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On the Long-Run Relationship Between Industrial Construction and Housing[1]

By

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[1] Some of the material in this this paper is taken from a report for the Housing Research Foundation, *The Economic Role of New Housing, Meen et al (2001).*

On The Long-Run Relationship Between Industrial Construction and Housing

Abstract

Most empirical analysis of property development treats the sub-components of the construction industry as independent of each other. For example, models of housing construction typically do not consider any possible relationship with industrial or commercial construction. New building and repair and maintenance are rarely modelled jointly. But, in fact, there are a number of ways in which changes over time may be interdependent.

For example, since similar labour skills are required across the sub-sectors and aggregate labour supply is not perfectly elastic, expansion in one sector might impose constraints on others. Furthermore, economic theory suggests that, under some conditions, housing investment crowds out industrial and commercial investment in a general equilibrium framework. In general, therefore, if there are any interdependencies, the presumption is that the relationship is negative.

In this paper, we test the interdependencies between the sectors, concentrating particularly on the relationship between new housing and industrial construction. We find that, in the long run, based on Johansen tests for British data since the sixties, the relationship is positive – movements in the two are complementary.

At first sight, this result is counter-intuitive, at least in an aspatial setting. However the result can be explained once a spatial dimension is added to the analysis, taking account of firm location decisions. Weak exogeneity tests indicate that, for the industrial sector, “jobs move to workers” rather than “workers moving to jobs” as standard residential location theory might suggest. Therefore a positive relationship occurs between housing and industrial construction, particularly in southern England, as newly-forming and relocating firms seek out highly skilled workers who, in turn, seek out high quality housing locations.

1. Introduction

Construction consists of a number of component sub-industries – housing, industrial, commercial, infrastructure and repair and maintenance, for example. However, in the modelling literature, each of these elements is typically treated as independent. For example, there are numerous studies of housing construction activity in different countries and a rather more limited set of empirical studies of industrial and commercial construction. But no study explicitly examines the interrelationships between, say, housing and industrial construction or housing and infrastructure investment. This is surprising since the sub-components use similar inputs, particularly in terms of labour and land so that an expansion in one sector may impose constraints on another. Furthermore all sectors appear to respond in a similar manner to broad economic trends. Peaks in housing and commercial construction broadly coincide over the economic cycle. It is also the case that an important strand of macroeconomic theory suggests that housing crowds-out other forms of so-called productive investment, including buildings.

At first sight, therefore, it appears that if any relationship exists at all between the sub-components, it is likely to be negative. This paper is concerned with explicit empirical tests of the relationship between the components of the construction industry, particularly between new housing and industrial construction[2]. Although part of the paper is concerned with short-term relationships, we are mainly concerned with the long-run covering the period from the mid sixties until the present day.

In contrast to expectations, the long-run relationship between UK industrial construction output and housing construction output turns out to be positive, based on Johansen cointegration tests. A major part of the paper is concerned with an explanation of the phenomenon. We show that, as soon as models are put in a spatial framework, a positive relationship is not unexpected. The question revolves around the issue of whether "workers move to jobs" or *vice versa*. Our findings are also in line with survey evidence.

Section 2 looks at the data on the main components of construction in the UK. Section 3 considers the non-spatial theory of the relationship between housing and industrial construction. Section 4 extends the theory to a spatial setting, whereas Section 5 conducts the empirical tests. Section 6 draws conclusions.

2. Trends in the Components of Construction

Figure 1 graphs private and public sector housing starts in Britain since the beginning of the sixties. Starts are measured in thousands of units[3].

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[2] This comprises primarily factories and warehouses.

[3] Rather than square metres of building, for example, which might be a better indicator but such measures are not available in Britain over long time periods.

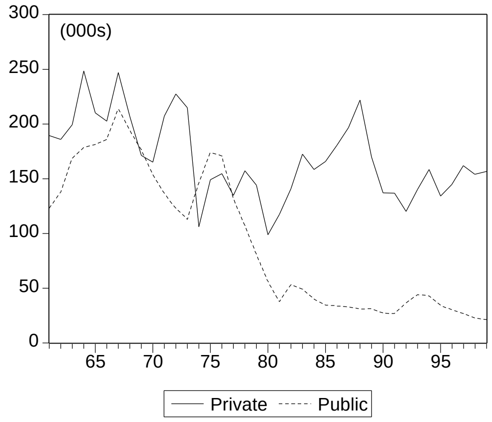

Figure 1 Private and Public Sector Housing Starts
Source: Economic Trends

Two features stand out - the long-run trends and the cyclical volatility. Abstracting from the cycle, in the private sector, in the sixties, new housing starts averaged more than 200,000 units per annum; in the seventies and eighties, starts averaged around 160,000, but fell to approximately 145,000 units during the nineties, although it is true that construction has been closer to the seventies and eighties average in the last four years. Therefore, in contrast to most economic aggregates, such as GDP, private housing starts have shown no upward trend over the last thirty years.

In addition, historically, housing and property in general are amongst the most volatile sectors of the economy. For example, between the peak in private housing starts in 1988 and the bottom of the subsequent trough in 1992, starts fell by 45%. But, by contrast, the stability of private housing starts since the mid nineties is striking. Despite a strong recovery in the economy as a whole, low levels of interest rates and sharp increases in house prices, new construction has not expanded in the same manner as in the late eighties housing market boom. An, as yet, unanswerable question is whether construction has entered a new more stable phase of development.

The long-run decline in construction is even more evident with the inclusion of the public sector. In the sixties, public housing starts averaged 168,000 units. In the nineties, the average stood at 31,000 and, in the period 1998-2000, starts have averaged only 20,000. Although estimates of social housing need vary widely, many commentators have suggested that the current level of production is well below the requirement to meet social housing need. The fall reflects the declining level of social housing provision over many years and the fact that house prices have risen substantially in real terms.

Figure 2 plots changes in repair, maintenance and improvement construction output (RMI) against the volume of total new housing construction[4]. In contrast to figure 1, in this case, each series is expressed in millions of pounds at constant, 1995 prices. The figure shows clearly that, over time, the negative trend in new building (-0.75% per annum between 1960 and 2000) has occurred at the same time as a rise in RMI, which has risen by an annual average 2.5% since 1960; this is faster than GDP as a whole. In fact, the ratio of RMI relative to new construction is now the highest in

[4] Note that the public and private sectors are amalgamated since separate figures for RMI are only available since 1980.

Europe amongst the major economies. RMI is now approximately twice as large as new housing construction. Only Italy is broadly comparable.

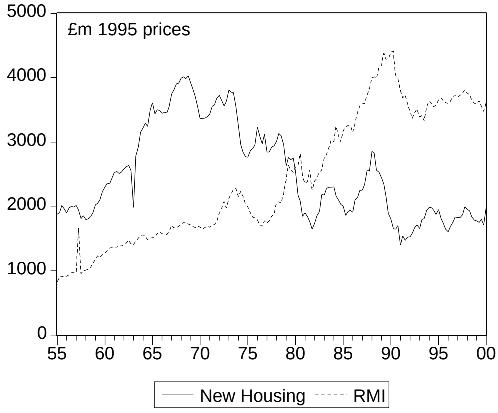

Figure 2 Repair, Maintenance and Improvement Output (1995 prices)

Source: DETR

Intuitively, we might think that housing and infrastructure investment are positively related. Housing requires support services in terms of roads, schools etc. The ratio of new private sector housing construction to infrastructure is shown in figure 3. Although, at first sight, the ratio seems broadly constant up to 1990, the ratio falls dramatically after 1990. This reflects privatisation. After that period, a large quantity of infrastructure investment was conducted, unrelated to new housing. At the current time *private* sector infrastructure comprises approximately 75% of the total.

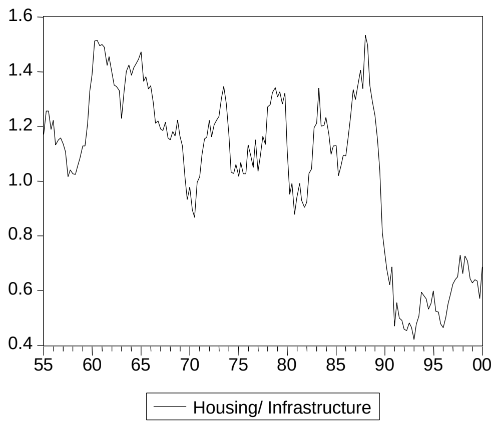

Figure 3. Ratio of Private Housing to Infrastructure Construction Output (constant prices)
Source: DETR

Figure 4 plots the three main components of private sector new construction – new housing, industrial and commercial – since 1955. Perhaps the most striking feature is the increasing dominance of commercial construction, which partly reflects the advance of the service economy at the expense of manufacturing. Whereas commercial work was the smallest of the categories at the start of the period, it had grown to be the largest by the end. The fortunes of the construction industry as a whole are increasingly bound up with the fortunes of the commercial sector. By contrast, the industrial sector, in line with new housing, has shown only a limited trend over time.

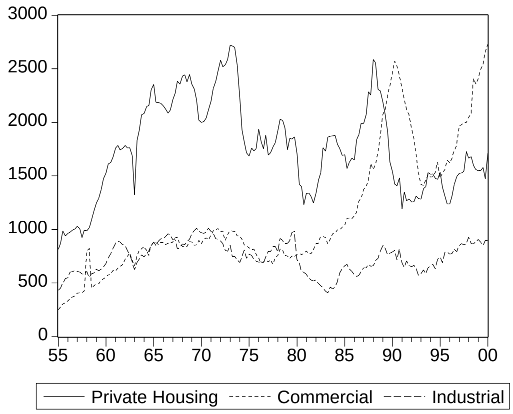

Figure 4. Construction Output - Private New Housing, Commercial and Industrial (£ million, 1995 prices; *Source* DETR)

Overall, therefore, by casual inspection, there is little obvious relationship between the sectors of the construction industry. However, there is an important caveat; Ball and Tsolacos (2000) point to serious shortcomings in the compilation of both new orders and construction output data in Britain. The allocation of construction output to particular component categories is partly carried out by government statisticians rather than being observed directly. It is possible that the methods employed introduce spurious correlation (or, indeed, disguise correlation) between the components of the industry. This is difficult to test directly although, since we are interested in long-run relationships, any bias in the statistics would have to be systematic rather than temporary or varying over the cycle.

3. Construction Activity – What Does the Theory Tell Us?

Casual inspection of the figures in the previous section suggests that housing construction is most likely to have a relationship with industrial construction and this is the area on which we concentrate. The underlying trends are, at least broadly, consistent. Unit root tests below also confirm this and suggest that any trends in the series are, at best, weak. We concentrate in this section on the theory underlying industrial construction models – in an aspatial framework – first in a single equation framework and, then, in a general equilibrium context. Previous empirical work demonstrates our primary problem. Although models of industrial construction may be able to explain cyclical changes, they cannot readily explain long-run movements. In order to explain long-run trends, we need to look at the relationship with other sectors of the industry. This brings us, first, to an aspatial general equilibrium setting and, in a later section, to a model that specifically incorporates space.

We discuss, first, the standard empirical approach to modelling industrial construction new orders (often taken to be the choice variable rather than output)[5]. Since the UK empirical evidence is limited relative to the vast quantitative literature on housing construction, this can be brief. Essentially most previous approaches have been based on accelerator models, typical of the more general investment literature. These models are subject to the criticism that, in conventional neo-classical analysis, buildings are simply treated in the same way as any other factor of production with the usual marginal optimising conditions determining the desired building stock. But smooth marginal adjustments are not typical of the property market; investment tends to be lumpy, indivisible and immobile and in some cases user specific. In addition, property diversity and spatial fixity suggest that there are potentially information problems in the market, so that mismatch may occur, enhanced by the major transactions costs involved in relocation. Furthermore we know that historically building investment has behaved in rather different ways from either plant and machinery or vehicle investment. A single modelling approach for all categories of investment is, therefore, unlikely to be successful.

The earliest empirical work on modelling industrial new orders or output in the UK dates back to Nicholson and Tebbutt (1979). Further models can be found in Barras and Ferguson (1987), Giussani and Tsolacos (1994), Ball and Tsolacos (2000), Thompson and Tsolacos (2000), Nanthakumaran *et al* (2000) at the national level and in Tsolacos (1995) for the UK standard regions. The Tsolacos studies test a variety of other variables, stressing the role of industrial rents and other financial variables as determinants, in addition to the more usual manufacturing or industrial output. For the US, the best-known study is, perhaps, by Wheaton and Torto (1990), who use manufacturing output, employment and the cost of capital as determinants. From our viewpoint, the essential feature of accelerator models is that they relate new orders to the *change* in output (and other variables). They are concerned with explaining short-run cycles in construction rather than long-run trends. Implicitly, the long-run level of new orders is a constant, along a steady-state growth path for output and rents, since there is no long-run relationship with the *level* of manufacturing output (or the other variables in the model). But in practice we observe that industrial new orders have experienced a weak long-run upward trend[6], which accelerator models cannot easily explain in their simplest forms. Alternatively, we may say that accelerator models contain no cointegrating vectors that explain long-term movements - our primary interest.

Note also that the distinction between property demand and supply is not always clear in these models. Accelerator models are generally considered as demand functions with perfectly elastic supply. The neo-classical model discussed below is also derived as a factor demand function. However, the idea that the supply of property is perfectly elastic in the short run is not attractive. Therefore the standard interrelated model combining user, investor and developer markets is more appealing and implies a

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[5] Since, for reasons which will become apparent, our main emphasis later will be on modelling industrial construction conditional on the housing market, we do not discuss the literature on housing construction itself; Meen (1996), for example, discusses this literature.

[6] The ADF(4) statistic over the period 1965(2)-2000(1) is –2.38(-2.9) including a constant and –2.60 (-3.4) including a constant and trend. The series appears to be difference stationary. The comparable ADF statistics for private housing output are –2.56 and –3.22. However, it should be noted that these are weak tests when the series are close to non-stationarity. The trends are, at best, weak. It might be noted that, over a shorter time span covering the period since the eighties, Ball and Tsolacos (2000) find new orders to be stationary.

short-run upward sloping supply function. For this reason, rents or capital values are a major determinant, but it is no longer clear what role (the change in) output has in the equation. There is a potential identification problem. In our model, presented in Section 5, this is less of an issue. Since we are modelling primarily the long run (where presumably supply is highly elastic), our function relates specifically to industrial property *demand*.

Some of these issues can be demonstrated in the following simple regressions given in table 1, which provide a baseline for our later work. In the first column the dependent variable is ln(*NOIND*), where *NOIND* represents industrial new construction orders, measured at constant, 1995 prices. New orders are chosen as the most appropriate decision variable, since the alternative (industrial construction output) is at least partly outside the control of the client. As in the conventional accelerator model, the independent variable is the percentage change in manufacturing output (? ln*QMF*). Lags are included on each variable. The estimation period is from 1964Q3 – 2000Q1.

Note immediately that this cannot be an adequate specification, because the orders of integration of the two series are inconsistent. We have already seen that new orders are non-stationary in levels. Unit root tests for *QMF* reveal that this series is stationary in first differences. Therefore we are regressing a non-stationary process on a stationary series. In the first column, this is revealed by the fact that the coefficients on the lagged dependent variables are not far below unity. Therefore in the second column this unity restriction is imposed so that the dependent variable is specified in first differences[7].

Table 1. Simple Accelerator Models of Industrial New Orders

Variable	***Equation 1***	***Equation2***	***Equation 3***	***Equation 4***
	ln NOIND	? ln NOIND	? ln NOIND	ln NOIND
Sample	1964Q3-2000Q1	1964Q4-2000Q1	1964Q4-2000Q1	1981Q1-2000Q1
ln NOIND(-1)	0.459 (7.0)	-	-	0.363 (4.4)
ln NOIND(-2)	0.384 (6.0)	-	-	0.159 (1.9)
? ln NOIND(-1)	-	-0.530 (7.5)	-0.440 (6.1)	-
? ln NOIND(-2)	-	-0.166 (2.4)	-0.121 (1.8)	-
? ln QMF	1.870 (3.1)	2.067 (3.4)	1.825 (3.1)	-
? ln QMF(-1)	1.675 (2.8)	1.724 (2.8)	1.896 (3.2)	4.666 (3.8)
? ln QMF(-2)	1.957 (3.3)	1.798 (2.9)	2.197 (3.6)	-
Ln NOIND(-1)	-	-	-0.153 (3.5)	-
Ln QMF(-1)	-	-	0.159 (1.5)	-
? ln RELP(-3)	-	-	-	2.779 (3.9)
constant	0.987 (3.5)	-0.028 (2.5)	1.675 (2.9)	3.036 (5.3)
R-squared	0.788	0.500	0.546	0.702
Adjusted R-squared	0.777	0.474	0.515	0.677
S.E. of regression	0.124	0.128	0.122	0.125
Durbin-Watson stat	1.842	1.761	1.782	1.705

t-values in brackets
Each equation includes one period dummies for exceptional new orders in 1991Q2 and 1995Q4. These are visible in figure 5.

[7] Note that compared with the first column an extra lag on the dependent variable has been added.

The problem now is that, although the restrictions are data-validated, the model has no long-run levels solution – all variables are specified in first differences. Although models of this form may be adequate in explaining the short-run cycle in construction, they cannot explain the long-run position.

The third column suggests one solution to the problem by estimating an error correction version, relating the level of new orders to the level of manufacturing output, although this is not entirely satisfactory in terms of the underlying theory. In fact, the lagged dependent variable is statistically significant, but the level of manufacturing output is not at the 5% level; we return to this issue later in terms of Johansen cointegrating systems, where we will suggest that manufacturing output is proxying something more fundamental. Note, however, that the *short-run* coefficients on manufacturing output are large giving an elasticity approaching 6. This is capturing the cycle shown in figure 5, where new orders are much more volatile than manufacturing output.

A further approach to tying down a long-run solution may come from standard neo-classical models. Under Cobb-Douglas technology and constant returns to scale, the conditional demand function for the capital stock (*K*) is determined by equation (1) and depends on relative factor prices, measured as the ratio of real wages (*W/P*) to the real user cost of capital (*UCC)*; (*a*), (*b*) are the exponents on labour and capital respectively in the production function and (*A*) is a scalar. Since in equilibrium the user cost will equal the real rent, the price ratio can be expressed as the ratio of the market rent to the nominal wage (*R/W*).

$$K = A^{-1}\left[a(UCC)/b(W/P)\right]^{-a} QMF \qquad (1)$$

In principle, therefore, long-run movements in industrial construction could be related to changes in relative factor prices, as in equation (2). This provides one explanation for the inclusion of rent variables in construction models, e.g. Tsolacos (1994). Note, however, that this is still an unlikely explanation of the *long-run trend* since the regressors are expressed in differences and are stationary. In (2), ln(*NOIND*) proxies the change in the capital stock[8].

$$\ln(NOIND) = -a\Delta\ln\left[aR/bW\right] + 1.0\Delta\ln QMF \qquad (2)$$

Although industrial rental data are not available for the whole of the period from the mid sixties, figure 6 shows the ratio of industrial rents relative to manufacturing earnings since 1980 and, indeed, the ratio has fallen nationally (although the percentage change in the ratio, used in (2), has not).

But the final column of table 4, which estimates equation (2) with the inclusion of lags, does not support the view that changes in factor prices can explain industrial new orders. The ratio of rents to earnings, $\Delta \ln RELP$, has a *positive* effect on investment, which is not consistent with the hypothesis based on a property demand function. It is, however, consistent with a short-run supply function. Nevertheless, as noted above, identification is an issue and it is not clear whether demand or supply functions are being estimated.

[8] Assuming that depreciation of buildings is small

In conclusion, none of the results so far are an adequate representation of the long-run determinants of industrial construction. As we explore in more detail later, an alternative view is that investment can rise over time because of spatial substitution. Property is immobile, but labour is not; therefore the movement of firms from cities to suburbs (which has been so important in explaining urban job losses, Turok and Edge 1999) raises the ratio of investment to employment, increasing construction at the same time as labour is shed. These changes can take place independently of factor prices. Note that this explanation implies that the *stock* of industrial buildings may have fallen at the same rate as manufacturing employment, even though investment is rising. The link is that the existing capital stock, particularly in cities, becomes obsolete, even though official statistics may not pick this up. Depreciation and scrapping rates may be high as firms substitute over space.

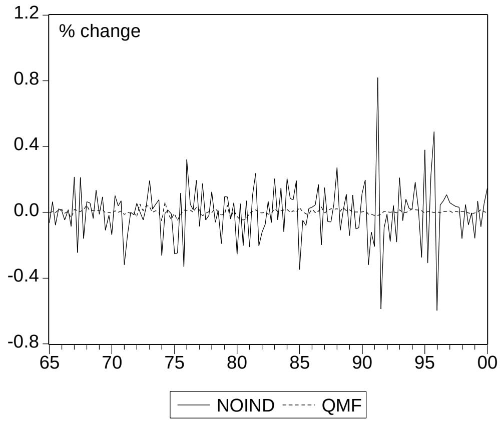

Figure 5. Industrial New Orders & Manufacturing Output (% changes)

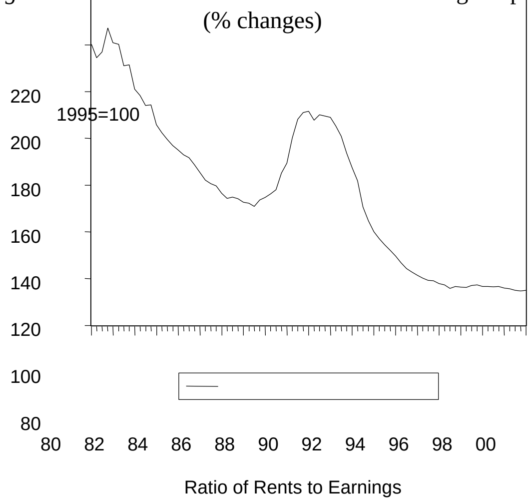

Figure 6. Industrial Rents Relative to Manufacturing Earnings

The analysis so far concentrates on single equation studies. As already noted, there are no empirical studies, either structural or reduced form that explicitly examine the relationship between the components of the construction industry. However, the theoretical macroeconomics literature has a great deal to say about the relationship between housing and other forms of investment, implicitly including industrial and commercial construction.

The initial stimulus to this literature arose in the seventies and eighties, primarily in the US, where it was argued that the combination of tax subsidies to housing and high rates of inflation led to a distortion in relative asset prices – notably a rise in the relative price of housing – generating a shift in resources away from so-called productive business investment towards housing[9]. A variety of different models came to the conclusion that housing and business investment are negatively related.

Capozza *et al* (1998) have recently returned to the issue, showing that the effect on prices depends on housing supply responses. This is indicative of recent general equilibrium analysis, typified by Turnovsky and Okuyama (1994). These authors construct a two-sector growth model consisting of housing and another aggregate good. The model can be used to demonstrate that, in the long run, the effects of housing subsidies depend on constraints on the mobility of labour between the two sectors. If labour is mobile, then the real price of housing is unaffected by housing subsidies. But prices do change under immobility. In neither case, however, is business investment necessarily affected. This depends on the effects of subsidies on the marginal productivity of capital. Only if this changes (for example if the subsidy is financed by a tax on profits or interest rates rise through increased government borrowing) is investment reduced.

Therefore, theoretical macroeconomic general equilibrium models indicate that the relationship between housing and business investment is likely to be either negative or zero. In fact, national empirical macro econometric models suggest that crowding-out does indeed occur, particularly in the longer term and close to full employment, (see Meen 1995). This occurs through a number of routes – changes in interest rates and inflation are key mechanisms.

Crowding-out is also implied by those who emphasise labour market constraints. Ball (1996), for example, stresses that supply constraints can occur through competing demands for resources in the different segments of the construction industry.

As we explore in more detail in the next section, the nature of the relationship changes fundamentally once we recognise one of the basic features of property – its spatial fixity, but it is worth noting (although we shall not explore the possibility further) that, even aspatially, a positive relationship may exist if housing generates externalities. Improvements in social capital may act as a magnet for further business investment. But no conventional model allows for this possibility.

4. Space and the Relationship Between Industrial Construction and Housing

Most models incorporating space into housing models are still based on standard residential location theory. For our purposes, however, there are two assumptions of the model that are inappropriate; first, the location of employment is fixed and concentrated on the urban centre. We need to recognise both the multi-centred nature

[9] Note that this ignored any externalities associated with housing. Particularly in the recent US literature externalities associated with social capital have provided one of the major justifications for the continuation of government support to owner-occupation; see, for example, Rossi and Weber (1996), Rohe and Stewart (1996), Haurin *et al* (2000).

of employment opportunities and the fact that industrial location is not exogenous, but changes in response to a variety of stimuli. The literature on international direct investment, for example, recognises that the location of multinationals depends on a wide variety of factors. Second, the model (in its simplest form) does not recognise the importance of amenities and neighbourhood quality, although Brueckner *et al* (1999) have incorporated amenities into an extended version.

The recognition of these factors suggests that employment and residential location may be jointly determined (Muth 1971). This is tested below through the use of weak exogeneity restrictions. Furthermore if, as neo-classical theory suggests, there is a relationship between the demand for labour and investment, through the factor demand functions, we expect a relationship to exist between industrial (buildings) investment and residential investment. In contrast to the previous section, the relationship will be *positive*.

The joint endogeneity of household and industrial location has been recognised, and tested, in the literature, which concentrates on the question of whether workers move (or commute) to jobs fixed in location or whether jobs move towards the location of (high-skilled) employees who represent a scarce resource. Evidence is available both from time-series econometrics and from surveys of the factors affecting firm location.

The assumption that employees move to jobs underlying the basic residential location model is therefore, by no means, universal in the literature although, as Thurston and Yezer (1994) suggest, formal tests of industrial location are more limited than those for household location.[10] However a number of US studies have attempted to distinguish whether "workers follow jobs" or "jobs follow workers". Early studies by Steinnes (1977, 1982), for example, conduct causality tests in a joint model of population change and employment in the manufacturing, retail and service sectors. He finds that, in manufacturing, jobs typically move to workers. Tests by Cooke (1978), which reformulated the Steinnes model in terms of population and employment gradients, also found evidence in favour of jobs following population in manufacturing. The main counter evidence comes from Thurston and Yezer (1994), who disaggregate to finer industrial sectors and use annual changes in the variables, rather than the more usual 5-10 year horizons. They find evidence that employment decentralisation in some industrial sectors subsequently influences population suburbanisation, but little evidence that jobs follow population except in the retail and service sectors.

Although the determinants of industrial location are multi-faceted, surveys also suggest that the availability of white-collar labour is one of the most important factors determining firm location across a broad range of industrial sectors (see Gordon 1999). Gordon also suggests that firms away from Central London typically place greater emphasis on the availability of skilled labour. But skilled labour is attracted to areas of better housing. Therefore, both firms and the skilled workforce tend to be co-located. Recent results from Simmie *et al* (2000) on the factors that affect the innovation performance of firms in the London region indicate that London itself has a poor performance in the innovation of new products in manufacturing, but

[10] Fingleton (1991) estimates a model of industrial firm relocation between London and other counties. However the work concentrates on cost differences and does not explicitly include such factors as labour availability and residential quality.

manufacturing innovation in Britain is heavily concentrated in the south eastern counties that surround London. However Greater London's relatively poor performance in manufacturing is compensated by the concentration of innovative service industries in the centre. But amongst innovating firms (aggregating over manufacturing and services), the most important factor that makes high rates of innovation possible is the presence of highly-qualified pools of technical and professional labour in the home counties. To quote from their survey, "Because of the higher incomes and, therefore, higher degrees of residential location choice of this type of labour, innovation needs to be examined not just from the point of view of firms and the economy but also in terms of quality of life choices by *high quality labour*". (my italics). Therefore, from these survey results, it appears that innovating industry is attracted to highly qualified labour, which, in turn, is attracted by high quality living conditions - which will not be in city centres but in the home counties.

If the results of these surveys generalise, it appears that jobs follow the skilled labour force to suburban locations where, at least in the case of Britain, amenities and the environment are better. These interactions generate cumulative processes of growth or decline between different locations, notably away from cities towards suburban locations. These processes are consistent with the Brueckner *et al* (1999) extension to the residential location model, which stresses the impact of both exogenous and endogenous amenities as drivers of population trends, also with the endodynamic and exodynamic growth processes emphasised by Galster *et al* (2000) and the literature that emphasises the importance of social capital, which suggests that areas that have increasing rates of owner-occupation are more likely to attract private industry. This is also consistent with *New Urbanism*. Under this view of the world, firms are increasingly including in their decision making quality of life issues, including environmental balance and social integration. To attract industry, authorities need to compete in these fields as well in more traditional aspects, such as competitiveness.

5. Empirical Tests of the Relationship Between Industrial Construction and Housing

The three questions considered in this section are (*i*) is there any long-run relationship between housing and industrial construction investment? This is an issue of cointegration (*ii*) if any relationship exists, is it negative (crowding-out) or positive (crowding-in)? This depends on the coefficients of any cointegrating relationship (*iii*) what is the direction of the relationship? This depends on Granger causality and weak exogeneity restrictions.

There is no necessary reason why the relationship between housing and business location should be the same for all sectors. In particular, the relationship might differ according to the strength of commuting patterns. If employees are prepared to commute long distances, there is no reason why firms should be constrained in their location choice by labour availability, since labour is in elastic supply. But in the absence of commuting, labour supply is inelastic and existing firms may be forced to relocate or new firms will locate in areas of plentiful labour with appropriate qualifications. Here we concentrate on industrial (mainly factories and warehouses) construction. Ideally tests for the commercial and retail sectors should also be conducted. However, appropriately disaggregated commercial construction data are unavailable. Nevertheless the industrial sector is still important in determining unemployment in cities. Turok and Edge (1999) and Bailey and Turok (2000) show that job losses from the conurbations have been concentrated primarily in manufacturing. Nevertheless it should be remembered that currently industrial construction comprises only 12% of new construction output.

Two further tests arise if firms are attracted primarily by labour availability - particularly skilled labour. First, we expect to observe a relationship only with private housing, since social housing has become an increasingly residualised sector with approximately 70% of tenants now receiving social benefits. This would also be consistent with the conclusions of the social capital literature. Second, we might expect any relationship to be stronger in the South East than in other regions, since this is where the most innovative firms, requiring highly skilled labour, have tended to concentrate in Britain.

It is, however, possible, that a positive long-run correlation could be caused by other explanations to those discussed above. The relationship could be generated by a common supply shock. For example, a technological improvement, which requires new factory space, could raise the economy's long-run growth rate. This, in turn, raises the demand for housing. But, under this view, changes in industrial construction would precede changes in the housing market. Alternatively, both industrial construction and housing might respond to common external factors such as land availability. So, for example, a relaxation of binding planning constraints would increase both housing and industrial construction. Both these hypotheses can be tested by weak exogeneity restrictions in the estimated system.

Our tests are based on the causality tests proposed by Steinnes and Thurston and Yezer, discussed above. But our tests are slightly different from those previously employed. First, rather than concentrating on population and employment, we consider the relationship between new housing construction and industrial construction investment, which are directly related to population and employment change respectively. This alternative set of variables has a number of advantages. First, the periodicity of the data is more frequent than population data. We can, therefore, use quarterly observations; this can be important if the lags between population and industrial changes are short. Using data at longer frequencies may, mistakenly, suggest that both are simultaneously determined. Second, the approach allows us to consider, at the same time, issues of crowding-out. If jobs follow workers, then business investment and housing will be *positively* related. Third, tests of causality are based on weak exogeneity restrictions set in a cointegration framework. Earlier Granger causality tests have generally been specified in terms of rates of change in order to induce stationarity. But this does not permit the testing of long-run relationships between the variables in levels. Since we are primarily concerned with the long run, cointegration is a more appropriate framework.

In table 1, based on the accelerator model, the key variables were industrial new orders and manufacturing production. This provides a baseline against which to assess alternative models. Note that manufacturing output was found to be significant in rates of change but not in *levels*. We begin by estimating a Johansen system over the same time period since 1964, but extending the variable set to include both public

QPBH and private *QPRD* new housing construction output[11]. Note that both variables are defined as *output* rather than *new orders*; this is in order to aid identification of the lags between the variables, since output occurs after new orders. The system includes three lags on each variable, which is sufficient to eliminate autocorrelation in the relationships[12]. The system, therefore, nests the accelerator model discussed earlier.

Although not shown here, both maximum eigenvalue and trace statistics indicate that there is a single cointegrating vector amongst the four variables. The unrestricted coefficients of the vector are shown in the first row of table 2. Normalisation on *NOIND* implies that the system is just identified. Two key points stand out; first, manufacturing output has no significant effect in the long run. Hence, in the second row, its coefficient may validly be constrained to zero. This concurs with table 1, where manufacturing output was also insignificant. Changes in manufacturing output may explain cyclical movements in industrial construction as accelerator models suggest, but the level of output does not explain any long-run trend in new orders. Second, both private and public housing construction have significant *positive* effects on industrial construction, although the size of the former elasticity is more than three times the size of the latter.[13] This is an indication that the low skilled are less important in determining industrial location. Since the relationship between housing and industrial construction is positive, housing appears to crowd-in industrial investment[14].

Table 2.Cointegrating Vectors Over Different Time Periods

Period	***QPRD***	***QPBH***	***QMF***	***NOIND***
1964Q4-2000Q1	-0.494 (2.23)	-0.147 (2.16)	-0.190 (0.47)	1.0
1964Q4-2000Q1	-0.472 (2.11)	-0.136 (2.16)	-	1.0
1964Q4-1980Q4	-1.383 (3.84)	-1.158 (4.20)	-	1.0
1973Q1-2000Q1	-0.512 (2.78)	-0.059 (1.06)	-	1.0
1980Q1-2000Q1	-0.489 (2.46)	0.129 (1.28)	-	1.0
1964Q4-2000Q1	-0.474 (2.11)	-0.133 (2.10)	-	1.0

t-values in brackets
each equation includes one period dummies for exceptional new orders in 1991Q2 and 1995Q4.
All variables are defined in logarithms.

The third to fifth rows consider results over different sub-periods. Over all periods, private housing remains significant and the coefficient is fairly stable except over the earliest period. But public housing has become increasingly less important over time and, in the most recent period, public housing changes sign - an inverse relationship with industrial new orders (although we need to bear in mind that new social housing construction has become very small in recent years). These changes in the relative importance of the two coefficients are precisely what we expect to observe on the basis of the changes in the composition of tenants in the social sector. In earlier years,

[11] Note that the VAR specification integrates both autoregressive and econometric approaches which, in the empirical property literature, are sometimes seen as alternative modelling strategies.

[12] Initial ADF tests indicate that all series are I(1) although as, we saw in Section 2, the trends are not strong. More unusually the cointegrating vectors include one-off dummy variables for 1991Q2 and 1995Q4 where industrial new orders experienced exceptionally large changes. This is always potentially a problem dealing with new orders data, since the effects of one-off contracts can be dramatic.

[13] In order to interpret the effects of each variable on new orders the signs have to be reversed.

[14] Note, however, that this does not necessarily imply that productive capacity in the economy as a whole is enhanced. If the investment is carried out by relocating existing firms rather than newly-forming firms, existing premises become obsolete.

the sector contained a high proportion of skilled workers, but this has become increasingly uncommon. If anything, industrial investment now appears to be deterred by the presence of social housing. This may be consistent with the importance of social capital outlined above.

In each of the first five rows no restrictions are imposed on the *alpha* matrix, i.e. the matrix of adjustment coefficients, which determines the speed of adjustment to equilibrium following any shock. The only over-identifying restriction is the zero coefficient on *QMF*. Over-identifying restrictions on the *alpha* matrix can be used to test for weak exogeneity. Table 3 sets out, for the full sample period, unrestricted and restricted estimates of the matrix[15]. Since the coefficients on *? ln QMF* and *? ln QPBH* can validly be restricted to zero, this implies that these variables are weakly exogenous to the parameters of interest and we can validly reparameterise the system in terms of the two variables *NOIND* and *QPRD* conditional on *QMF* and *QPBH*. As we see below, this implies that contemporaneous values on the two latter variables can now enter the system. Weak exogeneity of *QPRD* is less clear, although the significance of the adjustment coefficient is at best weak. The results suggest strongly that the main adjustment comes through *NOIND*. The adjustment parameter on (*NOIND*), which takes a value of (-0.277), implies that any disequilibrium in the long-run relationship is primarily eliminated by changes in new orders rather than in housing output. This suggests that private housing is either jointly endogenous or, perhaps, weakly exogenous and that industrial new orders are caused by changes in housing construction. This result is consistent with the view that existing firms in this sector relocate or newly- forming firms locate in places where more highly skilled workers desire to live.

However, for the moment, we re-estimate the system under the assumption that *NOIND* and *QPRD* are jointly endogenous. Nevertheless, the evidence suggests that private housing determines industrial new orders, rather than the other way round.

The results are also unlikely to be explainable in terms of the other two hypotheses outlined above. If industrial construction is subject to a supply shock, which then generates higher housing demand, the direction of causality would be the other way round. The coefficients of the adjustment matrix are not consistent with this view. Neither is it likely that both are jointly determined by the relaxation of planning constraints; in this case we would expect both variables (and perhaps public housing) to be jointly determined.

Table 3.Adjustment Coefficients: 1964Q4 – 2000Q1

	Unrestricted	***Restricted***
? ln NOIND	-0.280 (9.33)	-0.277 (9.89)
? ln QPRD	-0.024 (1.64)	-0.026 (1.86)
? ln QPBH	0.0099 (0.61)	-
? ln QMF	0.0004 (0.09)	-

Table 4 sets out the full dynamic model including the cointegrating vector (*ECM*) given by the final row in table 2. As noted above this is now a two equation model,

[15] The last row of table 2 sets out the coefficients of the cointegrating vector imposing the restrictions on the alpha matrix.

conditional on *QPBH* and *QMF*. The conditioning is not imposed *a priori*, but falls out naturally from the weak exogeneity tests.

There are a number of key findings. First, the equation for industrial new orders variance encompasses the accelerator model in table 1; the equation standard error falls from 12.2% to 11.7%. Therefore, the *level* of manufacturing output in table 1 acted as a proxy for housing construction. Second, the error correction coefficient in table 1 (-0.153) is noticeably smaller than in table 4 (-0.279); although not a formal test, the implied quicker speed of adjustment to equilibrium is suggestive of cointegration. The adjustment coefficient is also very similar to that in table 3; this must be the case since only data-validated restrictions are applied in the final dynamic specification. Third, the adjustment coefficient in the *QPRD* equation at –0.026 is statistically insignificant; this confirms our earlier suspicion that, in fact private housing is weakly exogenous; industrial construction does not Granger-cause housing, but housing Granger-causes industrial construction. In other words, for this sector, jobs move to workers, not the other way round. This means that the model could be again reformulated as a single equation for *NOIND* conditional on *QPRD*, *QPBH* and *QMF*; in other words a single equation method would have been adequate in this instance, although this could not have been predicted in advance. Note from the correlation matrix that the contemporaneous correlation between *? ln NOIND* and *? ln QPRD* is fairly small (0.15)

Fourth, in general, the *QPRD* equation is poorly defined statistically; but since it is weakly exogenous for the parameters of interest, it could be replaced in the system without affecting the properties of the *NOIND* equation. Nevertheless, the housing equation suggests a contemporaneous positive relationship between private and public housing; they are not substitutes.

Fifth, in the *short run*, the accelerator model still appears to hold as a representation of industrial construction. The sum of the elasticities on *? ln QMF* is still approximately five and is consistent with the cycles shown in figure 5. Sixth, in the short term, there appears to be a weak negative relationship between industrial construction and *public* housing, which could be consistent with crowding out.

Table 4 presents a range of diagnostic statistics. Both single equation and systems tests are presented. There is some limited evidence of remaining fifth-order autocorrelation (AR1-5), which we have not entirely eliminated, but there is no evidence of heteroscedasticity (ARCH 4) or residual non-normality. Figure 7 presents coefficient stability tests, through recursive regression[16]. These quickly settle down to very stable values (with the exception of the coefficient on public sector housing, which table 4 shows to be poorly determined). The stability of the error correction coefficient, which determines the long-run properties of the equation, is particularly noticeable. It does not appear to be the case, as some studies suggest, that the industry is subject to instability or structural change, once both the dynamics and long-run structure are adequately modelled.

[16] In fact, these were conducted on a single equation version of the final model. As we expect, given the weak exogeneity tests, the results were very similar to those in table 4. Note also that, in order to conduct recursive regression, the dummy variables have to be dropped, which would be expected to increasing the instability of the remaining coefficients.

Although we have argued that the results are inconsistent with either of the two alternative hypotheses suggested above, further tests are informative. Our hypothesis suggests that any relationship between housing and industrial construction is likely to be strongest in the South of England, where high technology firms are chasing highly skilled labour. But testing the relationship at the regional level is more difficult because constant price construction output data are not available below the national level and hence current price data have to be used. Furthermore available time spans are much shorter, beginning in 1980. Nevertheless, table 5 presents a selection of regional results, based on earlier work, taken from Meen (2001).

The table suggests that the finding of a positive relationship between industrial new orders and private housing is not uniform across the country. The results indicate that the relationship only holds in the three southern regions and that the coefficient is strongly negative in the North West. By contrast, public housing generally has an insignificant effect in the southern areas. Therefore, the national results disguise very distinct spatial patterns, which are consistent with the skill requirements of high technology companies, disproportionately distributed in the South East. Such companies need to be in locations where skilled labour can be found.

In summary, in terms of the original questions, it appears that there is a positive long-run relationship between industrial construction and housing - housing does not crowd-out industrial construction. The direction of causality suggests that jobs move to workers. The relationship is at its strongest with private housing and the relationship is dominated by the South of England.

Table 4.Dynamic Two Equation Model

Estimating the model by FIML
The sample is: 1964 (4) to 2000 (1)

Equation 1 for ? ln NOIND

Variable	**Coefficient**	**t-value**
? ln NOIND(-1)	-0.340426	-5.546
? ln QMF	1.6170	2.872
? ln QMF(-1)	1.3956	2.526
? ln QMF(-2)	1.9963	3.599
? ln QPBH	-0.222695	-1.565
ECM(-1)	-0.278574	-5.481
d912	0.832458	7.006
d954	0.615677	5.286
Constant	0.550040	5.183

S.E. of regression = 0.1165545

Equation 2 for ? ln QPRD

Variable	**Coefficient**	**t-value**
? ln QPRD(-2)	0.257333	3.048
? ln QPBH	0.142108	2.024
ECM(-1)	-0.0260983	-1.075
d912	0.119436	2.022
Constant	0.0535783	1.059

S.E. of regression = 0.05851416

LR test of over-identifying restrictions: $Chi^2(14)$ = 7.76074 [0.9014]

d912, d954 are dummy variables described above.

correlation of residuals

	? ln NOIND	? ln QPRD
? ln NOIND	1.000	
? ln QPRD	0.15123	1.000

? ln NOIND	: AR 1- 5 F(5,123) =	3.9842	[0.0022]
? ln QPRD	: AR 1- 5 F(5,123) =	3.0837	[0.0117]
? ln NOIND	: Normality $Chi^2(2)$=	0.605217	[0.7389]
? ln QPRD	: Normality $Chi^2(2)$=	9.1727	[0.0102]
? ln NOIND	: ARCH 4 F(4,120) =	1.4949	[0.2080]
? ln QPRD	: ARCH 4 F(4,120) =	0.410277	[0.8010]

Vector AR 1-5 F(20,248) = 1.1574 [0.2927]
Vector normality $Chi^2(4)$= 9.3005 [0.0540]

Table 5. *Regional Industrial Construction & Housing 1980(4)-1996(1)*

Region	Private	Public
South East (ex. London)	0.738	-0.074
East Anglia	0.901	0.089
South West	0.931	0.291
North West	-0.917	-0.474

Source: Meen (2001)

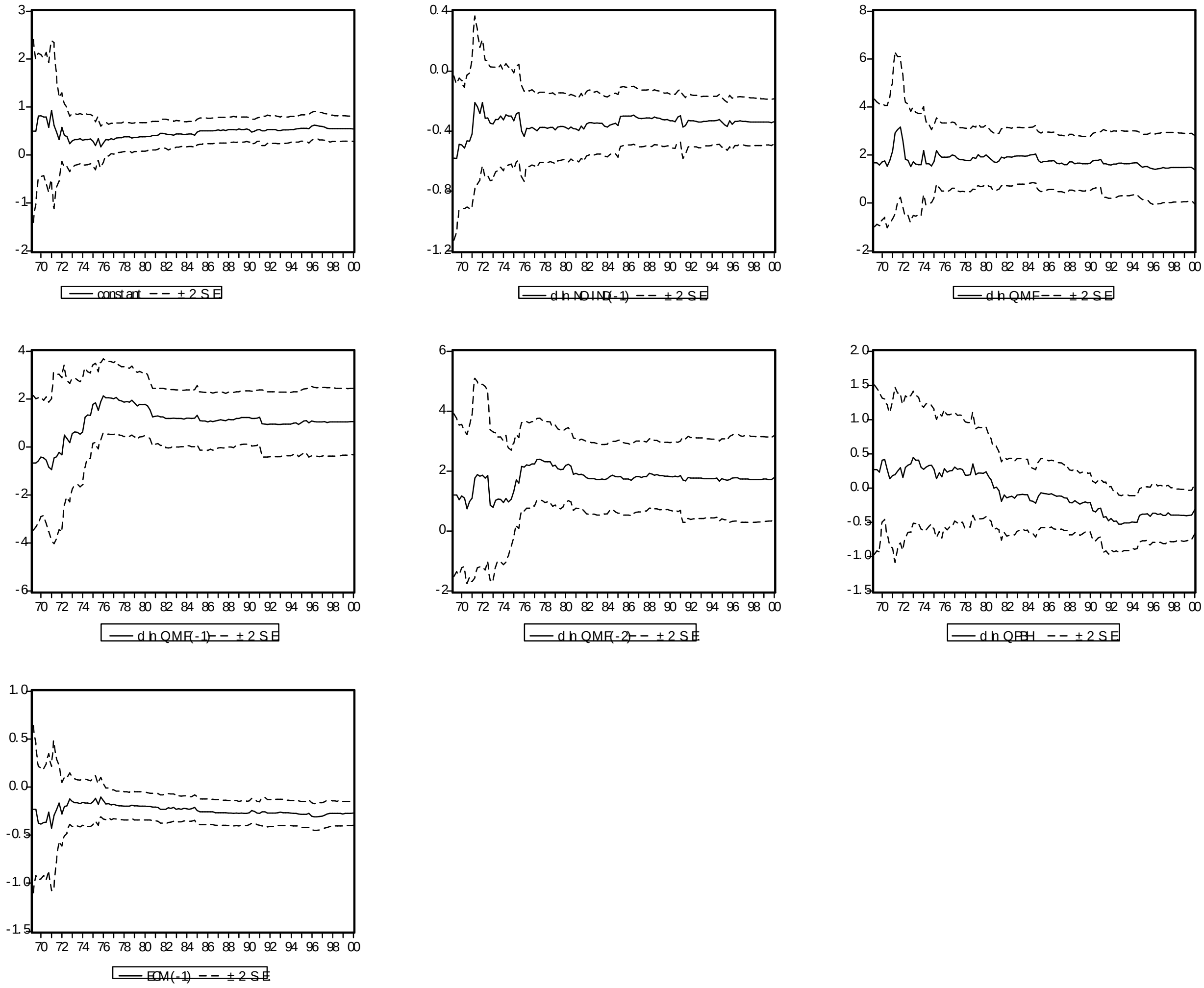

Figure 7. Coefficient Stability Tests

6. Conclusions

To conclude, although we cannot test the relationship in the same way, it is useful to speculate on the relationship between housing and commercial developments, which in absolute size now dominate industrial construction. In principle, we ought to be able to go through the same exercise as above, but the problem is that UK data do not split commercial construction between retail and office building (at least not at constant prices). Our expectation is that the relationship between housing and the two components would be very different. Since retail developments require concentrations of relatively low-skilled local employment and rely on local population centres for their markets, we might expect a strong positive relationship with housing, but any relationship with office development would depend on commuting patterns. Office developments might have little relationship with housing because of strong commuting patterns by employees in financial services, particularly if agglomeration economies in the sector are strong and still favour major cities.

We may ask whether the estimated relationship between new housing and industrial construction is of any consequence since the latter now only comprises 12% of total new construction work. In fact, any relationship does matter because it is primarily in the manufacturing sector that major cities have lost jobs, contributing to urban deprivation. Our model provides some evidence on why these job losses have occurred. The model suggests that there is little point in simply calling for more manufacturing jobs to be created in cities; this ignores the reasons why firms left cities in the first place. The trends over the thirty-five years of our sample are part of an endogenous process, related to housing conditions, which has been cumulative.

As a final comment, it might be argued that empirical time-series models of industrial construction have forgotten their roots. These roots lie in location theory. Most time-series models that have been estimated are more applicable to plant and machinery investment than to immovable property. It is to be hoped that future work in this area pays more attention to the micro foundations of the subject.

References

Bailey, N., and I. Turok. (2000). "Adjustment to Job Loss in Britain's Major Cities". *Department of Urban Studies: University of Glasgow*.

Ball, M. (1996). *Housing and Construction, a Troubled Partnership?* Joseph Rowntree Foundation.

Ball M, Tsolacos S (2000), "UK Commercial Property Forecasting: The Devil is in the Data", *forthcoming Journal of Property Research*.

Barras R, Ferguson D (1987), "Dynamic Modelling of the Building Cycle: 2 Empirical Results", *Environment and Planning A*, 19: 493-520.

Brueckner, J., J-F. Thisse., and Y. Zenou. (1999). "Why Is Central Paris Rich and Downtown Detroit Poor? An Amenity-Based Theory." *European Economic Review* 43: 91-107.

Capozza, D.R., R.K. Green, and P.H. Hendershott. (1998). "Tax Reform and House Prices: Large or Small Effect?" *Paper presented at the National Tax Association meeting*: Austin, Texas.

Cooke, T. (1978). "Causality Reconsidered: A Note." *Journal of Urban Economics* 5: 538-542.

Fingleton, B. (1991). "Industrial Location and Policy: A Spatial Statistical Analysis." *Papers in Regional Science* 70(3): 267-285.

Galster G.C, Quercia R.G, Cortes A (2000), "Identifying Neighborhood Thresholds: An Empirical Investigation", *Housing Policy Debate*, 11(3): 701-732.

Giussani B, Tsolacos S (1994), "Industrial Property Development in the UK: Modelling the Determinants of New Orders", *Journal of Property Research*, 11(1): 1-16.

Gordon, I. (1999). "London and the South East." Chapter 10 in M. Breheny (ed.), *The People Where Will They Work*. TCPA.

Haurin D.R, Parcel T.L, Haurin R.J (2000), "The Impact of Home Ownership on Child Outcomes". *Paper presented to the Symposium on Low-Income Home Ownership, Harvard University*.

Meen, G.P. (1995). "Is Housing Good for the Economy?" *Housing Studies* 10(3): 405-424.

Meen, G.P. (1996). "Spatial Aggregation, Spatial Dependence and Predictability in the UK Housing Market." *Housing Studies* 11(3): 345-372.

Meen, G.P. (2001), *Modelling Spatial Housing Markets: Theory, Analysis and Policy*. Kluwer Academic Publishers, Boston.

Meen G, Gibb K, Mackay D, White M (2001), *The Economic Role of New Housing*. Report for the Housing Research Foundation.

Muth, R.F. (1971). "Migration: Chicken or Egg?" *Southern Economic Journal* 37: 295-306.

Nanthakumaran N, Watkins C, Orr A, (2000), “Understanding Property Market Dynamics: Insights from Modelling the Supply-Side Adjustment Mechanism”, *Environment and Planning A*, 32: 655-671.

Nicholson R, Tebbutt S (1979), “Modelling of New Orders for Private Industrial Buildings”, *Journal of Industrial Economics*, 28(2): 147-160.

Rohe W.M, Stewart L.S (1996), “Homeownership and Neighborhood Stability”, *Housing Policy Debate*, 7(1): 37-81.

Rossi P.H, Weber E (1996), “The Social Benefits of Homeownership: Empirical Evidence from National Surveys”, *Housing Policy Debate*. 7(1): 1-35.

Simmie J, Wood P, Hart D, Sennett J (2000), “Innovation and Clustering in the London Metropolitan Region”, *Paper presented to the ESRC Symposium on Urban Competitiveness, South Bank University.*

Steinnes, D.N. (1977). “Causality and Intraurban Location.” *Journal of Urban Economics* 4: 69-79.

Steinnes, D.N. (1982). “Do People Follow Jobs or Do Jobs Follow People? A Causality Issue in Urban Economics.” *Urban Studies* 19(2): 187-192.

Thurston, L., and A.M.J. Yezer. (1994). “Causality in the Suburbanization of Population and Employment.” *Journal of Urban Economics* 35: 105-118.

Thompson B, Tsolacos S (2000), “Projections in the Industrial Property Market Using a Simultaneous Equation System”, *Journal of Real Estate Research*, 19(1/2): 165-188.

Tsolacos S (1995), “Industrial Property Development in the UK: A Regional Analysis of New Orders”, *Journal of Property Research*, 12(2): 95-125.

Turnovsky, S.J., and T. Okuyama. (1994). “Taxes, Housing and Capital Accumulation in a Two-Sector Growing Economy.” *Journal of Public Economics* 53: 245-267.

Turok I, Edge N (1999) *The Job’s Gap in British Cities*. The Policy Press: Bristol.

Wheaton W, Torto R (1990), “An Investment Model or the Demand and Supply of Industrial Real Estate”, *AREUEA Journal*, 18(4): 530-547.