects of infrastructure expenditure does not yet appear to have emerged in the literature.

2.2. Previous evidence on infrastructure using regional data

The associations become more complex area to study at the regional level, mainly due to presence of network effects and spill-over/leakage effects. Some studies use regional or state level panel approaches. Costa et al. (1987) provide evidence that labour and public capital are complementary inputs at the state level in the US and that public capital exhibits diminishing returns. In a similar vein, Duffy-Deno and Eberts (1991) using data from 28 US metropolitan areas report statistically significant, positive effects of public infrastructure on regional economic development, as measured by per capita personal income. Other studies echo these results e.g. Munnell and Cook (1990) and Garcia-Milà and McGuire (1992). Pereira and Andraz (2008) use US state-level annual data from 1977 to 1999 and find that public investment in highways provide positive impetus to private sector variables both at the aggregate and state levels. More importantly, they find that the biggest beneficiaries of public investment in highways tend relatively to be the largest states. The authors suggest this may indicate a concentration of private sector activity in the largest states.[5] Further analyses are more critical. For example, studies controlling for state-level heterogeneity (assuming fixed effects) tend to find that public capital variables are insignificant (e.g. Holtz-Eakin (1994), Evans and Karras (1994) and Garcia-Milà et al. (1996)).

An important aspect of regional analysis of the relationship between public investment and growth is the possibility of spill-over effects or leakage from investment from one region to other regions. For example, infrastructure improvement in one region may stimulate neighbouring regions. Haughwout (1998) presents evidence that increased level of spending in public goods may not necessarily lead to higher equilibrium output at the regional level and in a later study, Haughwout (2002), of large U.S. cities concluded that ambitious programmes of locally funded infrastructure provision may even generate negative net benefits for these cities.

Some commentators surveying the literature are generally skeptical about the estimates from aggregate studies of the impact of infrastructure investment on growth, because of the potential for reverse causality – growth affects infrastructure investment rather than the other way round; spillover effects; and incorrect measurement amongst a variety of other factors (Bannister and

---

[5] Also see Boarnet (1998), Holtz-Eakin and Schwartz (1995).

Berechman, 2000). It is difficult not to sympathise with such views. However, as even the critics point out, such studies do tend to identify some sort of relationship, even if its precise values may be uncertain (ibid). It is in this weak, but by no means redundant, sense that the analysis here is undertaken. Moreover, positing a relationship between additional infrastructure investment and the construction of extra built structures also has a more direct causal linkage than that of infrastructure to regional GDP, or to some productivity or input cost measure of regional industrial activity. It also picks up impacts on the service sector, the absence of which has been criticized in previous studies, as service sector enterprises are the main users of commercial property. Previous work has suggested a co-integrating relationship between built structures investment and GDP, as noted earlier, but it is not the purpose of this study to explore that relationship in any depth.

2.3. Modelling building supply

There is a substantial literature on modelling residential and commercial real estate investment.[6] The models vary in their complexity. They may include stock-adjustment factors, typically vacancy in commercial and market disequilibrium measures in residential and, in the case of residential, possibly demographic and migration variables as well. The modelling strategy adopted here was to have a simple standard investment flow model across both building types, with investment volumes in each building type for each English region as the dependent variables. The model takes the hypothesised form that an increase in building prices (or rents) stimulates investment demand; while rising construction costs and interest rates diminish investment volumes. Infrastructure expenditure is modelled as additional explanatory variables within this investment framework, potentially inducing additional building volumes. (Detailed model specification is given in the following section). The reasons for adopting a relatively simple modelling strategy relate to the aims of the exercise, data limitations at the regional level and the time series characteristics of the data.

The exercise has comparative intent in that the impact of infrastructure investment is modelled across regions and there are *a priori* reasons to expect differences in the scale of its impact between regions and also variations in lag structures. This expectation influenced model design,

[6] Surveys can be found in Ball et al, (2010 and 1998); Torto and Wheaton (1996) and Brooks and Tsolacos (2010).

with each region modelled separately in a common structural form rather than adopting a panel approach.

The expected differential impacts of infrastructure investments across the regions arise for a variety of reasons. Regions differ in their physical and economic geographies and in their initial infrastructure endowments, so that the marginal productivity of infrastructure investment is likely to vary substantially. Therefore, for example, any given volume of spending on road infrastructure is likely to have distinct effects on building investment opportunities depending on the type of investment undertaken and its location. A bridge across a river may open up a new area for urban expansion in a major expanding agglomeration; while an inter-urban road is likely to have a lower impact when it is laid between two spread-out low growth towns which already have optimal (or excess) stocks of buildings.

Infrastructure also covers a wide range of activities. Here, two distinct sub-categories are identified on the basis of the definitions given in the data source. The first is investment in roads and harbours, in which roads heavily predominate, and the second is investment in schools, universities and health facilities. The first is termed ‘physical infrastructure’ and the second ‘social infrastructure’.

Regions also vary in their politics and political economies, generating varying appetites for specific types of infrastructure provision and differential access to central government funds. It cannot be assumed that launched projects will be ranked according to their estimated net present values in cost-benefit analyses but rather to a variety of lobbying factors, at local and national level, so their impact is likely to be variable for these reasons as well. Political factors will also interact with institutional frameworks. For example, planning practices and strategies vary substantially regionally, with some areas more receptive to new building projects than others (Cheshire and Hilber, 2008). Regional heterogeneity in planning constraints is also likely to influence lag structures in the stimulus of infrastructure spending on building investment (Ball, 2011).

It is important when examining investment in built structures to undertake a long-term analysis, because of the lengthy and irregular cycles in building activity (Barras, 2009). However, a paucity of good quality historic data at the regional level also limits what can be effectively modelled. Regional construction volumes broken down by types of building are available from the mid-1960s to the present day. However, other data only exist from later periods restricting the sample time frame.

3. Data Description

The long-term data from the UK's Office for National Statistics (ONS) comprises annual information (1966 - 2009) on new orders (in 2005 prices) for several types of building investment: public and private housing, infrastructure by category, industrial, commercial property and other public building across the nine English regions (North East, Yorkshire & the Humber, East Midlands, East Anglia, Greater London, South East, South West, West Midlands, North West).

Annual data are used since quarterly data were found to contain significant 'noise' and 'spikes' that impair inferences. Regional house price information is obtained from the Halifax house price index, while annual IPD rental growth for regional office markets is used in the commercial property model, as an indicator of changing rents throughout commercial property. Annual average of 3-month LIBOR is taken as the interest rate variable. For the construction cost, information was derived using constant and current price construction order data. All variables are expressed in real terms. Table 1 provides a summary table of the variables and time period.

INSERT TABLE 1

The first step in time-series analysis is to determine the existence of unit root or the order of integration. The Augmented Dickey-Fuller (ADF) t-test was employed to find the existence of unit roots and determine the orders of integration. The unit root tests are carried out with one and two-period lag in annual data series and models are evaluated by incorporating trend and intercept. Table 2 presents the unit root test results for all the regions including England, as a whole. A large number of variables are integrated of order 1. Consequently, all models are specified in first-differences to obtain stationary series. A criticism of using first differenced data is that any long-term relationship is lost. However, it is reasonable to use first-differenced approaches in this context because the focus is on detecting 'extra' investment in residential and commercial sector due to 'additional' investment in infrastructure, while wishing to avoid spurious results due to common trends.

INSERT TABLE 2

4. Empirical Framework and Analysis

The empirical framework is a standard Auto-regressive Distributed Lag (*ARDL*) structure, where *AR(m)* and *DL(n)* processes are combined assuming a causal relationship between $\{y_t\}$ and $\{x_t\}$ as follows:

$$y_t = \alpha + \phi_1 y_{t-1} + \phi_2 y_{t-2} + ... + \phi_p y_{t-m} + \beta_1 x_t + \beta_2 x_{t-1} + ... + \beta_q x_{t-n} + v_t \tag{1}$$

For the sake of parsimony in model specification, the optimal lag structure within each region is determined within the models.

There were significant reductions in public infrastructure investment and a substantial change to the planning system during the period under review, so it was decided to test for the existence structural breaks for all types of structures investment used in the analysis. The conventional Chow tests in multivariate set-up were performed testing for the possibility, using 1996 as the breakpoint.[7] (Rolling Chow tests to find the breakpoint were not performed, since analyzing the timing of structural breaks is not the focus of this paper.) The results varied across the regions but were not sufficiently widespread to suggest rejection of the common structure approach adopted here.[8]

The broad structure of the models has already been discussed above. With regard to the effects of physical infrastructure spending, Equations 2 to 4 specify the particular models when total housing investment (*TH*), which includes both public and private housebuilding; private housing investment alone (PH); and commercial building investment are the dependent variables

[7] See Pereira and Schmidt (2009) for a discussion.
[8] Details are available from the authors on request.

respectively. The explanatory variables in all equations include the lagged dependent variable, physical infrastructure investment (*PI*), interest rate (*IR*) and changes in construction costs (*CC*). House price changes (*HP*) completed the housebuilding equations and office market rental growth (*R*) the commercial building one. The equations are in semi-log form.

$$\Delta \log TH_t = \alpha + \beta_1 \Delta \log TH_{t-1} + \beta_2 \Delta \log PI_{t-n} + \beta_3 \Delta HP_{t-n} + \beta_4 \Delta IR_{t-n} + \beta_5 \Delta CC_{t-n} + v_t \quad (2)$$

$$\Delta \log PH_t = \alpha + \beta_1 \Delta \log PH_{t-1} + \beta_2 \Delta \log PI_{t-n} + \beta_3 \Delta HP_{t-n} + \beta_4 \Delta IR_{t-n} + \beta_5 \Delta CC_{t-n} + v_t \quad (3)$$

$$\Delta \log PC_t = \alpha + \beta_1 \Delta \log PC_{t-1} + \beta_2 \Delta \log PI_{t-n} + \beta_3 \Delta R_{t-n} + \beta_4 \Delta IR_{t-n} + \beta_5 \Delta CC_{t-n} + v_t \quad (4)$$

With regard to the effects of social infrastructure spending (*SI*), Equations 5 to 6 specify a similar model form to those for physical infrastructure for total housing and private housing alone respectively.

$$\Delta \log TH_t = \alpha + \beta_1 \Delta \log TH_{t-1} + \beta_2 \Delta \log SI_{t-n} + \beta_3 \Delta HP_{t-n} + \beta_4 \Delta IR_{t-n} + \beta_5 \Delta CC_{t-n} + v_t \quad (5)$$

$$\Delta \log PH_t = \alpha + \beta_1 \Delta \log PH_{t-1} + \beta_2 \Delta \log SI_{t-n} + \beta_3 \Delta HP_{t-n} + \beta_4 \Delta IR_{t-n} + \beta_5 \Delta CC_{t-n} + v_t \quad (6)$$

The results for each model for England and its regions are presented in Tables 3 to 7. The models perform reasonably well in most cases. The degree of fit tends to be worse at the regional level than at the national level, which is to be expected given regional diversity. The Durbin-Watson statistics are of the right order indicating that the first-differencing strategy was an appropriate one.

INSERT TABLES 3 TO 7

The signs of the independent variables are as expected and in both housing formulations house price changes and construction costs are significant. A similar picture arises with commercial property investment with rental growth and construction coats generally behaving as expected. However, interest rates were insignificant for both housing and commercial property, with the exception of commercial property in one region. This result was unexpected in view of the general significance found in other studies and may be due to the use of the Libor measure to ensure commonality across models, rather than more market specific mortgage interest and commercial property borrowing rates because the spread between them and Libor may vary significantly over time.

With regard to one of the variables of concern to this study, physical infrastructure, the results were mixed as anticipated. For total housing, in 7 out of the 9 regions the variable was significant at the 10% level and four at the 5% level, though it was insignificant for England as a whole. The strongest significance was recorded in the South East, South West, East Midlands and North West. For private housing investment, 6 regions were significant at the 10% level and 5 at the 5% level; with strongest significance in the South East, Yorkshire & Humberside, North East, East Midlands and North West. Lag structures varied across the regions as predicted. The significant coefficients ranged in value from 0.1 to 0.2. If these values of logged variables are interpreted as elasticities, they may seem quite small but the scale of housing investment is much larger than that of roads and harbours, so that the implied effect in terms of £millions of extra housing investment leveraged by extra roads spending is actually quite large.

For commercial property the impact of increases in physical infrastructure was confined to far less regions. Only London, the South East and Yorkshire & Humberside have significant coefficients at the 10% level and only the South East and Yorkshire & Humberside at the 5% level. However, this finding may perhaps be explained by the fact that the bulk of English commercial property investment is actually located in these regions. It is noteworthy that the coefficient is also significant for England as a whole. In this context, the findings have much greater importance, especially as the South East has the largest and most significant coefficient for physical infrastructure of 0.2. The Yorkshire effect may reflect the specific economic and physical geography of this large, spread-out region. Similarly, the South East is obviously more spread out than London and, therefore, specific road projects are likely to have a greater impact on travel patterns within it than in the long-established urban areas of London. Furthermore, the South East includes many of London's farther suburbs and satellite towns; so that intuitively it would seem feasible that extra road building there would aid service employment decentralization from London and the creation of sub-regional retail centres.

The two housing models that include social infrastructure (education and health buildings) show interesting results with respect to this type of infrastructure. For total housing investment, public and private, two-thirds of the regions have significant values at the 5% for this variable - the South East, South West, East Anglia, North West, East Midlands and West Midlands – and five of them are significant at the 1% level. Similar results were found for private housing alone. Moreover, social infrastructure produced notably higher elasticities than did physical infrastructure: ranging from 0.22 to 0.48. It may be the case that omitted variables may be generating this result, with population change acting as a common driver of social infrastructure and housing investment. However, the lag structures are interesting in that, with the exception of the South East, additional social infrastructure investment leads extra housebuilding by 2 to 3 years. So, it may suggest that social infrastructure investment makes regions better places in which to live, boosting housing demand which induces extra supply.

5. Conclusion

This paper uses a unique data set that has never been used to study the impact of regional infrastructure investment before: long-term regional data on building work. The objective has been to investigate whether any stimulus to infrastructure investment leads to subsequent increases in housebuilding and commercial property, using time series modeling. England's regions are used as a case study.

The focus is on the analysis of regional variation, utilizing simple models of building investment. Both physical (roads and harbours) and social infrastructure (education and health) are examined across the nine regions in England. A significant effect for physical infrastructure is found across most regions, with variable lags. There is also a significant and quite strong effect of social infrastructure on housebuilding in several English regions, again with variable lags.

The models used are relatively simple (though similar ones are found elsewhere in the literature) in order to facilitate comparisons. Missing variables may be driving some of the findings, so that clear qualifications must be made and standard criticisms of aggregate studies of the consequences of infrastructure investment must also be borne in mind. Nonetheless, a plausible relationship does often emerge across the regions examined of additional infrastructure investment stimulating extra housebuilding and, possibly, more commercial buildings as well. So, a more indirect route than looking directly at regional GDP or production function changes may be fruitful in the context of the merits of extra infrastructure spending debate. Namely, additional infrastructure in a region may leverage extra buildings for the benefit of service sector employment, and improved housing standards and costs.

References

Aschauer, D. (1989a). "Is Public Expenditure Productive?" *Journal of Monetary Economics*, 23, 177-200.

Aschauer, D. (1989b). "Does Public Capital Crowd Out Private Capital?" *Journal of Monetary Economics*, 24, 171-188.

Ball, M. (2011) "UK planning controls and the market responsiveness of housing supply", *Urban Studies*, 48(2), 349-362.

Ball, M. and A. Wood. (1996). "Does building investment affect economic growth? Some long-run evidence from the UK". *Journal of Property Research*, 13, 99-114.

Ball, M., Meen, G. and Nygaard, A. (2010) "Housing supply price elasticities revisited: evidence from international, national, local and company data" *Journal of Housing Economics, 19.4, 255-268*.

Ball, M. Lizieri, C. and MacGregor, B. (1998) *The Economics of Commercial Property Markets, Routledge,* London.

Berndt, E. and B. Hansson (1992). "Measuring the Contribution of Public Infrastructure Capital in Sweden". *The Scandinavian Journal of Economics*, 94, 151-168.

Boarnet, M. G. (1998). "Spillovers and the Locational Effects of Public Infrastructure," *Journal of Regional Science*, 38, 381-400.

Canning, D. and M. Fay. (1993) "The Effect of Transportation Networks on Economic Growth." Columbia University, mimeo, May.

Cheshire, P. and C.A.L. Hilber. (2008) Office space supply restrictions in Britain: the political economy of market revenge". *Economic Journal*, 118, 529-540.

Chirinko, R.S. (1993). "Business Fixed Investment Spending: Modelling Strategies, Empirical Results, and Policy Implications," *Journal of Economic Literature,* 31, 1875-1911.

Costa, J., R. Ellson and R. Martin (1987). "Public Capital, Regional Output, and Development: Some Empirical Evidence," *Journal of Regional Science*, 27(3), 419-437.

Ezcurra, R., C. Gil, P. Pascual and M. Rapun (2005). "Public Capital, Regional Productivity and Spatial Spillovers", *The Annals of Regional Science*, 39(3), 471-494.

De Long, J.B. (1992). "Productivity Growth and Machinery Investment: A Long-run Look, 1870-1980", *Economic History Review,* 52, 307-24.

De Long, J.B. and L.H. Summers (1991). "Equipment Investment and Economic Growth", *Quarterly Journal of Economics,* 106, 445-502.

De Long, J.B. and L.H. Summers (1992). “Equipment Investment and Economic Growth: How Strong is the Nexus?”, *Brookings Papers on Economic Activity,* 2, 157-211.

Duffy-Deno, K. and R. Eberts (1991). “Public Infrastructure and Regional Economic Development: A Simultaneous Equations Approach,” *Journal of Urban Economics*, 30, 329-343.

Evans, P. and G. Karras (1993). “Is Government Capital Productive? Evidence from a Panel of Seven Countries,” *Journal of Macroeconomics*, 16(2), 271-279.

Evans, P. and G. Karras (1994). “Are Government Activities Productive? Evidence from a Panel of U.S. States,” *Review of Economics and Statistics,* 76(1), 1-11.

Ford, R. and P. Poret (1991). “Infrastructure and Private-sector Productivity”, *OECD Economic Studies,* 17, 27-41.

Garcia-Milà, T. and T. McGuire (1992). “The Contribution of Publicly Provided Inputs to States’ Economies,” *Regional Science and Urban Economics*, 22, 229-241.

Garcia-Milà, T., T. McGuire and R. Porter (1996). “The Effect of Public Capital in State-Level Productions Functions Reconsidered,” *Review of Economics and Statistics*, 78(1), 177-180.

Gramlich, E. (1994). “Infrastructure Investment: A Review Essay,” *Journal of Economic Literature*, 32, 1176-1196.

Haughwout, F, (1998). “Aggregate Production Functions, Interregional Equilibrium, and the Measurement of Infrastructure Productivity,” *Journal of Urban Economics*, 44, 216-227.

Haughwout, F. (2002). “Public Infrastructure Investments, Productivity and Welfare in Fixed Geographical Areas,” *Journal of Public Economics*, 83, 402-428.

Holtz-Eakin, D. (1994). “Public Sector Capital and the Productivity Puzzle,” *The Review of Economics and Statistics*, 76(1), 12-21.

Holtz-Eakin, D. and A. E. Schwartz (1995). “Spatial Productivity Spillovers from Public Infrastructure: Evidence from State Highways,” *International Tax and Public Finance*, 2 (3), 459-468.

Lynde, C. and J. Richmond (1991). “The Role of Public Capital in Production,” *The Review of Economics and Statistics*, LXXIV(1), 37-44.

European Commission (2004) *A Study of the Factors of Regional Competiveness,* Cambridge Econometrics, ECORYS, R. Martin, European Commission, Brussels.

McCann, P. (2001) *Urban and regional economics.* Oxford, Oxford University Press, 2001.

Munnell, A. (1990a). "Why Has Productivity Declined? Productivity and Public Investment," *New England Economic Review*, January/ February, Federal Reserve Bank of Boston, 3-22.

Munnell, A. and L. Cook (1990b). "How Does Public Infrastructure Affect Regional Economic Performance?," *New England Economic Review*, September/October, Federal Reserve Bank of Boston, 11-33.

Nadiri, M. I. and T. P. Mamuneas (1994). "The Effects of Public Infrastructure and R&D Capital on the Cost Structure and Performance of U.S. Manufacturing Industries," *The Review of Economics and Statistics*, 76(1), February 1994, 22-37.

Pereira, A. M. and J. M. Andraz (2004). "Public Highway Spending and State Spillovers in the US," *Applied Economics Letters* 11, 785-88.

Pereira, A. M. and J. M. Andraz (2006). "Public Investment in Transportation Infrastructures and Regional Asymmetries in Portugal," *The Annals of Regional Science*, 40(4), 803-817.

Pereira, A. M. and M. B. Schmidt (2009). "Structural Breaks in Public Infrastructure Investment in the US". College of William and Mary Working Paper No. 55.

Pereira, A. M. and J. M. Andraz (2008). "On the Regional Incidence of Public Investment in Highways in the USA", College of William and Mary Working Paper No. 70.

Seitz, H. (1994). "Public Capital and the Demand for Private Inputs," *Journal of Public Economics*, 54, 287-307.

Shah, A. (1992). "Dynamics of Public Infrastructure, Industrial Productivity and Profitability," *The Review of Economics and Statistics*, LXXIV(1), 28-36.

Stern, N. (1989). "The Economics of Development: A Survey", *Economic Journal,* 99, 597-685.

Tatom, J. (1991). "Public Capital and Private-Sector Performance," *Review of the Federal Reserve Bank of St. Louis*, 78(3), 3-15.

Table 1: Variable Description and Summary Statistics

Variables	Transformation	Source	Sample	Mean	SD
Social Infra: School/University/Health	*2005 price, £million;*	Office of National Statistics	*1966-2009 10 areas*	553.29	43.31
Phy. Infra: Roads & Harbours	*2005 price, £million*	Office of National Statistics	*1966-2009 10 areas*	510.54	41.69
Total Housing	*2005 price, £million*	Office of National Statistics	*1966-2009 10 areas*	3179.39	247.86
Private Housing	*2005 price, £million*	Office of National Statistics	*1966-2009 10 areas*	2500.81	190.18
Private Commercial	*2005 price, £million*	Office of National Statistics	*1966-2009 10 areas*	1788.18	141.23
House Price Growth	*Inflation adjusted, year-over-year change (%)*	Halifax/ Lloyds TSB Bank plc,	*1984-2009 10 areas*	3.52	0.67
Office Rental Value Growth	*Inflation adjusted annual rate (%)*	IPD	*1981-2008 10 areas*	-0.77	0.46
LIBOR 3-month	*Inflation adjusted average annual rate (%)*	Bank of England	*1978-2009 Same across areas*	3.39	0.36
Change in Construction Cost	*Inflation adjusted, year-over-year change (%)*	Office of National Statistics*	*1966-2009 Same across areas*	-14.94	6.21

NOTES: Retail Price Index (RPI) is used for inflation adjustment.
* We use constant and current construction order data to derive construction cost series.

Table 2: Test of Stationarity and Order of Integration

	(1) England	(2) Greater London	(3) South East	(4) South West	(5) East Anglia	(6) Yorkshire Humber	(7) North East	(8) North West	(9) East Midlands	(10) West Midlands
Social Infrastructure	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***
Physical Infrastructure	I(1)***	I(0)**	I(1)***	I(0)*	I(0)**	I(1)***	I(0)**	I(0)**	I(0)*	I(0)**
Total Housing	I(1)***	I(1)***	I(1)***	I(0)*	I(1)**	I(1)***	I(0)**	I(1)***	I(1)***	I(0)**
Private Housing	I(1)***	I(0)*	I(1)***	I(0)*	I(1)**	I(1)***	I(1)***	I(0)**	I(0)**	I(0)**
Private Commercial	I(1)***	I(1)**	I(1)***	I(1)**	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)**
House Price Growth	I(1)**	I(1)**	I(1)***	I(1)**	I(1)**	I(1)***	I(1)**	I(1)**	I(1)**	I(1)**
Office Rental Value Growth	I(0)**	I(0)*	I(0)*	I(1)***	I(1)**	I(1)**	I(1)***	I(1)**	I(1)**	I(1)*
LIBOR 3-month	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***	I(1)***
Changes in Construction Costs	I(0)***	I(0)***	I(0)***	I(0)***	I(0)***	I(0)***	I(0)***	I(0)***	I(0)***	I(0)***

NOTES: The unit root tests are carried out within the Augmented Dickey-Fuller (ADF) framework with one and/or two-period lag in annual data series and models are evaluated by incorporating trend and/or intercept. ‘***’, ‘**’, and ‘*’ denote 1 percent, 5 percent and 10 percent significance levels.

Table 3: Regression Analysis of Physical Infrastructure Investment
(Dependent Variable: Total Housing Investment)

	(1) England	(2) Greater London	(3) South East	(4) South West	(5) East Anglia	(6) Yorkshire Humber	(7) North East	(8) North West	(9) East Midlands	(10) West Midlands
Δlog Total Housing (t-1)	0.379**	0.096	0.362***	-0.039	0.195	0.424**	0.031	0.192	0.405	0.359**
	(2.23)	(0.46)	(2.92)	(-0.22)	(0.91)	(2.17)	(0.15)	(0.67)	(1.63)	(2.24)
Δlog Phy. Infra (t-1)									0.126**	
									(2.44)	
Δlog Phy. Infra (t-2)		0.011	0.147*	0.105**	-0.022	0.092*		0.134**		
		(0.13)	(2.05)	(2.26)	(-0.37)	(2.02)		(2.18)		
Δlog Phy. Infra (t-3)	0.051		0.131**				0.147*	0.136*		
	(0.78)		(2.51)				(1.99)	(1.81)		
Δlog Phy. Infra (t-4)										0.069*
										(1.86)
Δ House Price Growth (t)	0.012***	0.021***	0.015***	0.016***	0.013***	0.007*	0.007**	0.005**	0.011***	0.006***
	(3.87)	(4.18)	(5.37)	(4.02)	(4.08)	(2.06)	(2.58)	(2.09)	(2.82)	(3.55)
Δ LIBOR 3-month (t)	-0.005	0.073			0.034	-0.029	-0.033	-0.029		
	(-0.21)	(1.28)			(0.81)	(-0.87)	(-0.65)	(-0.96)		
Δ LIBOR 3-month (t-1)			0.015	-0.001					0.021	-0.022
			(0.61)	(-0.03)					(0.62)	(-0.83)
Δ Change in Construction Cost (t)		-0.001**	-0.001**	-0.001***						
		(-2.48)	(-2.41)	(-4.11)						
Δ Change in Construction Cost (t-1)	-0.001*			-0.001**	-0.001***	-0.002***	-0.002***	-0.001**	-0.002***	-0.001*
	(-1.84)			(-2.11)	(-3.49)	(-4.12)	(-7.43)	(-2.51)	(-3.41)	(-1.97)
Δ Change in Construction Cost (t-2)				-0.002***			-0.003***			
				(-3.67)			(-8.66)			
Prob(F-statistic)	0.001	0.054	0.001	0.006	0.004	0.001	0.005	0.041	0.002	0.004
Durbin-Watson	1.53	2.06	2.01	2.29	2.47	2.06	1.91	2.11	1.89	2.21
Adj. R^2	0.537	0.258	0.665	0.496	0.465	0.579	0.481	0.314	0.504	0.465
N	25	25	25	25	25	25	25	25	25	25

NOTES: T-statistics (with robust standard error) are reported within the parentheses. '***', '**', and '*' denote 1%, 5% and 10% significance levels.

Table 4: Regression Analysis of Physical Infrastructure Investment (Dependent Variable: Private Housing Investment)

	(1) England	(2) Greater London	(3) South East	(4) South West	(5) East Anglia	(6) Yorkshire Humber	(7) North East	(8) North West	(9) East Midlands	(10) West Midlands
Δlog Private Housing (t-1)	0.417**	0.254***	0.334***	-0.054	0.186	0.475**	-0.009	0.267	0.525*	0.367**
	(2.24)	(1.91)	(2.91)	(-0.28)	(0.93)	(2.77)	(-0.04)	(1.12)	(2.01)	(2.13)
Δlog Phy. Infra (t-1)									0.148**	
									(2.48)	
Δlog Phy. Infra (t-2)		-0.022	0.154*	0.102*	-0.056	0.108**		0.181**		
		(-0.29)	(1.76)	(1.79)	(-0.88)	(2.33)		(2.16)		
Δlog Phy. Infra (t-3)	0.081		0.163**				0.193**	0.114		
	(0.87)		(2.78)				(2.21)	(1.16)		
Δlog Phy. Infra (t-4)										0.062
										(1.36)
Δ House Price Growth (t)	0.013***	0.023***	0.016***	0.017***	0.014***	0.008**	0.009*	0.009*	0.009**	0.007***
	(3.68)	(4.24)	(6.72)	(4.04)	(4.29)	(2.21)	(2.86)	(1.91)	(2.24)	(3.51)
Δ LIBOR 3-month (t)	-0.014	0.036	0.006		0.015	-0.036	-0.037	-0.031		
	(-0.52)	(0.92)	(0.26)		(0.32)	(-1.28)	(-0.65)	(-0.63)		
Δ LIBOR 3-month (t-1)				-0.001					0.032	-0.017
				(-0.02)					(0.92)	(-0.57)
Δ Change in Construction Cost (t)		-0.001*	-0.001**	-0.001***				0.001		
		(-1.76)	(-2.14)	(-3.98)				(0.34)		
Δ Change in Construction Cost (t-1)	-0.001			-0.001**	-0.001	-0.002***	-0.002***		-0.002***	-0.001
	(-1.67)			(-2.55)	(-1.69)	(-4.98)	(-8.27)		(-3.37)	(-1.28)
Δ Change in Construction Cost (t-2)				-0.002***			-0.003***			
				(-3.98)			(-7.55)			
Prob(F-statistic)	0.001	0.004	0.001	0.009	0.005	0.001	0.003	0.147	0.001	0.009
Durbin-Watson	1.79	2.28	1.95	2.27	2.44	1.89	1.81	1.84	1.88	2.28
Adj. R^2	0.534	0.451	0.684	0.462	0.441	0.679	0.502	0.173	0.517	0.409
N	25	25	25	25	25	25	25	25	25	25

NOTES: T-statistics (with robust standard error) are reported within the parentheses. '***', '**', and '*' denote 1%, 5% and 10% significance levels.

Table 5: Regression Analysis of Physical Infrastructure Investment
(Dependent Variable: Private Commercial Investment)

	(1) England	(2) Greater London	(3) South East	(4) South West	(5) East Anglia	(6) Yorkshire Humber	(7) North East	(8) North West	(9) East Midlands	(10) West Midlands
Δlog Pvt. Commercial (t-1)	0.635*	-0.011	-0.489***	-0.281	-0.846***	0.362*	-0.455**	-0.111	-0.531**	-0.159
	(6.33)	(-0.08)	(-3.55)	(-1.61)	(-4.55)	(1.88)	(-2.11)	(-0.73)	(-2.79)	(-0.89)
Δlog Phy. Infra (t-1)						0.113***				
						(2.97)				
Δlog Phy. Infra (t-2)	0.225**	0.086*	0.205**	0.035				0.084		
	(2.76)	(2.02)	(2.21)	(0.57)				(1.19)		
Δlog Phy. Infra (t-3)					0.083		0.022		0.054	
					(1.17)		(0.133)		(0.83)	
Δlog Phy. Infra (t-4)										0.059
										(0.94)
Δ Office Rental Value Growth (t)	0.013***	0.022***		0.021***		0.014***		0.022***	0.016**	
	(6.17)	(4.17)		(4.88)		(3.97)		(3.53)	(2.11)	
Δ Office Rental Value Growth (t-1)			0.037***		0.043***		0.021*			0.011***
			(6.09)		(4.71)		(1.81)			(3.21)
Δ LIBOR 3-month (t)	-0.019	-0.015				-0.054**	0.093	-0.054	0.051	
	(-1.49)	(-0.36)				(-2.21)	(1.38)	(-1.59)	(0.94)	
Δ LIBOR 3-month (t-1)			0.019	0.041	-0.043					0.055
			(0.57)	(1.31)	(-0.95)					(1.08)
Δ Change in Construction Cost (t)		-0.001								
		(-1.58)								
Δ Change in Construction Cost (t-1)	-0.001**		0.001*	-0.001***		-0.003***	0.001	-0.002***	-0.001***	
	(-2.21)		(1.78)	(-3.32)		(-9.39)	(0.91)	(-6.25)	(-3.01)	
Δ Change in Construction Cost (t-2)					-0.001					-0.001***
					(-1.71)					(-4.31)
Prob(F-statistic)	0.001	0.006	0.001	0.011	0.006	0.001	0.151	0.001	0.122	0.098
Durbin-Watson	2.24	2.36	1.88	1.71	2.02	2.36	1.81	2.28	2.13	2.24
Adj. R^2	0.634	0.399	0.497	0.368	0.403	0.623	0.137	0.512	0.159	0.182
N	27	27	27	27	27	27	27	27	27	27

NOTES: T-statistics (with robust standard error) are reported within the parentheses. '***', '**', and '*' denote 1%, 5% and 10% significance levels.

Table 6: Regression Analysis of Social Infrastructure Investment (Dependent Variable: Total Housing Investment)

	(1) England	(2) Greater London	(3) South East	(4) South West	(5) East Anglia	(6) Yorkshire Humber	(7) North East	(8) North West	(9) East Midlands	(10) West Midlands
Δlog Total Housing (t-1)	0.371**	0.098	0.331**	0.277***	0.249	0.394*	-0.146	0.386	0.134	0.322**
	(2.36)	(0.47)	(2.76)	(3.29)	(1.57)	(1.98)	(-0.71)	(1.49)	(0.89)	(2.43)
Δlog Social Infra (t)			0.309**							
			(2.61)							
Δlog Social Infra (t-2)					0.218***	0.042	0.061	0.311***		
					(2.94)	(0.48)	(0.57)	(2.94)		
Δlog Social Infra (t-3)		0.084		0.377***					0.414***	0.219**
		(0.44)		(4.03)					(3.72)	(2.68)
Δlog Social Infra (t-4)	0.298*									
	(1.75)									
Δ House Price Growth (t)	0.011***	0.021***	0.013***	0.017***	0.015***	0.007*		0.009*	0.018***	0.005**
	(4.33)	(4.15)	(4.04)	(8.02)	(6.43)	(1.86)		(1.75)	(6.99)	(2.61)
Δ House Price Growth (t-1)							0.006*			
							(2.09)			
Δ LIBOR 3-month (t)	-0.009	0.067		0.011		-0.062*		0.007		
	(-0.41)	(1.24)		(0.31)		(-1.87)		(0.29)		
Δ LIBOR 3-month (t-1)			0.012		0.011		-0.026		0.026	-0.049*
			(0.36)		(0.31)		(-0.45)		(0.88)	(-1.85)
Δ Change in Construction Cost (t)		-0.001**		-0.001***						
		(-2.45)		(-5.43)						
Δ Change in Construction Cost (t-1)	-0.001**		-0.001		-0.001*	-0.002***	-0.002***	-0.001**	-0.001*	-0.001**
	(-2.27)		(-1.62)		(-1.78)	(-3.29)	(-5.74)	(-2.11)	(-1.86)	(-2.81)
Δ Change in Construction Cost (t-2)							-0.003***			
							(-8.51)			
Prob(F-statistic)	0.001	0.049	0.001	0.001	0.001	0.001	0.018	0.018	0.001	0.002
Durbin-Watson	1.46	2.19	1.75	2.07	2.33	1.97	1.99	2.36	1.82	1.98
Adj. R^2	0.606	0.266	0.625	0.631	0.607	0.524	0.398	0.355	0.638	0.493
N	25	25	25	25	25	25	25	25	25	25

NOTES: T-statistics (with robust standard error) are reported within the parentheses. '***', '**', and '*' denote 1%, 5% and 10% significance levels.

Table 7: Regression Analysis of Social Infrastructure Investment
(Dependent Variable: Private Housing Investment)

	(1) England	(2) Greater London	(3) South East	(4) South West	(5) East Anglia	(6) Yorkshire Humber	(7) North East	(8) North West	(9) East Midlands	(10) West Midlands
Δlog Private Housing (t-1)	0.431**	0.245	0.286**	0.255**	0.201	0.456**	-0.216	0.517*	0.229	0.363**
	(2.55)	(1.57)	(2.23)	(2.18)	(1.42)	(2.66)	(-0.88)	(2.01)	(1.51)	(2.49)
Δlog Social Infra (t)			0.248**							
			(2.33)							
Δlog Social Infra (t-2)		-0.004			0.224***	0.101	0.071	0.437***		
		(-0.04)			(3.04)	(1.29)	(0.61)	(3.98)		
Δlog Social Infra (t-3)				0.416***					0.478***	0.219**
				(3.61)					(3.93)	(2.27)
Δlog Social Infra (t-4)	0.356*									
	(2.04)									
Δ House Price Growth (t)	0.012***	0.023***	0.015***	0.018***	0.017***	0.009**		0.012**	0.018***	0.006**
	(3.91)	(4.29)	(4.86)	(7.71)	(6.95)	(2.13)		(2.04)	(6.92)	(2.81)
Δ House Price Growth (t-1)							0.007*			
							(1.76)			
Δ LIBOR 3-month (t)	-0.018	0.041		-0.003		-0.072**		0.009		
	(-0.77)	(1.01)		(-0.07)		(-2.42)		(0.28)		
Δ LIBOR 3-month (t-1)			-0.002		0.015		-0.004		0.037	-0.043
			(-0.06)		(0.43)		(-0.07)		(1.28)	(-1.45)
Δ Change in Construction Cost (t)		-0.001*		-0.001***						
		(-1.85)		(-3.56)						
Δ Change in Construction Cost (t-1)	-0.001*		-0.001		-0.001	-0.002***	-0.002***	-0.001	-0.001*	-0.001*
	(-2.02)		(-1.18)		(-0.41)	(-3.89)	(-5.78)	(-0.94)	(-1.86)	(-1.95)
Δ Change in Construction Cost (t-2)							-0.003***			
							(-6.69)			
Prob(F-statistic)	0.001	0.005	0.001	0.001	0.001	0.001	0.037	0.013	0.001	0.004
Durbin-Watson	1.68	2.28	1.88	2.08	2.41	1.84	2.09	2.07	1.72	2.16
Adj. R^2	0.604	0.447	0.581	0.593	0.576	0.632	0.336	0.378	0.662	0.451
N	25	25	25	25	25	25	25	25	25	25

NOTES: T-statistics (with robust standard error) are reported within the parentheses. '***', '**', and '*' denote 1%, 5% and 10% significance levels.