DOES THE BON CURVE APPLY TO INFRASTRUCTURE MARKETS?

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Bon (1992) argues that construction demand is low where economies have yet to expand. During their expansion phase, the growth in construction outstrips the rest of the economy and therefore increases as a share of GDP. As the economy approaches maturity, the rate of increase in construction slows and as a result the proportion of GDP taken up by construction declines. While this may indeed be the case for construction activity as a whole, it would appear that at least one submarket within the construction sector does not follow that pattern. Infrastructure output may be seen as continuing to increase more rapidly than GDP regardless of the state of maturity of the economy. This may be because as the economy grows, more infrastructure is required to support ever more sophisticated requirements such as rapid movement of goods, increased volume of traffic and greater expectations and use of quality urban environments as commuters increase their demands for rapid transit and improved quality of life. Using a model of infrastructure based on infrastructure as a share of construction output in the UK, infrastructure in all countries was estimated. This enabled a comparison of infrastructure in the different countries to be compared. This was used to show the relationship between infrastructure as a percentage of GDP and the level of income per head. While both low and high income countries tend to have low levels of spending on infrastructure, the majority of countries in the mid range of income tend to have a wide range of infrastructure to GDP, with no particular pattern. These results may have implications for interpreting the Bon curve. Indeed, the current call for investment in infrastructure even at a time of recession is witness to the ever increasing demand for roads, rail, air, communication, water and sewage services, and energy even in relatively wealthy economies.

Keywords: Bon curve, European construction sector, infrastructure.

INTRODUCTION

There is something appealing and intuitive about the Bon curve that has stimulated a number of researchers to produce papers in support. In his seminal paper on the topic Bon (1992) argues that there is a link between the level of economic development as measured by income per capita and investment in construction as a proportion of GDP. The phases of economic development from agrarian to industrial economies have been described as less developed, newly industrialized and advanced industrialized. As countries move from being less developed to advanced industrialized economies, investment in construction as a percentage of GNP peaks during the transition at the point, where countries are said to be newly industrialized.

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Bon's view is reinforced by Ruddock (2000) in a report on the availability and reliability of construction data. However, the report goes on to conclude that much work needs to be done to allow reliable comparisons to be drawn. Ruddock and Lopes (2006) give a clear description of the share of construction output in GDP by level of GDP per capita as a measure of development. As countries move up the league table, to begin with they tend to increase their level of construction output and then as they enter the most developed group of countries the ratio of construction to GDP tends to decline. The poorest countries spend 2.4 to 10.1%, the next poorest 3.6 to 10.4%, the next 3.9 to 10.5% and the richest countries 4.8 to 7.9% of GDP. Their argument is that as one compares construction as a share of GDP those countries with the greatest percentage of construction to GDP tend to be the middle two categories and the smallest construction share in GDP tend to be in the poorest and richest countries.

Ruddock and Lopes point to the shift toward repair and maintenance in post industrial economies to account for the decline in the share of construction in GDP. It follows from the durability of the built environment that as the stock increases more resources are required to maintain it. However, it does not follow that this accounts for a decline in the relative share of construction in GDP as well as an absolute decline in construction output as claimed by Bon (ibid). Such a relative decline could be indicative of a shift to services away from manufacturing, a rise in the productivity of capital due to the digital economy and a decline in the real cost of fixed plant and equipment at the same time as a rise in the real value of construction output.

Mehmet and Yorucu (2008) also relate construction output to GDP. They discuss the relationship both in terms of the relatively short term business cycle and the long term development of an economy. They describe the stages of economic transition, referring to Rostow's approach. Although it is possible to discern different phases of economic development, the process of transition appears to vary from one country to another depending on contingent historical, political and economic events. Indeed, because they perceive a link between construction and economic growth, Mehmet and Yorucu assert construction is the engine of economic growth over the business cycle.

However, the reverse can also be argued, namely that economic growth is the engine of construction, as growth necessitates investment in infrastructure and commercial and other buildings. Indeed, Mehmet and Yorucu (ibid.) recognize the diverse output of construction arguing that the composition of construction output varies as economies shift from agrarian to industrial. In their description of the North Cyprus construction market, they report major deficiencies in infrastructure as a result of rapid construction growth. In the end they assert that in small states in the short term there may be volatile movements in the relationship between GDP and construction output. This is completely reasonable and accountable in terms of the impact of relatively large projects in a small economy and in terms of government intervention to counter the negative effects off rapid construction output growth.

This volatility over time is not an issue if an alternative approach is adopted namely cross sectional data. This approach has been adopted in a number of studies including Crosthwaite (2000) who studied the relationship between GDP and construction as a whole in different countries. While most studies look at the Bon curve longitudinally, this study takes some cross sectional data and compares the ratio of estimates of infrastructure to GDP and infrastructure to GDP per head in different countries. In other words does the Bon curve hold in cross sectional data of infrastructure in the different countries in Europe, where development ranges from the poorer countries of

Eastern Europe to the wealthier countries of Western Europe. Although Wong, Chiang and Thomas (2008) argue that differences between countries renders comparisons implausible, it is precisely these differences that account for many of the differences to be found. Provided one is not seeking to find a cause and effect, it is more than useful to compare countries to find what relationships to exist and to identify similarities and differences. Indeed these can be ascertained to some extent by using multiple regression techniques to examine the statistical significance of size, topology and even cultural difference. In their study of the construction industry in Hong Kong, from their analysis of the data, Wong *et al.* contend that construction can be said to cause economic growth but economic growth in Hong Kong cannot be said to cause construction growth. More specifically they argue that infrastructure was a driver of economic growth in Hong Kong.

The Bon curve can be interpreted in different ways: for example, as a time series of the ratio of construction to GDP in a given country as that country's income per head increases or as a ratio of construction to GDP over the ratio of income per capita in a number of countries. While the discussion has been mainly in terms of total construction output in relation to GDP, some types of output might perform differently from construction as a whole and it is for that reason that this paper concentrates on the behaviour of infrastructure markets. Ofori and Han (2003) trace the development of theories of the relationship between construction and national income. They also compare this relationship in different provinces in China. This paper uses a similar approach and in particular is concerned with the built infrastructure sector in several countries rather than the relationship between construction and the rest of the economy over the business cycle in only one economy. The implication is that as countries develop or as income per capita increases, marginal construction output follows a law of diminishing marginal construction output, what Wong *et al.* (ibid.) refer to as a "marginal diminishing function with the GDP". Marginal construction output may be defined as the change in construction output as per capita income increases. Per capita income is taken as a proxy for development. This implies a simple regression analysis of infrastructure as a percentage of Gross Domestic Product and income per capita as a proxy measurement of development.

There is a further point worth noting. The relationship may be a one way relationship dependent on continuous economic growth. It does not follow from the Bon curve that if per capita income declines construction would increase to a peak and then begin to decline as per capita income declined. De-industrialization may well lead to a completely different pattern of construction output. No longer is here any need for net investment and replacement investment is not required as capacity is reduced. In such circumstances, construction output could begin to approach zero. In growth phases even where the level of per capita income and the change in per capita income were identical to that when the economy were growing, there would not only be a need for net investment but also repair and maintenance of existing stock.

METHOD

In order to carry out a cross sectional analysis of the relationship between the share of infrastructure and the level of development of each country, the study used data from 26 EU countries, and Iceland, Norway, Turkey and Switzerland. Malta was omitted due to lack of data.

It is not possible to identify infrastructure investment consistently in all economies as definitions and components vary. In the UK, construction infrastructure includes the main components, published by the Office for National Statistics (ONS, 2009), namely: water, sewerage, electricity, gas, communications, harbours, air, railways and roads. The UK data was used to estimate infrastructure as a percentage of Gross Fixed Capital Formation (GFCF) in each country. Unfortunately, GFCF does not include repair and maintenance. In order to find a total figure for all infrastructure work, new build was grossed using the method discussed in Gruneberg (2008).

Not all construction is included in GFCF because GFCF only includes new build. In order to allow for repair and maintenance a multiplier is applied to new build based on the following method. According to the Construction Statistics Annual (ibid) in the UK work on existing stock is approximately 46% of total construction output. If 46% of infrastructure investment is repair and maintenance, then new build only represents 54% of the total infrastructure market. Total infrastructure output is therefore new build multiplied by 1.85, the inverse of 54%.

UK infrastructure output as a percentage of GFCF was used to estimate infrastructure investment from the GFCF data of the different countries. In the period from 1998 to 2005, infrastructure output in the UK was equivalent to just over 4% of GFCF. In 2006 UK GFCF was approximately 18% of GDP, having risen from 14% of GDP since 1995 (ONS, 2007). Infrastructure investment (at just 4% of 18% of GDP) is therefore less than 0.75% of GDP in the UK. These coefficients were then applied to the 2005 GFCF of all countries to estimate infrastructure. In order to test the link between the stage of development and the infrastructure share of national income, the ratios of infrastructure to GDP and GDP per capita were used. The data was transformed into logs to overcome the curve of the Bon hypothesis. The use of natural logarithms transforms the curve into a "straight line" to permit analysis using simple regression, which assumes a straight line relationship between the dependent and independent variables.

The hypothesis of the Bon curve is that the stage of development determines the percentage of national expenditure on infrastructure. To test this here, the function used is:

$$ln\ (I) = \alpha + \beta\ ln\ (D) + c$$

where I = infrastructure investment as a percentage of GDP

and D = level of economic development. The level of development is measured by the proxy of GDP per capita.

The null hypothesis is therefore H0: $\beta = 0$ and the alternative hypothesis is H1: $\beta \neq 0$. This can be interpreted to mean that the level of economic development does not determine the level of infrastructure investment as a proportion of GDP.

FINDINGS

Table 1 provides data on the GDP, GDP per capita and infrastructure spending in 2005.

Table 1: GDP, infrastructure and GDP per capita by country 2005

Country	Euros (m) Infrastructure	Euros (m) GDP	Euros GDP per capita
Belgium	2,501	302,845	26,900
Bulgaria	216	21,882	7,800
Czech Republic	1,021	100,190	17,100
Denmark	1,735	207,367	27,800
Germany	15,935	2,242,200	26,300
Estonia	140	11,182	13,800
Ireland	1,715	162,091	32,299
Greece	1,750	195,366	20,600
Spain	10,871	908,792	22,900
France	13,891	1,726,068	24,900
Italy	11,931	1,429,479	23,600
Cyprus	105	13,659	20,400
Latvia	162	13,012	10,900
Lithuania	193	20,870	11,900
Luxembourg	245	30,282	57,200
Hungary	825	88,646	14,200
Netherlands	3,934	513,407	29,400
Austria	2,036	243,585	28,000
Poland	1,816	244,420	11,500
Portugal	1,316	149,123	17,300
Romania	749	79,802	7,900
Slovenia	294	28,758	19,700
Slovakia	417	38,462	13,500
Finland	1,214	157,307	25,700
Sweden	2,022	294,674	27,100
United Kingdom	12,633	1,833,954	27,400
Turkey	2,317	386,937	9,500
Iceland	150	13,124	29,300
Norway	1,828	242,935	39,600
Switzerland	2,586	299,554	30,000

Note: Gross Domestic Product at market prices

Source: Eurostat, http://epp.eurostat.ec.europa.eu/tgm/download.do?tab=table& plugin=1&language=en&pcode=tps00001

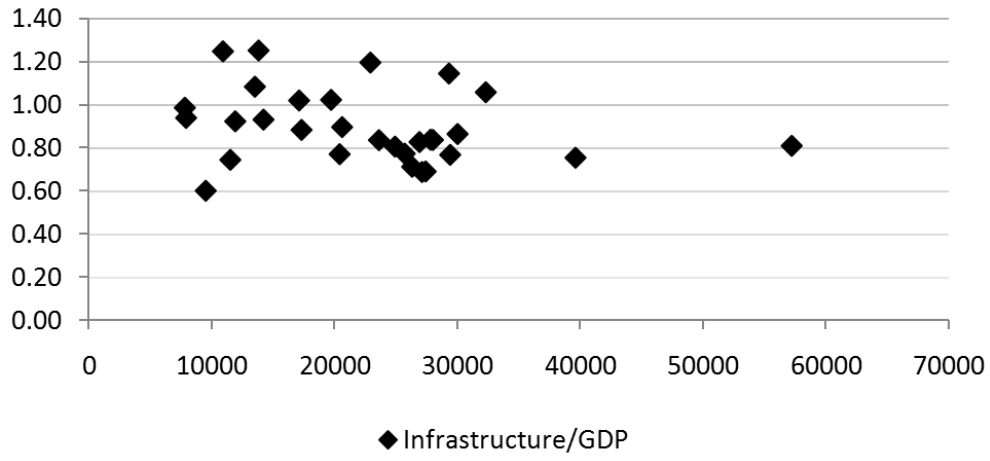


Figure 1: Percentage share of GDP by income per capita

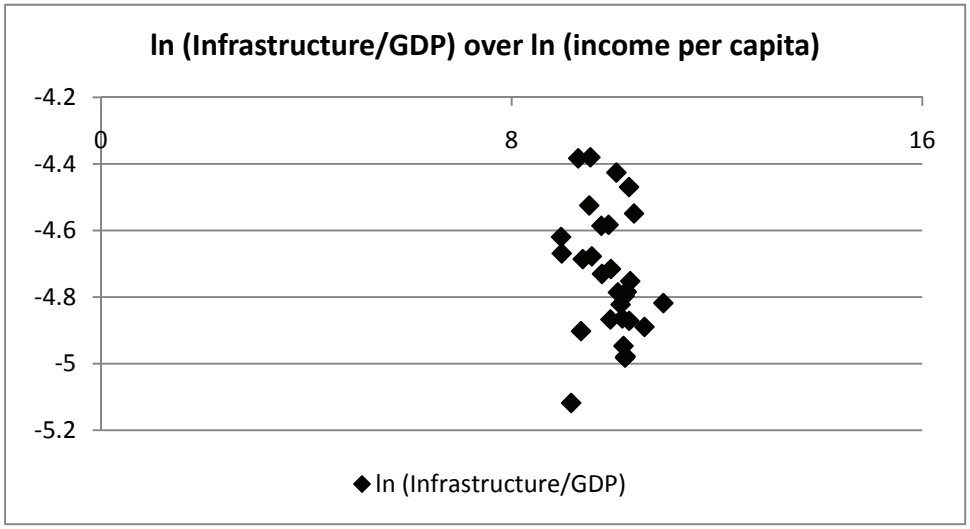
Table 2 Log ratios of infrastructure to gross domestic product and gross domestic product per capita

Country	ln (Infrastructure/GDP)	ln (GDP per capita)
Belgium	-4.80	10.20
Bulgaria	-4.62	8.96
Czech Republic	-4.59	9.75
Denmark	-4.78	10.23
Germany	-4.95	10.18
Estonia	-4.38	9.53
Ireland	-4.55	10.38
Greece	-4.72	9.93
Spain	-4.43	10.04
France	-4.82	10.12
Italy	-4.79	10.07
Cyprus	-4.87	9.92
Latvia	-4.38	9.30
Lithuania	-4.69	9.38
Luxembourg	-4.82	10.95
Hungary	-4.68	9.56
Netherlands	-4.87	10.29
Austria	-4.78	10.24
Poland	-4.90	9.35
Portugal	-4.73	9.76
Romania	-4.67	8.97
Slovenia	-4.58	9.89
Slovakia	-4.52	9.51
Finland	-4.86	10.15
Sweden	-4.98	10.21
United Kingdom	-4.98	10.22
Turkey	-5.12	9.16
Iceland	-4.47	10.29
Norway	-4.89	10.59
Switzerland	-4.75	10.31

Using the data in Table 1, Figure 1 shows the relationship between the infrastructure as a percentage of GDP (on the vertical axis) and income per capita (on the horizontal axis). Figure 1 illustrates the absence of a pattern similar to a concave Bon curve (see Figure 3). The majority of countries are clustered below 30,000 Euros per head. As income per head increases Instead most countries are grouped at between 10,000 and 35,000 Euros with the infrastructure of countries comprising between approximately 0.5% to just under 1.5% of GDP.

In order to carry out a simple regression analysis, Table 2 shows the log transformed data based on the data in Table 1. This resulting transformation is also shown in Figure 2. A simple regression analysis was carried out on the data in Table 2 and the results are given in Table 3. It can be seen from Table 3 that the P-value of 0.19 shows that the t-statistic of GDP per capita is not statistically significant at the 5% level of significance and therefore the null hypothesis cannot be rejected, $\beta = 0$. Hence, GDP per capita does not explain the level of infrastructure investment. In any case, the value of R2 is only 0.06, which implies that only 6% of the variation in infrastructure as a percentage of GDP can be accounted for by per capita income levels. When comparing different countries in terms of the Bon curve, the stage of development is not a predictor of infrastructure investment potential.

Figure 2 Log transformed infrastructure share of GDP over log transformed income per capita



In fact a scatter plot graph of the data shows that there is only a tentative link between GDP per capita and infrastructure output as a percentage of GDP. When applied to infrastructure it would appear that the poorest and wealthiest countries in Europe invest little in infrastructure as a ratio of GDP while those countries that lie in the mid range of income per head invest greater or lesser percentages of GDP in infrastructure without a clear link between income per head and infrastructure investment emerging.

Table 3: Regression results

Regression Statistics	
Multiple R	0.24
R Square	0.06
Adjusted R Square	0.03
Standard Error	0.18
Observations	30.00

ANOVA

	df	SS	MS	F	SignificanceF
Regression	1.00	0.06	0.06	1.79	0.19
Residual	28.00	0.95	0.03		
Total	29.00	1.01			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-3.79	0.70	-5.38	0.00	-5.24	-2.35
GDP per capita	-0.09	0.07	-1.34	0.19	-0.24	0.05

DISCUSSION

This weak relationship between infrastructure and level of development may be due to the size of infrastructure projects, the lumpiness and timing of their occurrence and government policies and ambitions. A major determinant of the demand for construction and infrastructure is also the increase in the global population and international movements of people. Construction is today faced with unprecedented demand from a growing population. In the space of one generation there has been a need to build as much as was built by all generations until some point in the 20th

century in order to house the additional population. This also requires major improvements to the built infrastructure. It remains to be seen how long the population explosion can be maintained and what the implications are construction.

Based on Figure 15.2, Share of construction in GNP versus GNP per capita in Bon (2000, p279). Given Bon's further analysis of construction over time rather than over per capita income, another problem is highlighted. What happens at the end of the Bon curve? Does it continue to decline or does it reach a lower turning point and begin to increase again. In other words, does construction vary over time in a cyclical manner? Similar questions also arise at the "end" of the Bon curve over per capita income. If the curve continues, (the solid curve in Figure 3), it will tend towards zero construction. Clearly that is implausible. What is more likely to occur is (as Bon (1992) states) a slowing down in the rate of decline. Perhaps a more appropriate interpretation of the data is to see the trend in infrastructure investment as a percentage of GNP as a bell shaped curve with a very long tail as illustrated by the dashed line in Figure 3. It this case following the stage of becoming newly industrialized countries move on to become advanced industrialized countries, at which point the level of infrastructure investment as a share in GNP may continue to decline or may reach a level of stability following the burst of activity needed to establish the bulk of the built infrastructure environment.

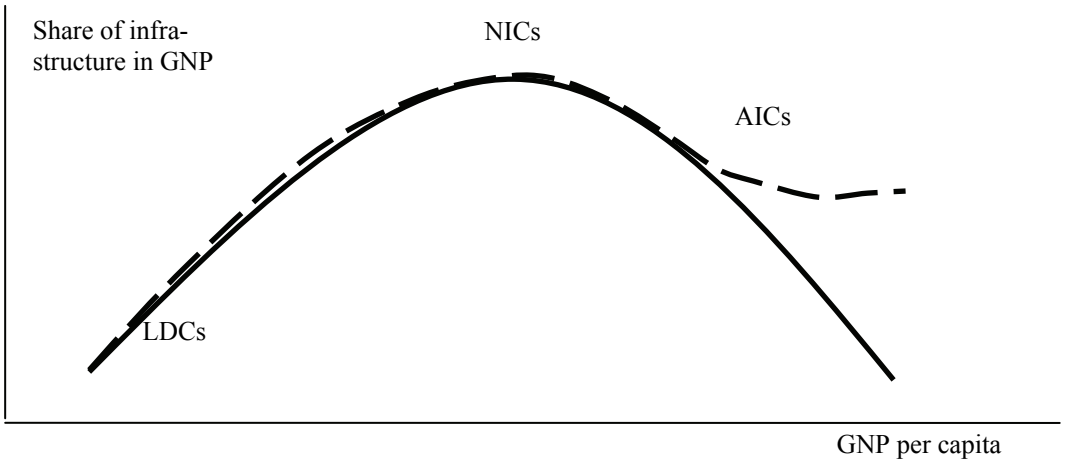


Figure 3: The Bon-type curve or a skewed Bon-type bell shaped curve.

CONCLUDING REMARKS

The results in this paper do not compare the same countries used by Crosthwaite (2000). Bearing that in mind, the results in Crosthwaite are not indicative of the findings here. Seen in general terms the results and conclusion found in this study are very different from those of Crosthwaite, who concluded that he had identified relationships between economic growth and construction growth consistent with Bon's proposition of the Bon curve. Crosthwaite had assumed that each country could be defined in terms of it being less developed, newly developed or advanced developed. This study appears to show the opposite, that in countries in Europe the ratio of infrastructure to GDP compared to the stage in their development as measured by per capita income varies widely.

The wide variance in the relationship between infrastructure and the level of economic development as measured by income per head is due to political factors found in Europe in the decade of the study, a decade in which the strategy of the European

Union was to accelerate investment in Eastern Europe to bring it up to the living standards found in the more established countries of Western Europe. Decisions and interventions by the European Union and the European Bank for Reconstruction and Development, (EBRD), clearly allowed major projects to be undertaken in some countries more than in others.

As these would have been administered decisions they would have been based on exogenous and contingent factors, which no model could have predicted. For example, according to the EBRD (2010), in Albania the bank supported transport and energy projects to provide improved regional integration and secure energy supplies. It also viewed continuing investment in roads as necessary. This contrasts with the trend in infrastructure activity and intervention by the EBRD in the Czech Republic, where the EBRD began to withdraw from participating in projects as the government no longer felt it necessary to use the services of the EBRD. In 2008 investment activity in Latvia amounted to €1,224 of which the EBRD had committed €327 million (though not all necessarily infrastructure). Intervention in Poland had been even greater. By the beginning of 2006 the EBRD had committed €3,446 million, which had attracted a further €9,173 million (again not all necessarily in infrastructure or construction).

There is no doubt Bon's intuitive theory about the role of construction as economies transform themselves from less developed to advanced industrialized countries has contributed a clear framework for investigating the relationship between construction and the rest of the economy. In this paper we have considered built infrastructure investment alone, not construction output as a whole. The Bon curve does not fit the cross section data analysed. Ofori and Han (2003) analysed data for Chinese provinces and found contradictory results. For example, the more developed the province in China the higher was construction employment but the value added by construction was inversely correlated to GDP. This demonstrates that the relationship between construction and stage of development is complex and unlikely to be accounted for by only the stage of development. It is therefore possible to question the Bon curve and view it as capable of further examination and development.

REFERENCES

Bon, R (1992) The future of international construction: secular patterns of growth and decline. *Habitat International*, **16**(3), 119-28.

Bon, R (2000) *Economic Structure and Maturity*, Aldershot, Ashgate Publishing Ltd.

Crosthwaite, D (2000) The global construction market: across-sectional analysis. *Construction Management and Economics*, **18**(5), 619-27.

European Bank for Reconstruction and Development, (2010), EBRD Country Strategies, http://www.ebrd.com/about/strategy/index.htm#country. Accessed 23 May 2010.

Gruneberg, S (2008) Modelling the UK built infrastructure market using gross fixed capital formation. *In:* Dainty, A R J (Ed.) *24th Annual ARCOM Conference*, Cardiff, UK. Association of Researchers in Construction Management, 1, 587-95.

Mehemet, O and Yorucu, V, (2008) Explosive construction in a micro-state: environmental limit and the Bon curve: evidence from North Cyprus, *Construction Management and Economics*, **26**, 79-88.

Office for National Statistics, (2009) *Construction Statistics Annual*, Table 2.8, Office for National Statistics.

Ofori, G and Han, SS (2003) Testing hypotheses on construction and development using data on China's provinces. *Habitat International*, **27**(1) 37-62.

Rostow, WW (1956) The take-off into self-sustained growth, *Economic Journal*, **66**(261), 23-48.

Ruddock, L, (2000) An international survey of macroeconomic and market information on the construction sector: Issues of availability and reliability. *RICS Research Papers*, **3**(11), London, RICS.

Ruddock, L and J Lopes (2006) The construction sector and economic development: the 'Bon curve' *Construction Management and Economics*, **24**, 717-723.

Wong, J, Chiang, MW, Ng, YH and Thomas S (2008) Construction and economic development: the case of Hong Kong, "Construction Management and Economics", 26(8), 813-824.