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empirical evidence for the period 2000-2011

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Abstract

This article provides evidence of an inverted U-shaped relationship between the share of construction in GDP and economic development, employing panel data for world countries for the period 2000-2011. The relationship holds only after logarithmic transformation of the data, implying that the curve is asymmetric with respect to its maximum. This means that the relative level of construction activity tends to increase in developing countries, to peak during industrialization and to decrease at a slowing pace in industrialized countries, approaching stabilization in mature economies. The fitness of the model increases significantly if we measure economic development by means of alternative indicators instead of per-capita GDP. The curve is robust to the inclusion of control variables and there is evidence of a linear relation between income distribution and construction activity level.

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I. Introduction

In a seminal paper in construction economics Bon (1992) proposed an inverted U-shaped pattern for the relation between construction and economic development. The share of construction in GDP tends to increase during the first stages of economic growth, to stabilize in middle-income countries and to decline in advanced economies.

Providing an empirical framework to explain the level of construction activity in a country, Bon's model could help forecast construction sector dynamics and assess whether the size of the construction sector is in line with its long-run pattern or whether short-run factors (for example a property bubble) are influencing it in a relevant way.

Even though the relation proposed is essentially empirical, most of the literature discussing Bon's model is rather descriptive. This article aims at filling this gap, by providing stronger empirical evidence in support of Bon's hypothesis, employing panel data for world countries for the period 2000-2011.

With respect to previous studies we employ a new dataset, which allows us to measure construction activity through gross investment instead of value added (the latter being employed in most previous works). As we argue later, investment is a broader and more appropriate measure of construction activity. Furthermore, we control for three sources of distortion that may have affected previous studies, namely non-stationarity, omitted-variables bias and outliers.

Besides this, we refine the model proposed by Bon from two points of view. First, we show that the curve is asymmetric with respect to its maximum. This implies that the share of construction in GDP decreases at a slowing pace after industrialization, approaching some kind of "plateau" in mature economies. Moreover, we take into account a broader definition of economic development by replacing GDP per capita with alternative indicators.

In order to be useful for forecasting and drawing policy implications the model would clearly need to be enriched with an assessment of the other structural factors that influence construction activity, which is one of the tasks that we try to deal with here. It turns out that physical indicators, like population density, carry no explicative power, while a better (i.e., less concentrated) income distribution is significantly associated with a bigger relative size of the construction sector. This appears to suggest that, on a microeconomic level, demand for housing exhibits a positive and decreasing income elasticity.

The article is organized as follows. Section II summarizes and discusses the literature on the long-run relation between construction activity and economic development. The first part of Section III describes the main features of the data and reports the preliminary tests that were used in order to choose a model specification. In the second part of the section we report and discuss results, while conclusions are in section IV.

II. Investment in construction and economic development. A critical review of literature

There are three main strands in the literature on the economic role of the construction sector. The first one studies the relationship between construction and economic development. The second tries to assess whether investment in construction leads GDP growth or vice versa, or whether there is simultaneous causality (De Long and Summers, 1991, 1992; Ball and Wood, 1996; Hosein and Lewis, 2005; Chang, 2004). The third one employs input-output tables to study the role of construction in a national economy (Bon and Pietroforte, 1990; Bon and Yashiro, 1996; Pietroforte and Gregori, 2003). This article is concerned with the first strand.

Early seminal papers investigating the role of construction in economic development are the ones of Strassmann (1970), Turin (1969 and 1974) Drewer (1980), Wells (1985) and Bon (1992). These studies tried to assess whether "the construction sector, like agriculture or manufacturing, follows a pattern of change that reflects a country's level of development", as Strassmann (1970) put it. The most influential was probably the work of Bon (1992). He argued that the share of construction in GDP follows a bell-shaped pattern: it tends to increase during the first stages of economic growth, to stabilize in middle-income countries and to decline in advanced economies. Formally, this relationship could be written as:

$$Y = \alpha + \beta_1 X + \beta_2 X^2 + \epsilon \tag{1}$$

with $\beta_1 > 0$ and $\beta_2 < 0$. Y stands for the share of construction in the national output, X represents per capita income and ϵ is an uncorrelated residual term. Following some recent literature (Ruddock and Lopes, 2006; Choy, 2011), we can refer to this pattern as Bon's curve[1].

The intuition behind Bon's curve is straightforward. Earlier stages of economic growth are characterized by intense processes of urbanization[2], demographic growth, creation of basic infrastructures and construction of industrial plants. Thus, the construction sector tends to grow faster than the rest of the economy during this phase, increasing its relative weight. In later stages, once these phenomena have reached their peak and start slowing down, growth in construction investment tends to slowdown with respect to the overall economy. At this stage, demand for other kinds of goods and services (possibly with a higher technological content) grows faster than demand for new houses and basic infrastructures (while demand for non-residential buildings – especially offices –, as well as maintenance and renewal activity, does not necessarily decline according to Bon). This theory is consistent with the empirical finding that both fixed capital formation and the share of durable physical assets in investment tend to be larger in developing countries and to decline in advanced economies (Bon, 1992; Maddison, 1987).

Bon's curve appears to be compatible with a Lewisian view of economic

[1]It is fair to note, however, that well before the work of Bon this bell-shaped relationship had already been highlighted by Strassmann (1970), which, by means of a cross-section analysis on 27 world countries, found a positive association between the construction share of GDP and per capita income in low-income countries, and a negative one in industrialized economies

[2]Indeed, Bon's curve is consistent with the S-shaped relationship that has been found between urbanization and economic growth (Berry, 1973), which means that the share of urban population in total population first grows at an increasing rate and then at a decreasing rate as GDP per capita increases.

development. According to the Lewis model (Lewis, 1954) the ultimate cause of economic development is the shift of labour force from a low-productivity subsistence agricultural sector[3] to a capitalist 'advanced' industrial sector. Owing to underemployment, expanding capitalist industries enjoy an unlimited supply of unskilled labour at a subsistence wage[4]. As long as profits are reinvested, the process is self-sustaining: increasing investment results in a further expansion of the industrial sector, which allows further extraction of underemployed workforce from agriculture. Within this theoretical framework, there are reasons to expect the construction sector to grow faster than the rest of the economy in developing countries. Strong internal migration flows, from rural areas to urban agglomerates, are a necessary complement to growth, so strong demand for construction activity is a structural feature of developing economies. Furthermore, the construction industry is particularly suitable for the task of extracting underemployed labor from subsistence agriculture, because it typically requires a less sophisticated level of entrepreneurship than other industrial sectors and employs a large amount of unskilled labor.

Some recent works have used cross-section analysis to investigate empirically Bon's curve, with mixed results. Crosthwaite (2000) estimated the curve with an OLS regression over a sample of 150 countries, using average values of construction spending as a share of GDP and per capita income for the period 1996-1998. He found that both $\hat{\beta}_1$ and $\hat{\beta}_2$ were statistically significant and had the expected sign, but the explicative power of the model was rather low (R^2 is 0.027).

Choy (2011) grouped 205 world countries into four groups, on the basis of per capita income, and performed 40 cross-section analyses (one for each year between 1970 and 2009), calculating the average value of the construction's share of GDP

[3] Actually, according to Lewis agriculture was the main but not the only source of underemployed labour. "Disguised" unemployment – he wrote – also comes from "casual labour, petty trade, domestic service, wives and daughters in the household, and the increase of population" (Lewis, 1954)

[4] Lewis adopts a classical approach, so the subsistence wage is defined as in Adam Smith as the wage that allows the worker not only to satisfy its basic physical needs, but rather to buy the basket of commodities that is necessary to reach an acceptable social status, given the current social context (Smith, 1776).

(measured by gross value added) in the four groups. Only in nine out of forty years his findings are consistent with Bon's model, while for most years he found the average share of construction in GDP to be slightly higher in rich countries than in middle-income economies (while in middle-income countries the average is always found to be higher than in low-income ones). Choy also performed time-series estimations of Eq.1 for each country over the period 1970-2009. He found both the linear and the quadratic coefficient to be significant in most high-income countries, concluding that it is more appropriate to interpret the Bon curve as explaining variation within countries over time than as explaining variations across countries at a given time.

Even though Bon's model appears rather convincing and with sound theoretical bases, some criticism could be raised concerning three main aspects.

i. Bon's curve is widely recognized as a model for the relationship between construction activity and economic development (as claimed by Bon himself (Bon, 1992)). However, a rather mono-dimensional definition of development underlies the original formulation of the model, that strictly identifies it with GDP growth. Nowadays most development theorists believe that there is far more to economic development than aggregate income growth (UNDP, 1990; Sen, 2000; Stiglitz et al., 2010). When estimating Bon's curve, other indicators beyond per capita income should be employed in assessing the level of economic development of a country, as the flaws and biases of this indicator have been shown by extensive literature[5].

ii. Recent dynamics of construction activity in high-income countries seem to suggest that, at a certain stage, the construction's share of GDP tends to stabilize, or at least to decrease more slowly, even in the presence of further economic growth. This suggests that the "Construction-Development Curve"

[5] The most extensive work on this topic is probably the report of the French Commission on the Measurement of Economic Performance and Social Progress (Stiglitz et al., 2010)

may be, unlike the Bon's curve, asymmetric with respect to its maximum. A different formulation may then be needed in order to allow for possible asymmetries.

iii. Empirical works testing Bon's curve have been rather descriptive. Most of them (with the exception of Crosthwaite, 2000) group countries into four categories depending on per capita income and then calculate a simple average of the construction's share of GDP in each group. In some cases, these average values are taken over multi-year periods, so they are likely to be biased because of non-stationarity of the data and changes in the composition of groups. Omitted variable-bias and outliers are two further potential sources of distortion: none of these studies checked for the presence of possible outliers in their samples[6]; none of them tried to assess whether other factors influence the share of construction in GDP, beyond the level of per-capita income, so the robustness of the Bon's curve to the inclusion of control variables has never been tested.

III. Empirical evidence for the period 2000-2011

In what follows we test empirically a quadratic model for the relationship between the share of construction in GDP and economic development. We find that the curve is statistically significant and asymmetric, and that the model fits better if economic development is measured through alternative indicators instead of per capita GDP. The first part of this section presents the dataset, describes the main features of the data and reports the preliminary analysis that was performed in order to choose a model specification, eliminate outliers and identify structural breaks. In the second part the results of the estimations are reported and discussed.

[6]Strassmann (1970) could perhaps be considered as a partial exception, since he included in his sample only countries with a population over one million, if one considers that small countries are more likely to behave like outliers.

Descriptive analysis of the data and preliminary tests

Statistical information about construction investment in world countries comes from the Simco database[7], managed by Cresme Ricerche[8]. Simco gathers data from official national sources, covering 149 countries (accounting for 99% of world GDP, 98% of world population and 98% of world surface) for the 2000-2011 period (Table 1).

According to the Simco database, global construction activity reached 5600 billion Euro[9] in 2011, displaying, in real terms, a 48% increase over 2000. Basic infrastructures represent the main component of construction investment in African and South American countries, while Europe is characterized by a major incidence of residential activities, especially those related to renewal and maintenance. Non-residential investment is the main source of construction investment in India and Russia, but it is also dominant in the United States, where residential activity has not yet recovered after the burst of a huge housing bubble in the late 2000s. The composition of global construction investment by sector and macro-area in 2011 is summarized in Table 2.

As shown in Fig. 1, construction investment as a share of GDP has been increasing in Africa, Asia and South America. However, a peak in worldwide investment has been reached in 2006, when the sector was at a peak level in Europe (12,2%) and North America (9,8%).

The boom and bust in the housing market of some industrialized countries may of course have affected the data. Other major episodes which happened during our sample period and are likely to have affected the data for some economies were two historical peaks in commodity prices (and a steep fall in between) and some major episodes of civil turmoil in certain countries. In some economies, especially the smaller and less diversified ones, the short-run fluctuations caused by these idiosyn-

[7]Cresme has kindly allowed the authors to provide the dataset used in this work by e-mail to anyone who requests it for academic purposes.

[8]An Italian non-profit institution whose aim is to produce research on the building sector, the real estate market and on their impact on land transformation.

[9]Investment in construction is measured in Euro at 2011 prices.

cratic shocks in our variable of interest (i.e. construction investment as a share of GDP) may have been huge enough to obscure and overwhelm the long-run tendency that we are trying to investigate. For this reason, we try to identify outliers by making use of clustering procedures[10] that allow us to recognize observation patterns. We then look for possible outliers both within and between homogeneous groups. Our approach is to try to minimize exclusions, by limiting them to clear cases of 'wrong datum' or to cases in which reasonable economic arguments explain 'out of of trajectory' behaviours (presence of leading factors exogenous[11] to the model).

On the basis of the cluster analysis, we excluded three main groups of countries from the sample:

- Countries that have experienced an anomalous level of construction activity due to a strong housing bubble. This is the case of Spain, Ireland and Iceland, where annual residential construction investment increased by more than 35% between 2000 and 2006 and then decreased by about 60% in the following four years. Certainly other western countries have also been affected by housing speculation in the same period, most importantly the United States and the United Kingdom, but in those countries the share of construction investment in GDP was relatively unaffected, because of their larger and more diversified economies (see Fig. 2).

- Small economies. Mainly small oil exporting countries, such as Qatar, Bahrain and Arab Emirates. Despite a high per capita GDP, these economies are heavily affected by oil revenues and commodity market dynamics, while construction investment is driven by oil-related infrastructures. A different case is the one of Singapore, that has been excluded because of its particular city-state nature.

[10]More precisely, we apply a simple k-means clustering method in a bi-dimensional space defined by construction investment as a share of GDP and per-capita GDP

[11]With the term exogenous here we refer to factors that can influence the model variables but that are not influenced by them.

- Countries which data display evidence of inconsistency, due to scarcity and/or inconsistency of statistical information. In most cases we acknowledged that different sources provided very different estimates (this is the case of some African countries, Albania, North Korea and Vietnam). In the case of Afghanistan, the lack of reliable statistical information is due to the armed conflict that the country has experienced during our period of interest.

Overall, we have removed 20 records[12], reducing our sample from 149 to 129 countries. After removing those observations our sample still accounts for 94% of world population and 95% of world GDP.

Estimation strategy Different estimators can be employed in a panel setting, depending on the characteristics of the data. The nature of our panel is such that a between-groups estimator (which consists in a cross-section regression, using the average value of the data over the sample period for each unit of observation) appears to be a natural choice. In our sample variability between countries is, in practice, the only source of relevant information, since we have countries with very different levels of economic development, while the time dimension of the panel is far too short to allow us to observe different stages of development within each single country. In such a short time span the level of economic development of a country can be considered almost as a time-invariant factor, so there would be no point in trying to exploit within-groups variability to estimate its effect. Analysis of variance, reported in Table 3, confirms the presence of heterogeneity (thus ruling out the use of an OLS pooled estimator) and shows that also variability in the dependent variable is mainly between countries.

Model specification Visual inspection of the data suggests that the relation between construction investment and economic development[13] could be asymmetric

[12] Spain. Ireland, Iceland, Bahrain, Qatar, Libya, UAE, Albania, Vietnam, Singapore, Angola, Somalia, Eritrea, Lesotho, Guinea Bissau, Zambia, Democratic Republic of Congo, Afghanistan, North Korea, Tajikistan.

[13] At this stage, we follow the literature in measuring economic development through per capita GDP

with respect to the maximum. However, a symmetric relationship (i.e., a bell-shaped pattern) seems to be recovered after logarithmic transformation of both variables (Fig. 3).

A preliminary cross-section analysis confirms this intuition. We estimate equation 1 for each year in the sample using three different specifications: taking both variables in absolute values ('lin-lin'model); taking logarithms of the independent variable ('lin-log model'); taking logarithms of both variables ('log-log'model). The log-log model appears to be the best choice in terms of parameters significance (see Table 4). This implies that the relationship between construction activity level and economic development is not symmetric with respect to the maximum. The relative level of construction activity grows rapidly in the earlier stages of economic development, reaches a maximum during industrialization, and then starts to decrease at a slowing pace, approaching some kind of 'plateau' in mature economies (see Fig. 4).

Stationarity test In order to test whether our model was stationary during the observed period, we perform separate estimates of the log-log model for each year in the sample period 2000-2011. The obtained time-series of estimated yearly coefficients (plotted in Fig. 5 together with 95% confidence intervals) is suggestive of a structural break in 2006.

After 2006, we observe what seems to be a structurally higher level of β_1 and a lower level of β_2. This change probably reflects the burst of a huge housing bubble in some major advanced economies, which triggered the global financial crash of 2007-2008. A higher β_1, as well as a lower β_2, means that after 2006 the peak in construction activity level is reached on average at a lower level of per capita GDP. This could be the result of a higher average level of construction activity in developing countries and/or of a lower one in high-income countries. Probably in this case we had both. Indeed, huge public infrastructure-related investments were put in place in some major developing countries (most notably in the so-called BRICs), as an attempt to boost growth after the crisis. At the same time, the relative level of construction activity decreased in advanced countries, where construction has been hit harder than other economic sectors during the crisis (Fig. 6). In order to take into account this structural change and to avoid a non-stationarity bias in the estimated coefficients, we split our sample into two sub-periods, 2000-2006 and 2007-2011.

Results

On the basis of the preliminary analysis reported above, after having removed outliers from the sample, we estimate the Construction-Development Curve employing a between-groups estimator, with the variables taken in natural logarithms. Hence, we estimate the following equation in our sample:

$$\log(\bar{Y}) = \alpha + \beta_1 \log(\bar{X}) + \beta_2 \log(\bar{X})^2 + \epsilon, \tag{2}$$

where Y is the relative level of construction activity, X is a proxy for the level of economic development, ϵ is the independent residual term and the bar over a variable means that its average value over the sample period is taken.

At first, we employ per capita GDP[14] as a proxy for economic development. Results are reported in Table 5. In 5a, the share of construction in domestic output is measured by construction fixed investment as a share of GDP, while in 5b it is measured through the construction's share of value added. In both cases, the inverted U-shaped relationship holds, since the coefficients have the expected sign (positive for β_1 and negative for β_2) and are statistically significant at any conventional level in both sub-periods.

When employing fixed investment the R^2 of the model increases significantly in the second sub-period (from 8.7% to 13.6%), while when employing value added the goodness of fit of the model does not change between the two sub-periods (R^2 is 9.6% in both sub-periods). Furthermore, in the specification using value added

[14]Measured at purchasing power parity (PPP).

the difference in the estimated coefficients between the two sub-periods is lower (although we still observe a structural break).

In order to explain these differences, one can observe that gross fixed investment was more volatile than value added in the period considered. Fig. 6 shows that in all macro-areas the relative level of construction fixed investment changed much more than that of value added between the two sub-periods, decreasing in high-income countries and increasing in developing economies. The construction's share of value added was more stable: it displayed the same dynamics, but in a definitely milder fashion.

Beyond this, we find no other significant difference between using gross fixed investment and value added as the measure of construction activity. However, for our purposes gross fixed investment appears to be a more suitable indicator than value added, since it represents a broader measure of the weight of construction in a national economy, taking into account not only the net product of the sector, but also its demand for intermediate goods.

From these results we can get an estimate of the average level of per-capita income at which the share of construction in GDP tends to reach its maximum level. According to our results, investment in construction as a share of GDP reaches a peak of 12% at an income level of $6,500$ Euro per capita (measured at PPP) in the 2000-2006 period, while in 2007-2011 it peaks at 14%, with per capita income at $4,900$ Euro. The construction's share of value added reaches a maximum of 5.6% at a level of per capita income of $7,900$ Euro in 2000-2006, while in 2007-2011 the peak is at 6.4% at a level of per capita income of $6,500$ Euro.

Replacing GDP per capita with alternative measures of development As already mentioned, there is extensive literature showing that GDP is a rather poor and mono-dimensional measure of economic development and stressing the need for broader and more comprehensive indicators, in order to take into account qualitative aspects of economic growth. Encouraged by this, we re-estimate eq.2

replacing GDP per capita with alternative indicators of economic development.

At first, one is lead somewhat naturally to use the Human Development Index (HDI) calculated by the United Nations Development Programme, which takes into account per-capita income, average and expected years of schooling and life expectancy at birth[15]. As shown in Table 6, the use of the HDI instead of per capita GDP as a proxy for development does not improve the fitness of our model. Indeed, when employing the HDI the relation is not significant in the first sub-period (2000-2006), while in the second subperiod (2007-2011) coefficients are statistically significant at any conventional level, but R^2 is lower than the one obtained by using per capita income (9.7% compared with 13.6%).

We then re-estimate the model employing a broader Economic Development Index (EDI)[16] which takes into account per capita income, life expectancy at birth, the share of labor force employed in agriculture and the maternal mortality ratio. With respect to the HDI, we exclude the education index, since countries with a similar level of economic development can present really different situations with respect to the diffusion of instruction, depending on the development strategy that they follow and on political choices[17]. By including employment in agriculture (as a share of total employment) and the maternal mortality ratio, we aim at taking into account structural changes related to economic development, which could affect demand for buildings. In particular, the share of workforce employed in agriculture is related to industrialization and urbanization[18], while the maternal mortality ratio is related to the availability of public health infrastructures (and of course both indicators are well-known for being strongly related to economic development).

[15] See (UNDP, 2011, pp. 168-169) for details

[16] We construct the EDI through principal component analysis. It is defined as a weighted geometric mean of the principal components, with weights proportional to the explained variance. The value of the EDI for each country in our sample is reported in Fig. 10

[17] Cuba is probably the most clear example of a country in which a high level of education reflects a precise orientation of public policies rather than a high level of economic development.

[18] Inclusion of this indicator is also suggested by our previous discussion (section 2) of the relation between the Construction-Development Curve and the Lewis model of economic development with unlimited supplies of labour (Lewis, 1954).

More in general, the differences between our EDI and the HDI reflect the fact that we did not aim at building a measure of well-being, but, more simply, an indicator of the level of development of the economy.

The use of this specifically-conceived index (see Table 7) yields a significantly higher explanatory power of the model in both sub-periods, with respect to the ones obtained by using per capita income or the HDI. R^2 is 13.5% in the first subsample (2000-2006) and 19.6% in the second (2007-2011), against 8.7% and 13.6% that we obtained by using per capita income and 6.6% and 9.7% that we obtained by using the HDI. Replacing GDP per capita with our EDI as a proxy for economic development does improve the model.

However, and rather interestingly, an even better approximation to the actual data is obtained if we use life expectancy at birth alone as the proxy for economic development. As shown in Table 8, the R^2 increases to 16.9% in the first subsample (2000-2006) and to 23.9% in the second (2007-2011). This could be due to the fact that life expectancy at birth is an indicator that is closely related to the level of economic development, without being distorted by country-specific factors that could instead influence other indicators[19]. In the first sub-sample (2000-2006) construction investment as a share of GDP tends to reach a maximum of 12% when life expectancy is 68.5 years, while in the second sub-sample (2007-2011) it reaches a maximum of 14.4% in correspondence with a life expectancy of 66.8 years.

It is worth noting that when replacing per capita GDP with alternative measures of economic development the estimated coefficients point to a more symmetric curve (even though there is still some asymmetry) than the one obtained by using per capita income (see Figs 7, 8 and 9).

Inclusion of control variables We then enrich the model, by including some further independent variables. There are two reasons for doing so. On the one hand, we want to assess whether other measurable factors influence the relative weight of

[19]In other words, it is probably safe to assume that no country has an idiosyncratic characteristic, unrelated to economic development, that makes life significantly longer for its inhabitants.

construction activity in a national economy, beyond the level of economic development. On the other hand, the inclusion of control variables allows us to test the robustness of the Construction-Development Curve[20].

Physical characteristics, such as surface, population and population density, are perhaps the most natural candidates. Land is a fundamental production factor for the construction industry, while the number of inhabitants is a measure of potential demand for buildings (especially in the residential sector) and infrastructures[21]. However, since our dependent variable is a relative measure of construction activity (i.e., construction investment as a share of GDP), which does not depend on the economy's size, the most appropriate variable to include in our model is probably population density[22]

A further factor that may help explain construction activity level is income distribution. A more equal distribution of income could result in a larger share of population which can afford decent housing and in a greater availability of public services, thus fostering demand for buildings and public infrastructures. An analogous way of seeing this relation is that of considering housing as a normal good with decreasing income elasticity: low- and medium- income families are likely to spend a larger share of their income on housing (through purchases of first homes, rents and mortgages) than high income families. We use the Gini Index[23] as a proxy for income distribution.

Of course another factor that could affect construction activity is the availability of credit. However, all indicators of financial development[24] resulted to be highly

[20] We use here our EDI as the proxy for economic development, but the robustness of the relation to the inclusion of control variables does not change if we employ GDP or life expectancy.

[21] Actually the correct measure of potential demand would be the number of families, but this statistic is not available in all countries in our sample.

[22] It is not clear, however, which sign should be expected from this relation. On the one hand, an higher population density could be associated, ceteris paribus, with greater demand for residential buildings and infrastructures; on the other hand, lower population density could result in a greater availability of land for construction projects.

[23] Downloaded in April 2013 from the World Bank Database at http://data.worldbank.org/indicator/SI.POV.GINI

[24] In particular, we tested the ones provided by the World Bank and available at this link http://data.worldbank.org/data-catalog/global-financial-development. They are highly correlated with all our measures of development, and they are non-linearly related with the share of

correlated with the level of economic development, as measured by GDP per capita or by our EDI. Thus, it was not possible to estimate the effect of financial development separately from the effect of economic development. One could argue that the development of the financial system is indeed one of the main constitutive elements of economic development.

As shown in Table 9 (which displays results for the 2007-2011 subsample), the coefficients of surface, population and population density are not statistically significant. To the contrary, the coefficient of the Gini Index is significant and has the expected (negative[25]) sign. A better (i.e. less concentrated) distribution of income appears to be associated with a higher level of construction activity. According to our estimates a unit increase in the Gini index (which in our dataset ranges between 25 and 67.4) is associated, on average, with a decrease of 0.01 in the natural logarithm of the share of construction in GDP. This implies that an increase in the Gini index from the third to the second quintile (which means an increase in the index by around 10%) is associated with a decrease of 4.4 percentage points in the expected value of the share of construction in GDP.

The Construction-Development Curve is robust to the inclusion of the abovementioned control variables. Both the linear and the quadratic coefficient of the Economic Development Index remain statistically significant at any conventional level, and with the expected sign. According to our estimates, as the EDI passes from its lower value in the sample (which is 57.7 and corresponds to Burundi) to the value that maximizes the curve (that is 81, near to the value assigned to Philippines, Georgia or Moldova) the expected value of the share of construction in GDP triples (more precisely, it increases by 210%), while as we pass from the peak of the curve to the maximum value of the EDI (which is 99.4 and corresponds to Norway) the expected value of the share of construction in GDP decreases by 34.7%. This means

construction in GDP just like the measures of development. When included linearly as further control variables in our model, their coefficients are not significant.

[25] In interpreting the sign of the coefficient, one has to remember that the higher the Gini Index, the more concentrated the distribution of income. The Gini Index, as released by the World bank, would take a value of 100 if income was entirely concentrated in the hands of the single richer individual, and a value of zero if income was equally divided between all individuals.

that, on average, in the increasing part of the curve (i.e., in developing countries) a 10% increases in the EDI is associated with a 38% increase in the share of construction in GDP, while in the decreasing part of the Curve (i.e., in mature economies) a 10% increase in the EDI is associated with an 18% decrease in the relative level of construction activity (see Table 9 and the relative notes).

IV. Conclusions

We have used panel data for world countries for the period 2000-2011 to provide evidence of a bell-shaped relationship between construction activity and economic development, consistent with the theory proposed by Bon (1992). However, the relation holds only after logarithmic transformation of the data. This implies that the curve is not symmetric with respect to its maximum: the size of the construction sector tends to increase in developing countries, to peak in newly industrialized economies and to decline at a slowing pace afterwards, approaching stabilization in the most advanced economies. We have called this asymmetric pattern the Construction-Development Curve (CDC).

We have also found that the curve fits better when employing alternative indicators to measure the level of economic development instead of per capita GDP. This supports the intuition that the size of the construction sector is not just a function of per capita output, but is related to broader socio-economic trends which are intimately linked with economic development, namely urbanization, industrialization and creation of basic infrastructures. In particular, we have found that the model fits better when economic development is measured through an index (EDI) composed of per capita income, life expectancy, maternal mortality ratio and the share of agriculture in employment. However, and rather interestingly, we have obtained an even better fit to the data when using life expectancy alone as the proxy for economic development. A possible explanation is that life expectancy at birth is not distorted by country-specific factors which could instead influence the empirical distribution of other measures of development.

According to our estimates, the peak in construction activity is reached at a per capita income level of almost 5,000 (in PPP Euro at 2011 prices), or when life expectancy in the country has reached almost 70 years. At its peak, investment in construction accounts on average for about 14% of a country's GDP (Tables 5, 7 and 8). According to our estimates, as the EDI passes from its lower value in the sample to the value that maximizes the CDC, the expected value of the share of construction in GDP triples, while as we pass from the peak of the curve to the maximum value of the EDI, it decreases by 34.7% (Table 9).

The curve is robust to the inclusion of control variables. Physical indicators, namely population, surface and population density, have turned out not to be statistically significant, while a better (i.e. less concentrated) income distribution appears positively related to the size of the construction sector, suggesting that low and medium income families tend to spend a larger share of their income on housing.

A question that arises almost naturally is whether the CDC holds within all sub sectors of construction, or whether it is the result of different dynamics experienced by housing, infrastructures and non-residential buildings or by new buildings as opposed to renewal and maintenance activities. Intuition (and a descriptive overview of the dynamics observed in major countries - see for example (Euroconstruct, 2012)) would for example suggest that the bell-shaped relationship could be determined by new buildings, while the incidence of renewal and maintenance activities may be linearly related to economic development (and so could explain the tendency toward stabilization in mature economies). These questions may inspire further empirical work.

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Table 1. Simco database on construction investment.

Coverage of main aggregates in 2011

	Simco DB	Share of World Total
Countries	149	80.5%
Population (millions of people)	6,727	98.1%
GDP (billions Euro)	49,661	98.9%
Surface (000s of km^2)	132,091	98.4%

World share is calculated from data provided by the International Monetary Fund (World Economic Outlook Database, October 2012)

Table 2. Investment in construction by sector and macro area in 2011 (Billion Euros)

	Residential		**Non-residential**		**Infrastructures**		**Total**	
	Investment	Share	Investment	Share	Investment	Share	Investment	Share
Asia	737	29.6%	819	32.8%	937	37.6%	2,493	100%
Europe	667	42.4%	522	33.2%	386	24.5%	1,575	100%
N.America	304	33.1%	329	35.9%	285	31.1%	918	100%
S.America	117	35.5%	87	26.3%	125	38.1%	329	100%
Africa	38	26.1%	35	24.0%	73	49.9%	145	100%
Oceania	43	26.9%	30	19.0%	86	54.1%	159	100%
World	**1,906**	**33.9%**	**1,822**	**32.4%**	**1,897**	**33.7%**	**5,619**	**100%**

Source: CRESME, Simco (2012)

Table 3. Analysis of variance (ANOVA)

Source	Sum of squares (SS)	Degrees of Freedom (DS)	Mean square (SS/DF)	F-test[a] (SSB/SSW)	Prob > F
Between Groups	3.48	127	$2.7 \cdot 10^{-2}$	51.64	0.0000
Within Groups	0.75	1,408	$5.3 \cdot 10^{-4}$		
Total	4.23	1,535			

[a] Test for the null hypothesis of no heterogeneity

Table 4. Average result of yearly cross-section analyses (2000-2011)

	lin-lin		**lin-log**		**log-log**	
	Parameters	P-Value	Parameters	P-Value	Parameters	P-Value
α	0.117	0.000	−0.460	0.124	−8.240	0.000
β_1	0.000	0.235	0.142	0.046	1.431	0.011
β_2	0.000	0.122	−0.008	0.052	−0.083	0.016
R^2	3.7%		6.9%		9.9%	

Table 5. Estimation of eq.2 with GDP per capita as the measure of economic development

a) Dep.variable: Investment in construction as a share of GDP				
	2000-2006		2007-2011	
	Coefficient	P-value	Coefficient	P-value
Constant	$\mathbf{-7.20}^{***}$	$3.6 \cdot 10^{-5}$	$\mathbf{-10.05}^{***}$	$1.2 \cdot 10^{-7}$
log(GDP per capita)	$\mathbf{1.16}^{***}$	$5.8 \cdot 10^{-3}$	$\mathbf{1.90}^{***}$	$2.3 \cdot 10^{-5}$
log(GDP per capita)^2	$\mathbf{-0.07}^{***}$	$8.8 \cdot 10^{-3}$	$\mathbf{-0.11}^{***}$	$2.8 \cdot 10^{-5}$
Y_{max}	12.0%		14.1%	
X_{max}	6,509		4,906	
Regression statistics	N = 128, F-Stat = 5.95, R^2 = 8.7%		N = 128, F-Stat = 9.83, R^2 = 13.6%	

b) Dep.variable: Construction's share of value added				
	2000-2006		2007-2011	
	Coefficient	P-value	Coefficient	P-value
Constant	$\mathbf{-7.70}^{***}$	$1.6 \cdot 10^{-5}$	$\mathbf{-9.11}^{***}$	$5.8 \cdot 10^{-6}$
log(GDP per capita)	$\mathbf{1.07}^{***}$	$1.2 \cdot 10^{-2}$	$\mathbf{1.45}^{***}$	$2.3 \cdot 10^{-3}$
log(GDP per capita)^2	$\mathbf{-0.06}^{***}$	$2.0 \cdot 10^{-2}$	$\mathbf{-0.08}^{***}$	$3.6 \cdot 10^{-3}$
Y_{max}	5.6%		6.4%	
X_{max}	7,931		6,501	
Regression statistics	N = 128, F-Stat = 6.57, R^2 = 9.6%		N = 128, F-Stat = 6.57, R^2 = 9.6%	

Table 6. Estimation of eq.2 with the HDI as the measure of economic development

Dep.variable: Investment in construction as a share of GDP				
	2000-2006		2007-2011	
	Coefficient	P-value	Coefficient	P-value
Constant	$\mathbf{-2.21}^{***}$	$8.2 \cdot 10^{-37}$	$\mathbf{-2.33}^{***}$	$3.0 \cdot 10^{-39}$
log(HDI)	−0.25	0.59	$\mathbf{-1.28}^{***}$	0.01
log(HDI)^2	−0.41	0.22	$\mathbf{-1.31}^{***}$	$2.6 \cdot 10^{-3}$
Y_{max}	11.4%		13.4%	
X_{max}	0.74		0.61	
Regression statistics	N = 127, F-Stat = 4.36, R^2 = 6.6%		N = 127, F-Stat = 6.63, R^2 = 9.7%	

Table 7. Estimation of eq.2 with the EDI as the measure of economic development

Dep.variable: Investment in construction as a share of GDP				
	2000-2006		2007-2011	
	Coefficient	P-value	Coefficient	P-value
Constant	$\mathbf{-178.4}^{***}$	$2.5 \cdot 10^{-3}$	$\mathbf{-301.2}^{***}$	$1.2 \cdot 10^{-6}$
log(EDI)	$\mathbf{78.8}^{***}$	$3.1 \cdot 10^{-3}$	$\mathbf{134.9}^{***}$	$1.5 \cdot 10^{-6}$
log(EDI)^2	$\mathbf{-8.81}^{***}$	$3.5 \cdot 10^{-3}$	$\mathbf{-15.2}^{***}$	$1.7 \cdot 10^{-6}$
Y_{max}	12.1%		14.4%	
X_{max}	87.7		84.6	
Regression statistics	N = 127, F-Stat = 9.67, R^2 = 13.5%		N = 127, F-Stat = 15.11, R^2 = 19.6%	

Table 8. Estimation of eq.2 with life expectancy as the measure of economic development

Dep.variable: Investment in construction as a share of GDP				
	2000-2006		2007-2011	
	Coefficient	P-value	Coefficient	P-value
Constant	$\mathbf{-71.1}^{***}$	$2.4 \cdot 10^{-3}$	$\mathbf{-149.2}^{***}$	$4.4 \cdot 10^{-7}$
log(Life Expectancy)	$\mathbf{32.6}^{***}$	$4.1 \cdot 10^{-3}$	$\mathbf{70.1}^{***}$	$8.0 \cdot 10^{-7}$
log(Life Expectancy)^2	$\mathbf{-3.86}^{***}$	$5.1 \cdot 10^{-3}$	$\mathbf{-8.43}^{***}$	$1.0 \cdot 10^{-6}$
Y_{max}	12.0%		14.4%	
X_{max}	68.5		66.8	
Regression statistics	N = 127, F-Stat = 12.58, R^2 = 16.9%		N = 127, F-Stat = 19.43, R^2 = 23.9%	

Table 9. Estimation of the model with control variables

Dep.variable: Investment in construction as a share of GDP					
	Coefficient	P-value	Impact[26]	**Regression Stats**	
Constant	-193.4	$2.2 \cdot 10^{-6}$	–	N	119
log(EDI)	$\mathbf{87.4}^{***}$	$3.2 \cdot 10^{-6}$	38.3%[27]	F-stat	5.8
log(EDI)^2	$\mathbf{-10.0}^{***}$	$3.8 \cdot 10^{-6}$	−18.1%[28]	P-val	$2.6 \cdot 10^{-5}$
Gini Index	$\mathbf{-0.01}^{**}$	0.04	−4.4%[29]	R^2	23.8%
Surface	$9.1 \cdot 10^{-9}$	0.63	–	$adj.R^2$	19.7%
Population	$1.2 \cdot 10^{-4}$	0.65	–		
Population Density	$-2.0 \cdot 10^{-4}$	0.40	–		

[26] Average percent change in the dependent variable associated with a 10% increase in the independent variable

[27] Average percentage change in relative construction activity when EDI increases by 10% in the increasing part of the curve (i.e., in developing countries). Calculated by evaluating the predicted variation of the share of construction in GDP for a 10% increase in the EDI at each point, from the lower value of the EDI to the peak of the curve, and taking the average variation

[28] Average percentage change in relative construction activity when EDI increases by 10% in the decreasing part of the curve (i.e., for medium and high levels of economic development). Calculated by evaluating the predicted variation of the share of construction in GDP for a 10% increase in the EDI at each point, from the peak of the curve to the higher observed level of the EDI, and taking the average variation

[29] Average percentage change in relative construction activity associated with an increase of the Gini index between the third and the second quintile of its distribution (which is roughly equivalent to a 10% increase of the index, in the years considered)

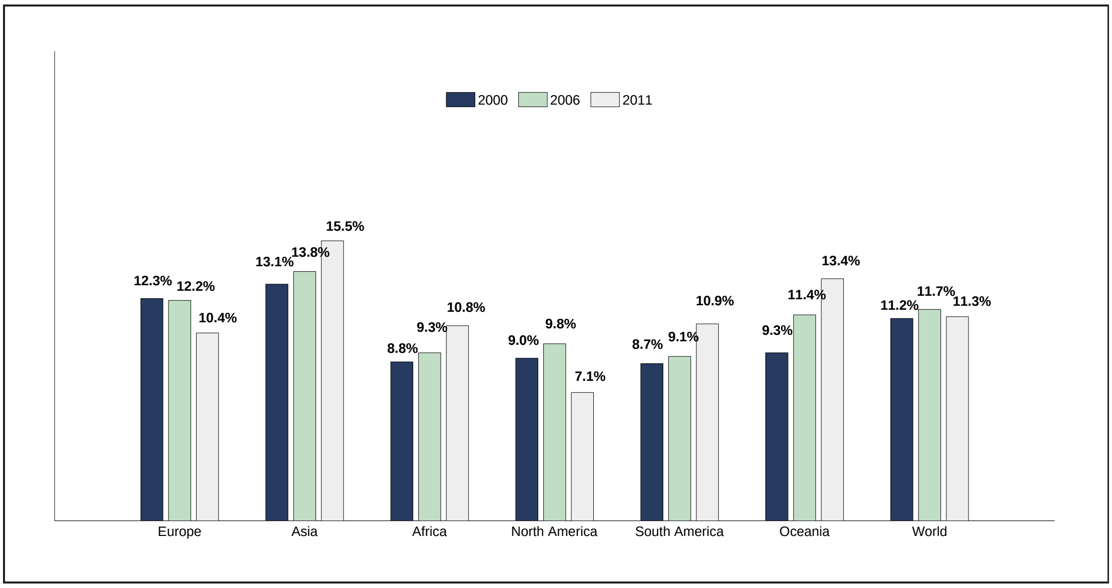

Figure 1. Fixed investment in construction as a share of GDP.
Source: Cresme/Simco 2012

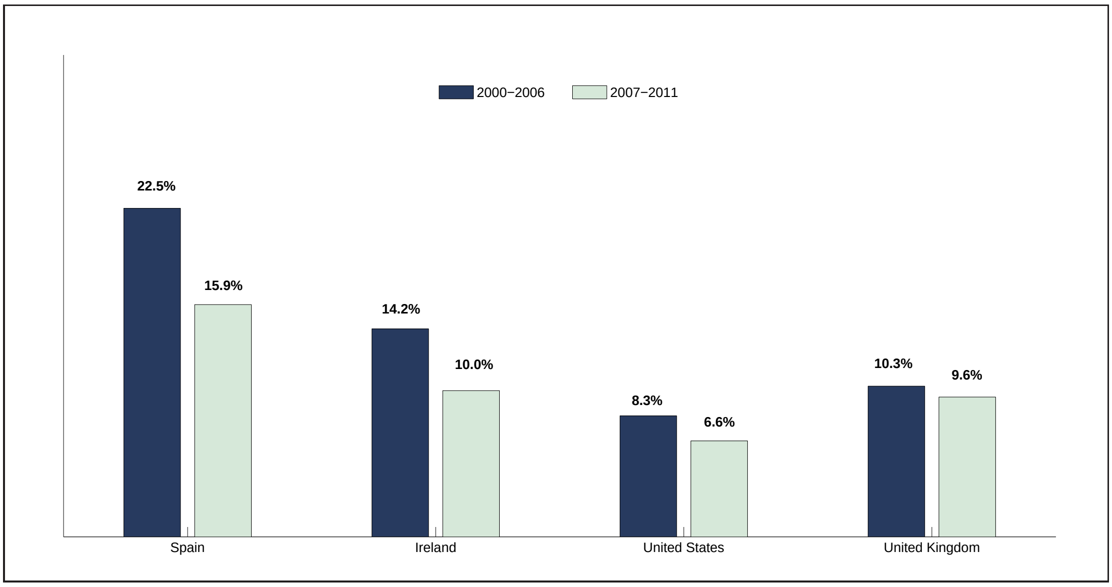

Figure 2. Construction investment as a share of GDP. Average in the two sub-periods.

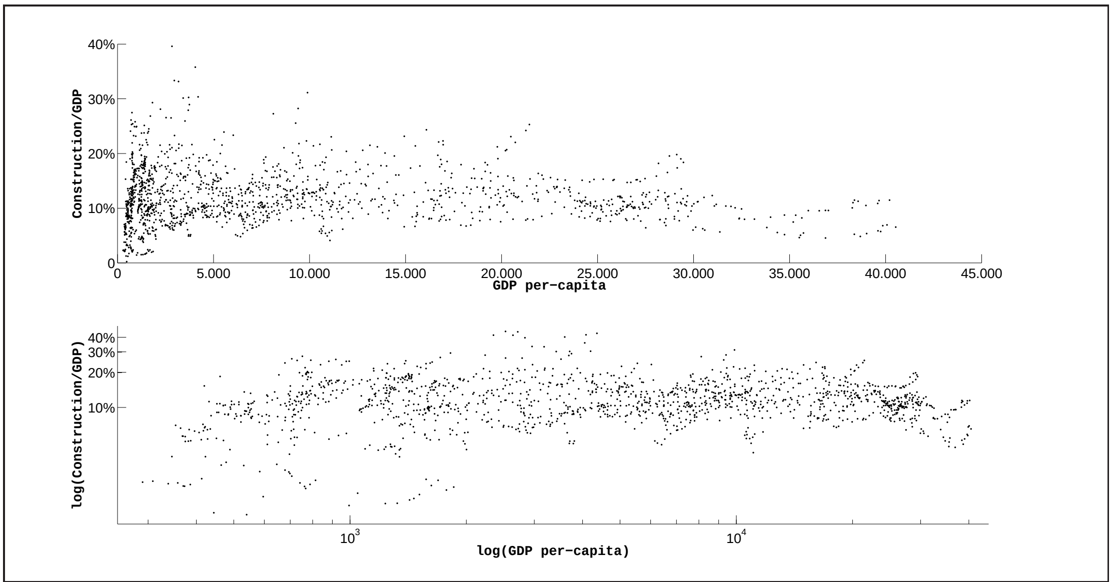

Figure 3. Country distribution with respect to GDP per-capita (horizontal axis) and construction investment as a share of GDP (vertical axis), panel 2000-2011, linear (top figure) and logarithmic scale (bottom figure)

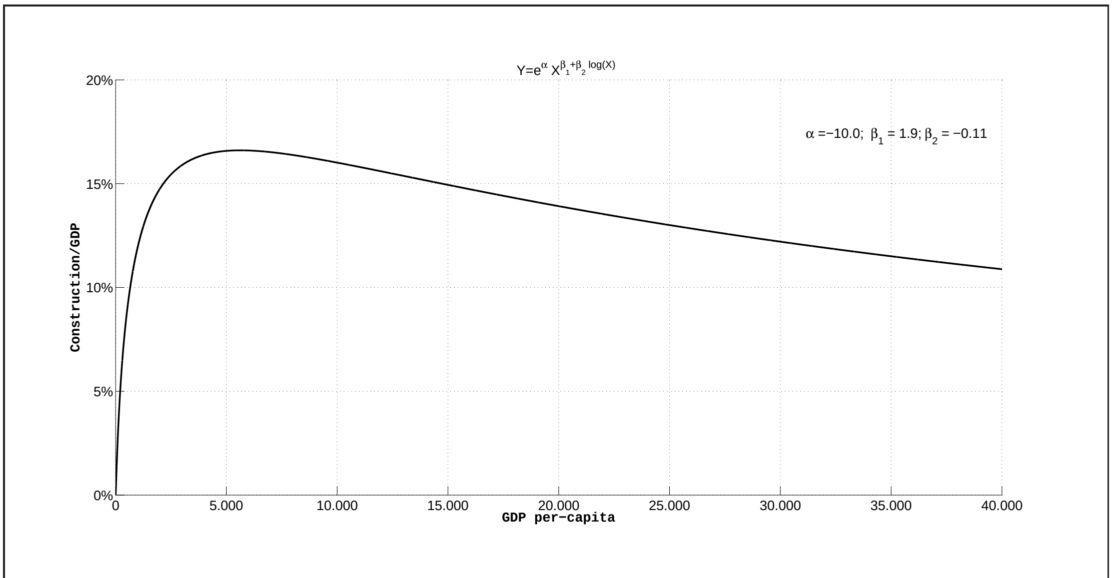

Figure 4. Construction/Development curve with parameters: $\alpha = -10.0$; $\beta_1 = 2.0$; $\beta_2 = -0.11$.

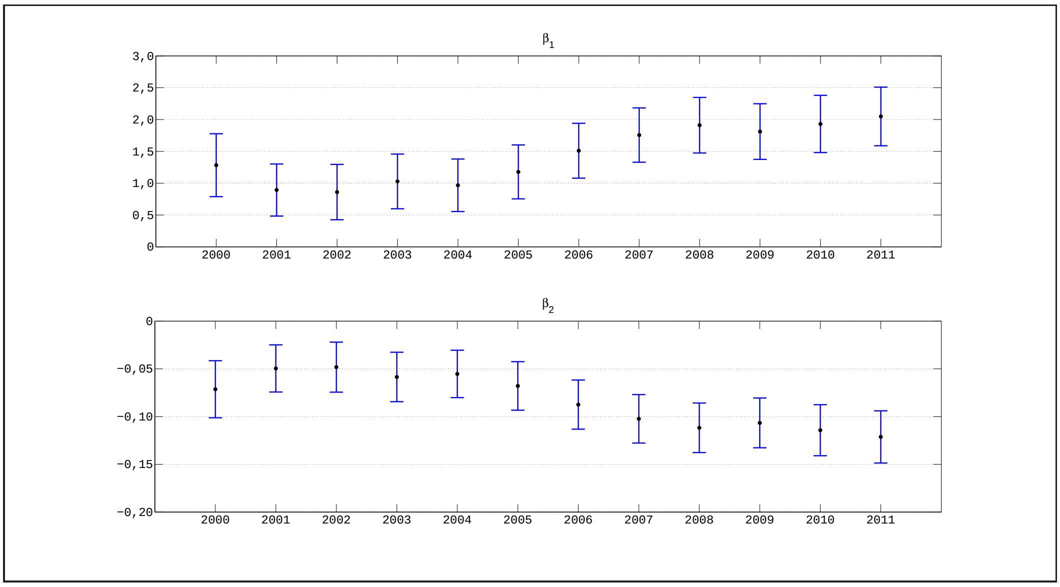

Figure 5. Structural break: yearly estimated coefficients and confidence intervals.

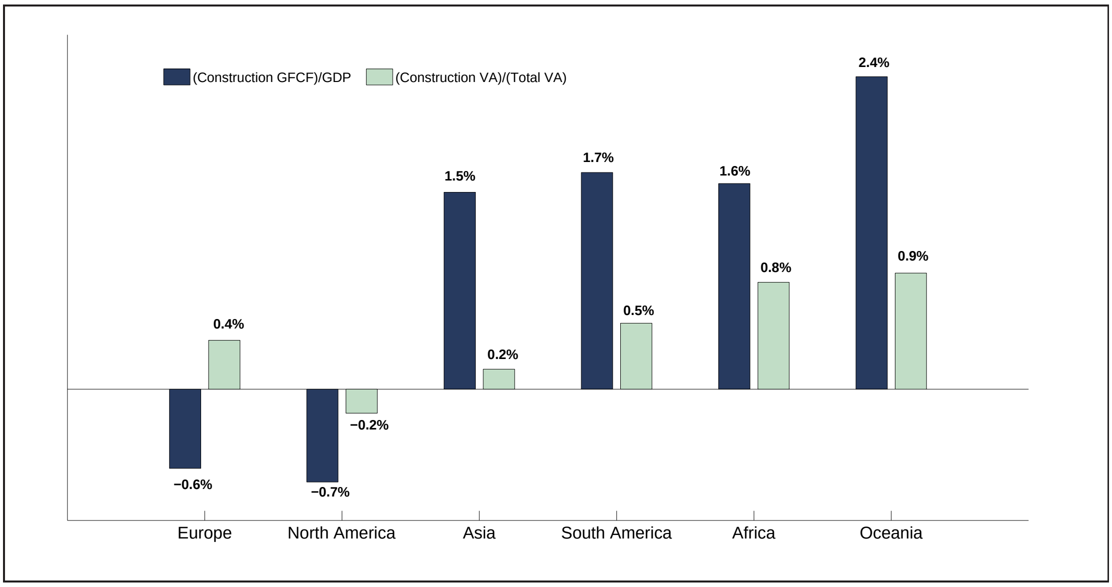

Figure 6. Difference in average values between the two subperiods (2000-2006 and 2007-2011)

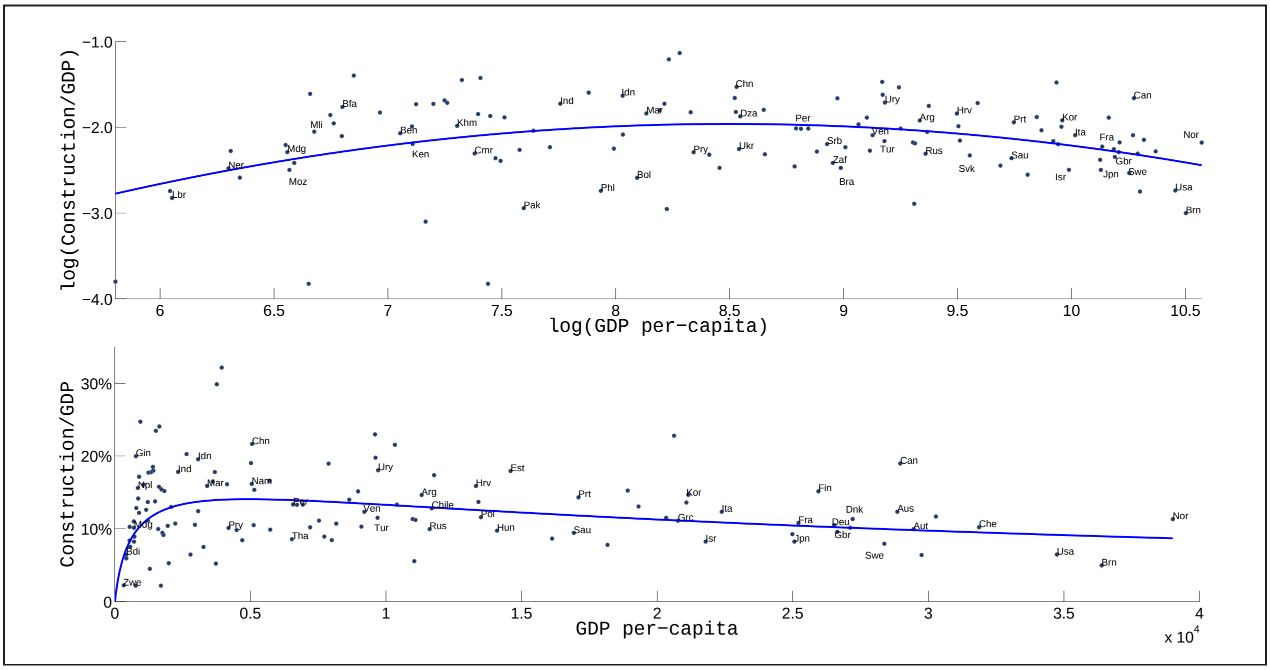

Figure 7. Construction-Development Curve with GDP per capita as a measure of economic development (2007-2011)

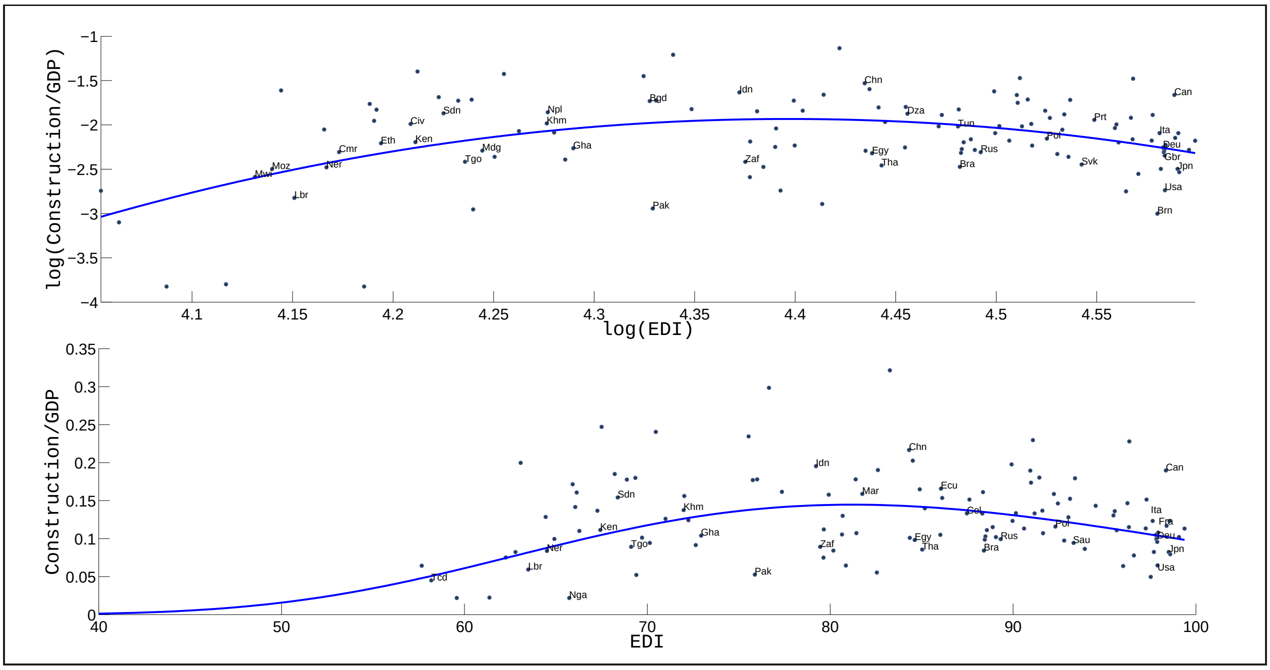

Figure 8. Construction-Development Curve with the EDI as a measure of economic development (2007-2011)

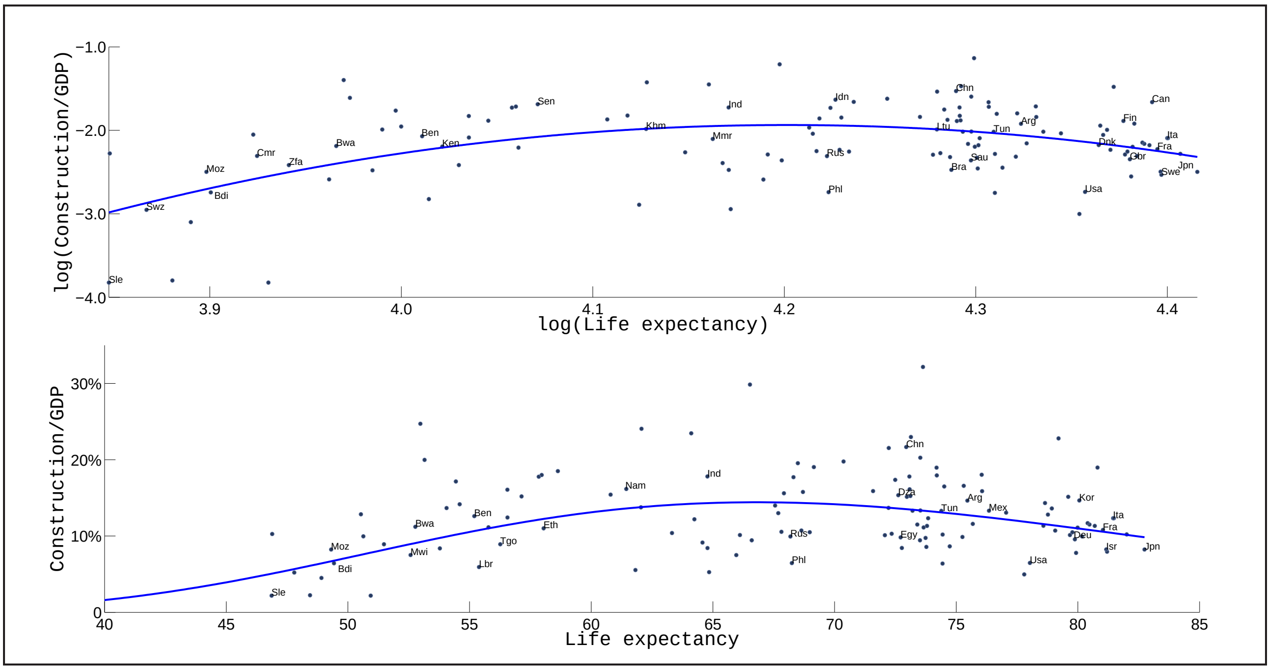

Figure 9. Construction-development Curve with life expectancy as measure of economic development (2007-2011)

Rank		EDI	Rank		EDI	Rank		EDI
1	Norway	99,4	43	Lettonia	91,0	85	Indonesia	79,2
2	Switzerland	99,1	44	Montenegro	90,9	86	Namibia	77,4
3	Sweden	98,6	45	Malaysia	90,6	87	Bhutan	76,7
4	Australia	98,6	46	Peru	90,2	88	India	76,0
5	Japan	98,5	47	Venezuela	90,0	89	Pakistan	75,9
6	The Netherlands	98,4	48	Belarus	89,9	90	Bangladesh	75,8
7	Canada	98,4	50	Russia	89,3	91	Sao Tome	75,5
8	France	97,9	51	Macedonia	89,1	92	Ghana	72,9
9	United States	97,9	52	Turkey	88,9	93	Yemen, Republic of	72,6
10	United Kingdom	97,9	53	Serbia	88,6	94	Congo, Republic of	72,2
11	Belgium	97,9	54	Iran	88,5	95	Nepal	72,0
12	Austria	97,8	55	Bosnia	88,5	96	Cambodia	72,0
13	Germany	97,8	56	Brazil	88,4	97	Benin	71,0
14	Israel	97,7	57	Jordan	88,4	98	Papua New Guinea	70,5
15	Italy	97,6	58	Tunisia	88,3	99	Lao People's Demo	70,1
16	Brunei Darussalam	97,5	59	Romania	87,6	100	Madagascar	69,7
17	Finland	97,3	60	Colombia	87,5	101	Swaziland	69,4
18	Denmark	97,3	61	Algeria	86,1	102	Mauritania	69,3
20	Malta	96,6	62	Ecuador	86,1	103	Togo	69,1
21	Cyprus	96,4	63	Ukraine	86,0	104	Gambia, The	68,9
22	New Zealand	96,3	64	Kazakhstan	85,2	105	Sudan	68,4
23	Korea, south	96,3	65	Thailand	85,0	106	Senegal	68,2
24	Kuwait	96,0	66	Sri Lanka	84,9	107	Uganda	67,5
25	Greece	95,7	67	Egypt	84,6	108	Kenya	67,4
26	Slovenia	95,6	68	Cape Verde	84,5	109	Côte d'Ivoire	67,3
27	Czech Republic	95,5	69	Paraguay	84,4	110	Ethiopia	66,3
28	Portugal	94,5	70	China	84,3	111	Tanzania	66,1
29	Slovak Republic	93,9	71	Armenia	83,3	112	Rwanda	66,1
30	Estonia	93,4	72	Guyana	82,6	113	Burkina Faso	65,9
31	Saudi Arabia	93,3	73	Gabon	82,6	114	Nigeria	65,7
32	Oman	93,1	74	Morocco	81,8	115	Cameroon	64,9
33	Chile	93,0	75	Moldova	81,4	116	Niger	64,5
34	Hungary	92,8	76	Georgia	81,4	117	Mali	64,4
35	Argentina	92,5	77	Philippines	80,9	118	Liberia	63,5
36	Poland	92,3	78	Uzbekistan	80,7	119	Guinea	63,1
37	Croatia	92,2	79	Mongolia	80,6	120	Mozambique	62,8
38	Costa Rica	91,6	80	Turkmenistan	80,2	121	Malawi	62,3
39	Lituania	91,6	81	Kyrgyz Republic	79,9	122	Zimbabwe	61,4
40	Uruguay	91,4	82	Botswana	79,6	123	Guinea-Bissau	59,7
41	Mexico	91,2	83	Bolivia	79,6	124	Sierra Leone	59,6
42	Bulgaria	91,1	84	South Africa	79,5	125	Chad	58,2
						126	Burundi	57,7

Figure 10. EDI Country ranking (average for the period 2007-2011 for countries included in our sample)