The Relation between Height and Economic Development in Spain: an Historical Perspective

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The Relationship between Height and Economic Development in Spain.An Historical Perspective [1]

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Universidad de Murcia
December, 2009

Abstract

This paper investigates the relationship between height and economic development in the modern Spain. The relation is investigated using recently constructed times series with recruitment data of conscripts. We observed changes in average height along the analyzed period. These variations could be explained by different indicators of economic development such as for consumption of hygiene products, for deflator of private consumption, schooling rate, infant mortality and trade. We model human stature as a Vector Autoregressive Model (VAR) and we proceed to estimate a Vector Autoregressive Equilibrium Correction Model (VECqM) to quantify the height response to different changes in the different explanatory variables. The analysis shows that there is a long-run relationship between height, income, and other indicators of economic development in Spain as consumption of hygiene products, and the degree of openness.

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1. Introducción

In the last decades anthropometric history has improved our knowledge on the quality of life of populations. The use of stature and other anthropometric indicators is widely accepted by economic historians and recently by economists to measure aspects of the human well-being and to explore the impact of socioeconomic processes on the biological welfare and health outcomes (Fogel, 1994; Komlos, 1994, 1995a; Steckel 1995, 2009; Steckel and Floud, 1997). Some of the topics mainly debated are the determinants of the height and the relationships between stature and the indicators of economic development. A high degree of correlation between height and economic development is observed in developing countries in the second half of the 20th century (Steckel (1979, 1983). Later contributions have clarified the existing relations among height, income per capita, and income inequality in the long term (Brinkman et al, 1985; Drukker and Meerten, 1995; Coll, 1998; Craig and Weis, 1998; Haines, 1998; Jacob and Tassenaar, 2004; Peracci, 2008). In the last years, a wide battery of indicators on livings standard is used to measure their relationships with the height, resulting in important contributions between health, mortality, and economic development (Easterlin, 2000; Arora, 2001; Deaton, 2003, 2007; Fogel, 2004; Lopez-Casanovas et al, 2005; Steckel, 2008).

In the cross-sectional analyses the correlations between height and levels of economic development are positive and almost perfect, at least in the populations of the pre-industrial past (Komlos, 1995b, 2003). However, in the longitudinal analyses the correlations are more controversial. Early papers established that the temporary series of income per capita could explain the variations in the changes of heights by ages and that the stature can be used as a proxy of the income in information absence on the material well-being (Brinkman and Drukker, 1985), although it is well known that both indicators did not necessarily evolve in parallel. There are many papers which studied this relationship in the world economic history. Several papers find that height tended to increase in developing countries in Europe, North America, and Japan in the late 19th and early 20th regardless of the level of industrialization (Sandberg and Steckel, 1997, Weir, 1997, Shay, 1994, Honda, 1997, Baten, 2000, Federico, 2003, Vecci and Coppola, 2006, Arcaleni, 2006). The height declined, however, in the United States, England, and the Netherlands while industrialization was proceeding at the end of 18th and the first

half of the 19th century (Margo and Steckel, 1983; Floud et. al, 1990; Komlos, 1998, Haines, 2004). Nevertheless, there is a consensus about an international convergence in biological welfare and other non-income indicators of the standard of living during the 20th century (see Kenny, 2005, Deaton 2007, 2008). The main reason is that the stature is also influenced -among other variables- by the conditions of health in childhood and adolescence, maternal education, public policies of social welfare, child work, geography, and cultural values (Komlos and Baten 1998; Schutkowski, 2008, Steckel, 2009).

The relationships between height and economic development have also found echo in Spain. The first studies of anthropometric history were led by economic historians who explored this issue with panels of data from military sources and different methods. Thus, Gómez-Mendoza and Pérez-Moreda examined the relationship between height and educational attainment and infant mortality in the early twentieth century. These authors compared the average height of recruits by province published in *Anuarios Estadísticos de España* with the economic performance and with the infant mortality of the region (Gómez-Mendoza and Pérez-Moreda, 1995). Martínez-Carrión explored the trends of height and income between 1850 and 1990 from local recruitment data of conscripts (Martínez-Carrión, 1994, Martínez-Carrión and Pérez-Castejón 2000); and Quiroga and Coll (2000) discussed height differences as a proxy for income inequality and that changes within the differences of heights among social groups could indicate shifts in income inequality. Given the limitations posed by some conventional indicators of welfare, the possibilities opened up by anthropometric studies are wide-ranging and relevant to the economic and social history of contemporary Spain.

Recently, using both Spaniards height data panels from the *Encuesta Nacional de Salud* (Spanish National Health Survey) and dataset of the European Community Household Panel (Eurostat), economists and demographics presents new evidence on the evolution of adult height and weight (García and Quintana-Domeque 2007, 2009). On the one hand, the influence of generational or environmental effects on adult height has been evaluated and the mechanisms through which socio-economic position may influence individuals' height have been discussed (Costa-Font and Gil, 2007; Spijker, Pérez and Cámara, 2008). On the other hand, the determinant of heights during a period of significant social-economic transformation (1960-2000) has been explored. Results

suggest that the epidemiological transition before the Spanish entry into the European Union led to improvements in adult height (Bosh, Bozzoli and Quintana-Domeque, 2009).

Parallelly, Spanish economic growth has been revised in the last years. According to recent estimates of Prados de la Escosura, Spain underperformed over the long run mostly due to its sluggish growth in the hundred years up to 1950. Higher destruction of human rather than of physical capital during the Spanish Civil War (1936-1939) and its aftermath explain its performance during the 1940s and 1950s. The 1940s constituted a phase of delay in the Spanish economy. This economy has been catching up with advanced countries over the last fifty years in which 1959-74 stand out as a period of outstanding performance (Prados de la Escosura, 2003, 2007).

The comparison between the behavior of the Spanish economy and the most advances nations of Western Europe reveals that Spain was located in a position near ¾ parts of the level of the product by European inhabitant and in the middle of the North American. The marked reduction of the Spanish relative position as a result of the civil conflict of 1936-39 would improve in the 1950s, but Spain did not reduce distances with developed nations. According to new estimates Spain's GDP per head stood at 50.4 percent of that of the United States in 1933 and decreased to 35 percent in the 1950s. The move towards a pro-market attitude with de-regulation and the gradual opening up of Spain to the international economy resulted in sustained growth and catching up with Western Europe during the second half of the twentieth century. A dramatic growth slowdown followed by a sustained catching up, separated by 1986 -the year of Spain's accession to the European Union- characterized the last quarter of the twentieth century (Prados de la Escosura, 2007).

This paper analyses the relationship between physical stature and economic development for Spain with new data of conscripts' height. It takes into account several development indicators such as income per capita, real consumption of hygienic products, price of consumption goods, schooling rate, mortality, and degree of openness which could potentially influence physical stature in the period 1850-2000.

In this paper we try to answer the following questions on the basis of anthropometric data from military records: (i) what are the long-run trends of height in Spain? and (ii) what are the main determinants of changes in Spaniards´ height ? We focus on Spanish males as no long-run information is available on female heights over the long-run.

The rest of the paper is organized as follows. Section 2 describes the data employed in this study. Section 3 investigates the determinants of changes in heights in Spain for the period 1850-1978 through the estimation of a Vector Auto-Regressive (VAR) with a Vector Equilibrium Correction Model. Finally, section 4 concludes.

2. Data description

For height, standardized time-cohort series can be constructed for Spain from the 1850s onwards[3]. Data for the early 19th century are both scarce and fragmentary, and almost non-existent before the end of the eighteenth century. The first recruitment is carried out in 1770 (with the Monarchy of Carlos IIII). During the last decades of 18th century, the replacements of the Spanish conscripts are formed by men aged between 16-40 years. In the first decades of the 19th century the conscription happened to be formed by men of 16-25 years old. It's necessary to hope the decade 1850s recruitment to find conscripts of a single age: 20 years (1850-1885), 19 years (1885-1900), 20 years (1901-1906) and 21 years (1907-1970). The main sources for an anthropometric study of long-run cohort series in Spain are the Local Military Recruitment Acts (LMRA), normally preserved in the local historical archives of the municipalities.

Our dataset pertains to eighteen municipalities of Southern and Levant Spain, corresponding to Community of Valencia and Region of Murcia. It's a good proxy for height at the national level because their economic and environmental characteristics are considered representative of the Spanish economy of the 19th and 20th centuries. Several studies on total productivity, labor productivity, income per capita, well-being and inequality, locate Levant populations in the average threshold of Spain (Domínguez, 2002; Germán, Llopis, Maluquer, Zapata, 2001; Núñez, 2005). Estimates of average height for the Spanish regions in the replacements of 1915-29 and 1965-80

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[3] A recent state of the art on the sources of stature data and on anthropometric history in Spain, to see the monographic number of the journal *Agrarian History*, 47, coordinated by Martinez-Carrión (2009).

reflect the height average of Spain in these analyzed periods (Gómez-Mendoza and Pérez-Moreda, 1995: 85; Martínez-Carrión, 1994: 697). The new series of height on Spanish men that we present in this paper contains data of 328,248 conscripts who were listed and measured between 1857 and 1969 to ages of 19-21 years. It's composed by the database of Spain Southeastern, elaborated by Martinez-Carrión and Perez-Castejón (1998, 2000) and the recent dataset of Gil-Puche (2009) on Community of Valencia presented in his doctoral dissertation[4]. The new series on human height in Spain links with the national series elaborated by the Statistics of Recruitment and Replacement of the Armies (Estadísticas del Reclutamiento y Reemplazo de los Ejércitos) from 1954 and estimated by Coll and Quiroga (1994) and Quiroga (2003a).

The most significant problems facing the literature on height that uses military information are: (i) changes in the recruitment age and (ii) the minimum height requirements for military service. In Spain, however, all potential recruits were measured before they were declared fit for military service or not as there was a universal draft, so there is no selective bias from a truncated distribution. With reference to the first problem in height series posed by the introduction of changes affecting conscription age and by the rounding of height data, it has been addressed by using standardized heights at age 21 taking into account estimations of growth[5]. Data here are presented by cohorts of births. We built a new height series using five-years moving averages standardized at the age of twenty one years.

How representative is our evidence? In other papers the reliability of data has been ascertained using the Kolmogorov-Smirnow and similar tests[6]. In this occasion data are normally distributed or Gaussian and do not suffer from typical truncation problems (Figure 1).

[Figure 1 about here]

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[4] Dataset is composed by 141,861 observations with height data. See doctoral thesis of Puche-Gil (2009), to whom we are grateful to provide us the data.

[5] On height standardized at the age of 21years, see Martínez-Carrión and Moreno-Lázaro (2007).

[6] Martinez Carrión and Pérez Castejón (2000) use a sample of the height of 127.310 conscripts out of a total of 141.911 men (89.7 per cent) called up for service. This height series has a high correlation with Quiroga's height series for the same sample period (0.95); see Quiroga (2003a). On height standardized at the age of 21years, see Martínez-Carrión and Moreno-Lázaro (2007).

For real income, we use the annual series of Spanish GDP per head at constant 1995 prices in pesetas provided by Prados de la Escosura (2003). His recent estimates on the economic growth show that in Spain there were three main phases in the long-run economic development: 1850-1950, 1951-1974 and 1975-2000, with a shift to a lower level during the first period as a consequence of the Civil War of 1936-1939. Phases or long swings in which growth rates differ from the long run trend as a result of economic policies, access to international markets, and technological change can be distinguished. During the first phase, 1850-1883, the growth rate of GDP per capita was well above the nineteenth century's average. A slowdown in growth took place between the mid 1880s and 1920.

The most intense growth of the period was achieved in the 1920s that coincided with Primo de Rivera Dictatorship (1923-1929). This was a period of institutional stability that provided a favourable environment for investment and business. Lastly, a fourth long swing took place between 1929 and 1952. The Civil War (1936-39) had a negative impact in the later growth, reducing the product per capita near 15% of the secular growth rate (Prados de la Escosura, 2003: 148). The weak recovery of the period 1944 - 1952 stands out in the international context. In spite of World War II, European economies achieved an average growth rate of 1.4 compared with Spain's 0.6 during the 1940s. Spanish economy did not recover pre-war GDP levels until 1951 (absolute terms), and 1955 (per capita terms). The change in trend which began in 1951 ushered in an exceptional phase of rapid growth which lasted until 1974. As in other countries in the European Periphery during the Golden Age (1950-1973), the main spurt of economic growth in Spain was delayed until the 1960s. Catching up took place in the late twentieth century, in which the years 1959-74 stand out as a period of outstanding performance (Prados de la Escosura, 2007).

[Figure 2 about here]

[Table 1 about here]

Figure 2 compares the evolution of GDP per head and the height for the period 1850-1978. GDP per head refers to the year in which recruits were measured. Our results do not reveal a clear relationship between both series until the end of the 19th century,

when similarities between the two series increased. Nevertheless, that relationship also seems to be high for the period 1900-1920. We obtain a correlation of 0.91 between both series for the whole sample period. Table 1 shows the average height and GDP per cápita for each different decade together with their variations. The lack of correlation between income and height during the initial stages of modern economic growth may well be related to Kuznets' inverted U hypothesis, namely that income inequality rises and then falls with the level of economic development. Recent research observes a long-term rise in the inequality index during the early phase of globalization that peaked by World War I (Prados de la Escosura 2008). With other databases of Spanish recruits, Quiroga and Coll (2000) show a long term increase in heights inequality among socio-professional groups between the turn of the century and World War I. Martínez-Carrión and Moreno-Lazaro (2007) demonstrate that inequality trends between rural and urban areas increased during the late nineteenth century. The Spanish case could support this hypothesis already verified in other countries during early industrialization and the first stages of economic growth.

[Figure 3 about here]

Figure 3 shows a scatter plot of the available data for height (in logs) and GDP per head (in logs) for the period 1850-1978. We also fit a nonlinear regression of height as a function of GDP per head and we observe that the relationship between them is concave, as expected. Table 2 offers the main results of this regression.

[Table 2 about here]

The literature on height and economic growth has shown the importance of using anthropometric measures linked to different dimensions of health and standard of living. With reference to these lines of research, we use two different measures of consumption directly related to health: consumption of hygienic products and personal care and the price level of consumption goods. These series are only available up to 1958 and are provided by Prados de la Escosura (2003) at constant 1995 prices. Following the interest in the relationship between mortality and height (Fogel 2004), we employ the mortality rate from 1858 to 1980 (Nicolau, 2005: 124-6; Carreras and Tafunell, 2005).

[Figure 4 about here]

[Figure 5 about here]

[Figure 6 about here]

[Table 3 about here]

Figures 4-6 plot the relationship between stature, mortality rate, consumption of hygiene products and deflator for private consumption, respectively. We observe how the relationship between GDP per head and mortality rate is clearer after the Civil War although it is also high during the rest of the sample period (see Table 3). The effects of the flu epidemic in 1918 and the Civil War 1936-39 were immediately shown in the mortality series and also influenced the height of next generations of conscripts, measured during the 1933-1959 period. With regard to the real consumption of hygiene products we observe a high value of the correlation coefficient for hygiene products (0.86).

[Table 4 about here]

The relationships between stature and human capital measured by the levels of education, schooling of children, and literacy rates have received the attention of specialists (Meyer and Selmer, 1999; Schultz 2003). Recently, Case and Paxson (2008) have recognized that height is associated with one better physical and mental health and cognitive ability. We have also included some education variables such as the schooling rate (Núñez, 2005). Spanish historians have indicated that the education and the human accumulation of capital in Spain have been delayed processes, very unequal in men and women at least until 1960. It constitutes a factor that explains part of the historical delay, relatively compared with the development in other European countries. Although studies demonstrate that literacy process spread widely and height average increased in the course of first half of century XX, there was inequality increase between literate and illiterate conscripts after the Civil War, what is confirmed by the divergence in stature

by both access to education and deterioration of signatures quality of Spanish recruits (Martínez-Carrión and Puche-Gil, 2009; Quiroga, 2001: 616-617).

The new estimate confirms that most of the human capital embodied in the Spanish population into the second half of the twentieth was due to expanded primary schooling rather than to secondary or university studies. Likewise, it identifies the Civil War of 1936-39 as one the most serious setbacks during two centuries of slow and irregular capital human accumulation. The Civil War and the early years of Franco regime contributed to the depletion of the stock of human capital and had negative effects on welfare population (Núñez, 2005). Our results show that there is a negative correlation of -0.77 between height and the schooling rate. Figure 7 depicts the relationship between *height* and our education variable: percentage of population without schooling.

[Figure 7 about here]

Finally, we have also included other important development indicators such as the *grade of openness* of the country, measured as the ratio export plus imports over GDP and built using Prados de la Escosura (2003: 188). There are very influential papers in literature that claimed to find a negative association between barriers to trade and economic growth (Ben-David, 1993, Sacks and Warner, 1995, Edwards, 1998 and Frankel and Romer, 1999). The association among health, well-being, and openness does not have evidence in anthropometric literature. Nevertheless, this association could consider the integration to the international trade and increase of the size of the state with the introduction in the welfare state (Rodrik, 1997, 1999). The annual series of the grade of openness we used come from recent estimations of Tena (2005: 628-631).

[Figure 8 about here]

Figure 8 shows the relationship between height and openness. The relationship between height and openness is positive (0.62) especially after 1959. The Stabilization Plan in 1959 ushered a new era during the dictatorship of General Franco when Spain experienced larger growth rates than before. This relationship was also strong during the period 1880-89 and before the Civil War.

3. Determinants of changes in Spaniards stature

According to anthropometrics, the average height of a given cohort is a function of its nutritional intake during infancy and childhood, letting aside genetic factors. Attained height reflects the trade off between the amount and quality of nutrients available for growth from childhood to maturity against the demands of body maintenance, disease and work. Thus, the influence of income on height is indirect. Income affects height because the former is one of the determinants of the consumption of food and hygiene products consumption and through its relationship with child labor and disease environment.

Thus, an increase in height in economy could stem from: (i) an increase in GDP, (ii) a decrease in food prices of, (iii) an increase in the consumption of hygienic products or (iii) a decrease in mortality or infant mortality rates. Other factors that indirectly influence income could also influence height such as the grade of openness or the human capital variables, e.g. schooling rate, previously mentioned.

Following Jacobs and Tassenaar (2004), we model human stature as a Vector Autoregressive Model (VAR). We let H_t^τ be the average height of conscripts at age τ of the cohort measured in year t, which is observed from t=1,…,T. The attained height at each age is by definition equal to the increments in stature from the year of birth:

$$H_t^\tau \equiv \Delta H_t^\tau + \Delta H_t^{\tau-1} + ... + \Delta H_t^1 + \Delta H_t^0 \quad (1)$$

where $\Delta H_t^{\tau-i} \equiv H_t^{\tau-i} - H_t^{\tau-i-1}$ is the increment in height of the cohort of conscripts measured in year t between age τ -i and τ -i-1 , i=1,…, τ and ΔH_t^0 is the length at birth. We assume that the (unobserved) increments in height depend linearly on income and other explanatory variables, such as these described in section 2.

$$\Delta H_t^{\tau-i} = \alpha_i Y_{t-i} + .\varepsilon_{t-i} \quad (2)$$

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where ε_{t-i} is an error term and α is the coefficient associated to the explanatory variables. Substituting in a recursive way gives:

$$H_t^\tau = \sum_{i=0}^{\tau} \alpha_{ti} Y_{t-i} + \sum_{i=0}^{\tau} \alpha_{ti} \varepsilon_{t-i} = \alpha(L) Y_t + .e_t \quad (3)$$

where L is the lag operator and e_t is a moving average error expression.

Estimating an equation like (3) is not exempted from problems. The main problem is that the majority of explanatory variables are endogenously linked. Therefore, estimating a single-equation for the height by Ordinary Least Squares (OLS) is not appropriate when regressors are endogenous.

So, we propose to estimate a structural VAR model which contemplates the possibility of the existence of a *cointegration relationship* among the variables in the equation (3).

For that purpose, our analysis is conducted by using Vector Error Correction Equilibrium (VECqM) VAR model as in (4),

$$\Delta Y_t = c + \sum_{i=1}^{p} \Phi_i \Delta Y_{t-i} - \lambda Y_{t-1} + \varepsilon_t \quad (4)$$

where Y_t is a vector of endogenous variables, c is a vector of constants, Φ_i the matrices of autoregressive coefficients and ε_t the vector of white noise processes. Identification of the structural shock is achieved by appropriately ordering the variables of interest and applying Cholesky decomposition to the variance-covariance matrix of the reduced form residuals ε_t.

Our baseline VAR consists of a five or six variable model. It includes height in natural logarithms (*height*), mortality rate (*mort*), consumption of hygienic products (*conshig*) in natural logarithms, deflator of private consumption in natural logarithms (*def*), real GDP in natural logarithms (*gdp*), and openness (*open*). We also include some dummy variables for the Civil War period (1936-39) and for 1918 when a flu epidemic

occurred. The percentage of population without schooling is also included as explanatory variable.

The use of a recursive identification scheme implies that the identified shocks contemporaneously affect their corresponding variables and those variables that are ordered at a later stage, but have no impact on those that are ordered before. Hence, it is sensible to order the most exogenous variable (the grade of openness in our study). The degree of openness shocks may affect all other variables in the system contemporaneously through any of the other shocks. The next variables in the system are income (GDP) and deflator of private consumption. With this ordering we implicitly assume a contemporaneous impact of income shocks on the prices while also imposing a certain time lag on the impact of prices shocks on income. The consumption of hygiene products and mortality rate variables are ordered next and are thus contemporaneously affected by all the mentioned shocks. Finally, height is ordered last, allowing to react contemporaneously to all variables in the model.

3.1. Preliminary step: unit root and Cointegration Tests

[Table 5 about here]

A preliminary step before estimating equation (4) is to proceed to do individual cointegration analysis. Two univariate unit-root tests were conducted. Table 5 reports the results from the augmented Dickey-Fuller test and the Phillips-Perron (1988) test. The evidence from the tests suggests that the variables are I(1), although, according to the Phillips-Perron test, in some cases the null hypothesis of a unit root in the *height* variable is rejected in favour of stationarity.

We also carry out a Johansen (1991)'s cointegration test to check the possibility of a long-run cointegration relationship among the variables and estimate the cointegration vectors. According to the λ-max statistic, the null hypothesis of no cointegration versus one cointegration vector and one cointegration vector versus two was rejected at the 95% confidence level. Two cointegration vectors were suggested.

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Johansen cointegration test

height= 0.003912*_conshig_-0.008317*_def_+0.008494*_gdppc_+0.002607*_openness_
(0.022)   (0.00181)   (0.0047)   (0.00093)

mort =-0.2964*_conshig_+0.1468*_def_-1.7673*_gdppc_-0.1457*_openness_
(0.081)   (0.067)   (0.3241)   (0.0352)

3.2. Main Results

We estimate the VECqM specification and we impose the two long-run cointegration relationships derived using Johansen's (1991) test. We observe how height depends positively on consumption of hygiene products, income and the degree of openness and negatively on the deflator of private consumption. Table 6 offers the derived cointegration relationships. The first column lists the results for the sample period 1850-1958 (consumption of hygiene products data ends in 1958) using the first cointegration relationship and the second column for the second one.

[Table 6 about here]

Once we have presented the long-run cointegration relationships, we comment the main results of the VAR estimated coefficients. If we center on the height equation we observe how the elasticity of this equation with respect to the long-run cointegration relationships is positive and significant for the first cointegration relationship (0.0246) and negative and significant (-0.0010) for the second one. Changes in stature clearly depend on changes in the consumption of hygienic products, changes in the prices of private consumption, income and the grade of openness. Our mortality rate depends positively on the deflator of private consumption and negatively on consumption of hygiene products, GDP per head and the grade of openness. Using these variables we can explain almost 60 percent of the changes in stature during the period 1850-1958.

3.3 Impulse response functions

[Figure 9 about here]

A convenient feature of this analysis is the possibility of representing accumulated impulse response of changes in stature to the rest of variables. Figure 9 offers us the accumulated response to one standard deviation innovation of height. As we can see height responds negatively to a positive increase in the mortality rate and an increase in the deflator of private consumption and positively to an increase in the GDP, consumption of hygiene products, and the grade of openness.

3.4. Variance decomposition

[Figure 10 about here]

In which proportion do the different innovations to explanatory variables contribute to the volatility of height? Figure 10 plots fraction of the k-step ahead forecast error variance for height explained by the different shocks. The results confirm that after twenty years 12.84% of variance of height is attributable to mortality shocks, 19.26% to an openness shock and 10.67% to a GDP per head shock. The less important component is the inflation shock (around 1.13%).

3.5. Robustness analysis

[Figure 11 about here]

[Figure 12 about here]

[Figure 13 about here]

To assess to what extent our results are sensitive to the choice of the identification schemes and changes in the variables we re-estimate the model in a different alternative way. We adopt an alternative ordering scheme in the VAR where the price deflator is

moved before the income variable. The estimated results under this scheme are very similar. Table 8 shows the derived long-term relationships in this case. An increase in the prices of private consumption decreases the growth of height, whereas increases in GDP growth, consumption of hygiene products or the grade of openness increase the rate of height growth. Figure 11 depicts the different accumulated impulse response functions of height growth to the different variables and Figure 12 the variance decomposition. Our main conclusions remain.

4. Conclusions

This paper has investigated the relationship between height and economic development in Spain for the period 1850-1958. The analysis shows that there is a long-run relationship between height, income, and other indicators of economic development in Spain such as mortality rates, consumption of hygienic products, deflator of private consumption, schooling rate, and the grade of openness.

We have proceeded to estimate a VAR-Vector Equilibrium Correction Model to calculate the height response to different changes in the explanatory variables. With variables included in our model, we got to explain almost 60 percent of the changes in stature during the period 1850-1958. From the accumulated impulse response of the changes in stature to different variables we observed how height responds negatively to an increase in the deflator of private consumption and positively to an increase in GDP, consumption of hygiene products, and the degree of openness.

To assess to what extent our results are sensitive to the choice of the identification schemes and some changes in the variables we have re-estimated the model in a different alternative way, by adopting an alternative ordering scheme in the VAR. Our further research should be centered on analysing the relationship between height and economic development by using alternatives methodologies. For instance, Den Haan (2000) suggested a procedure for analyzing the comovement between output and prices based on correlations of the corresponding VAR forecast errors at alternative forecast horizons which could be easily applied in this context to check whether this correlation is stronger in longer rather than shorter horizons.

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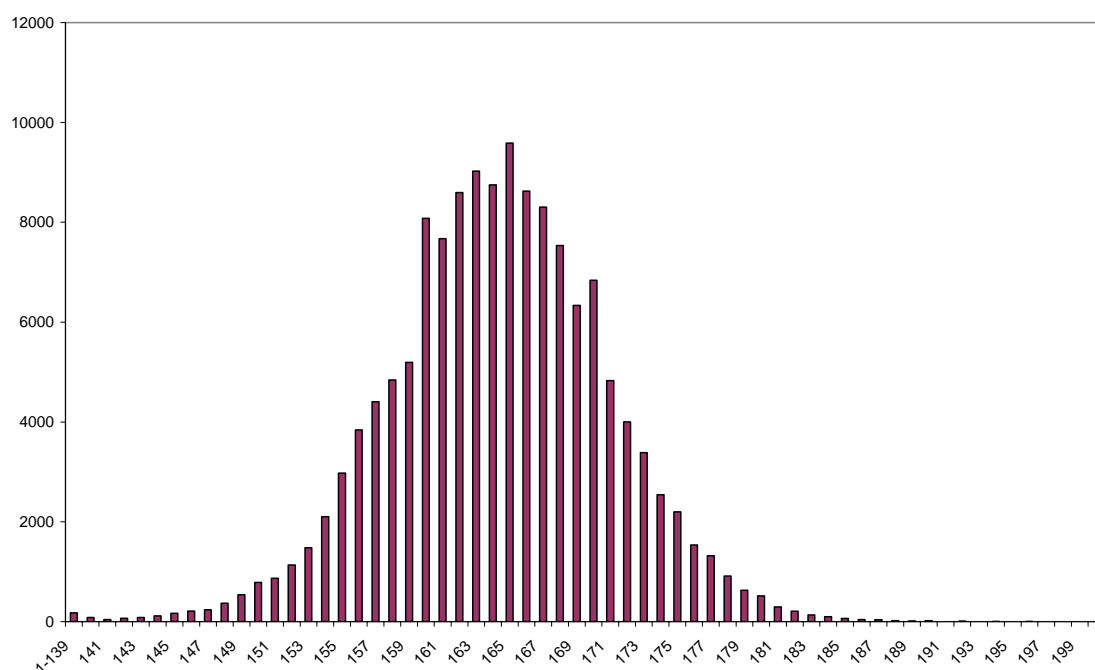
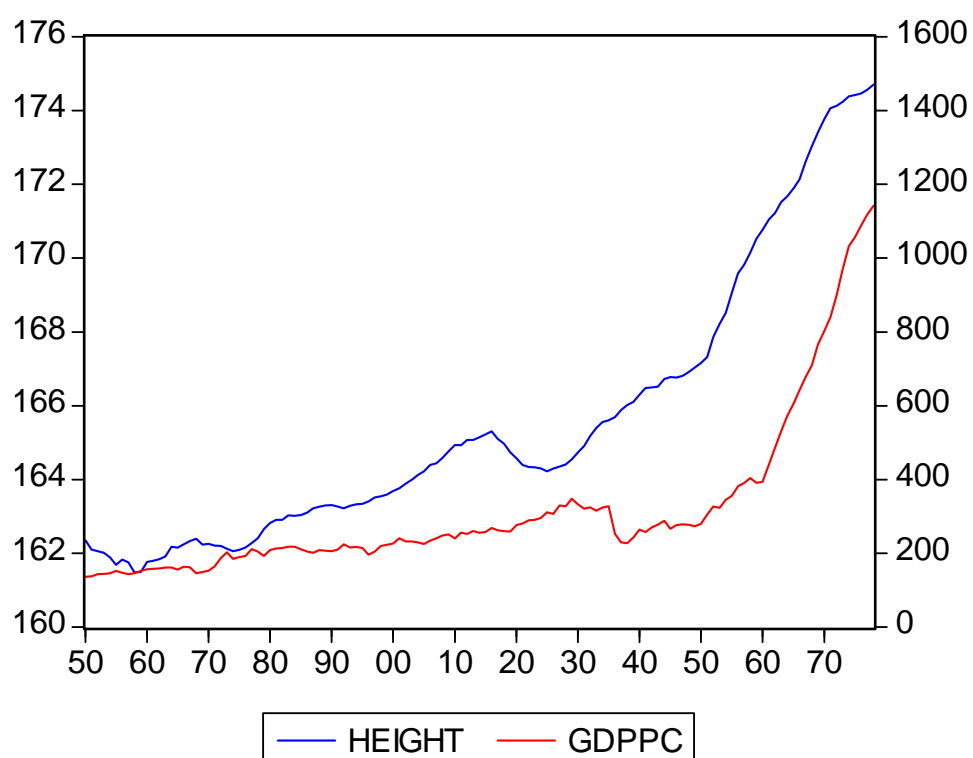**Figure 1: Distribution of heights**

Figure 2: Relationship between height (birth year) and GDP per capital (pesetas 1995), 1850-1978

Source: Prados de la Escosura (2003) and Martínez-Carrión and Puche-Gil (2009).

Table 1: Average height and GDP per head (1850-1978)

	Average Height	*Average GDP pc (ptas 1995)*	*Height variation (cm)*	*Annual GDP pc growth rate*
1850-59	161.87	142.25	-0.86	1.07
1860-69	162.08	157.75	0.47	-0.45
1870-79	162.25	188.69	0.40	2.33
1880-89	163.06	210.67	0.47	-0.09
1890-99	163.38	213.45	0.29	0.78
1900-09	164.19	236.46	1.07	1.02
1910-19	165.05	257.55	- 0.20	0.76
1920-29	164.38	305.88	- 0.02	2.32
1930-39	165.51	290.02	1.37	-3.08
1940-49	166.68	273.23	0.73	0.35
1950-59	168.82	350.60	3.37	3.37
1960-69	171.92	582.59	2.64	6.98
1970-78	174.30	994.50	0.94	4.11

Sources: Prados de la Escosura (2003) and Martínez-Carrión and Puche-Gil (2009).

Log HEIGHT vs. Log GDPPC
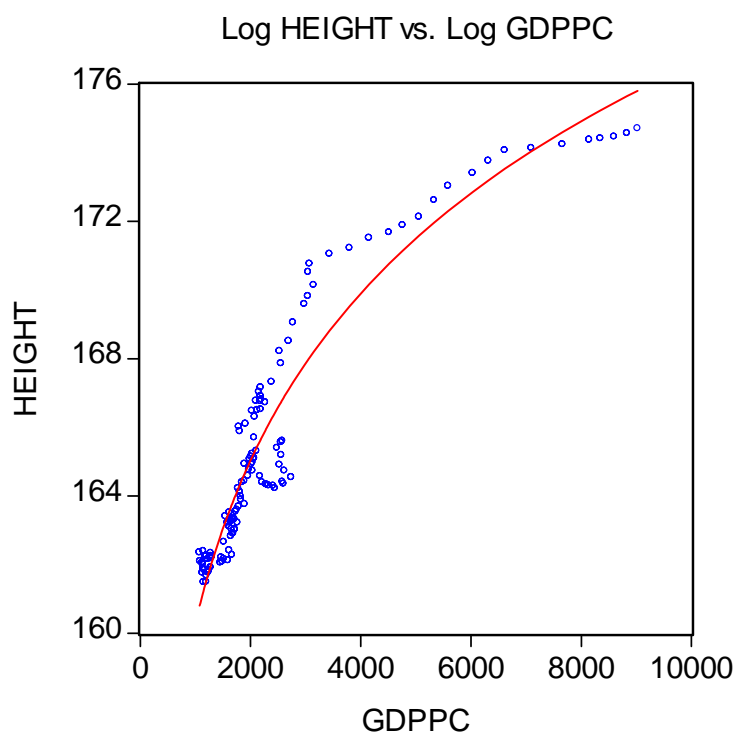
Figure 3: Height (y-axis) versus GDP per head (x-axis), 1850-1978

Table 2: Relationship between Height (in logs) and GDP per head (in logs)

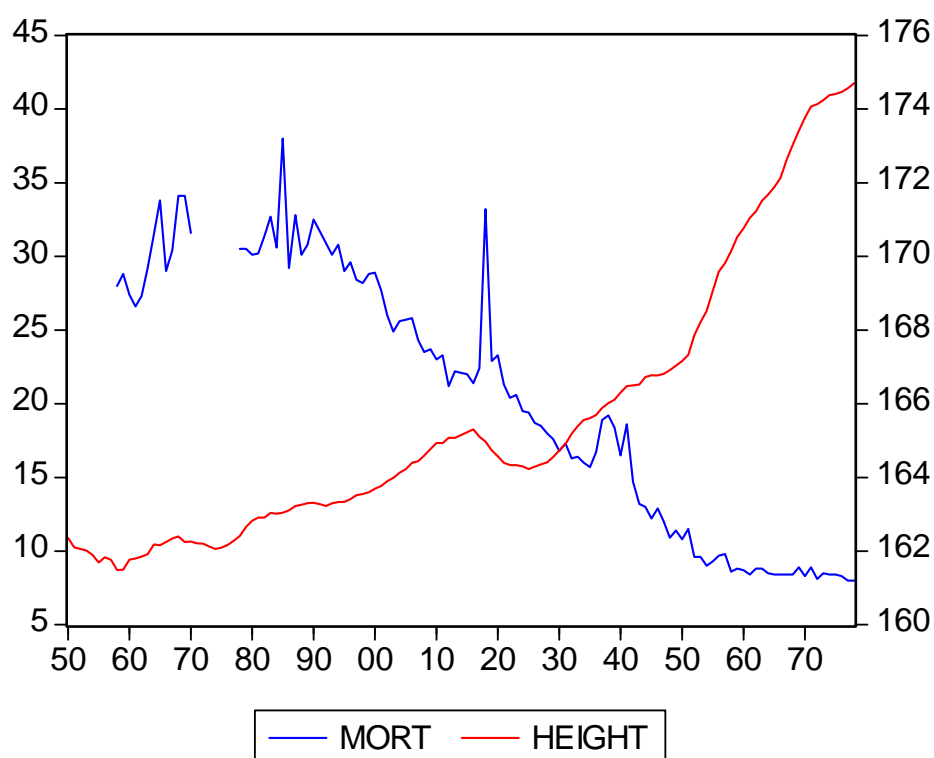| Dependent variable: Height	Estimation results
Constant	4.79
	(151.95)
GDP per head	0.081
	(8.54)
(GDP per head)^2	-0.004
	(-6.74)

t-statistics between parentheses

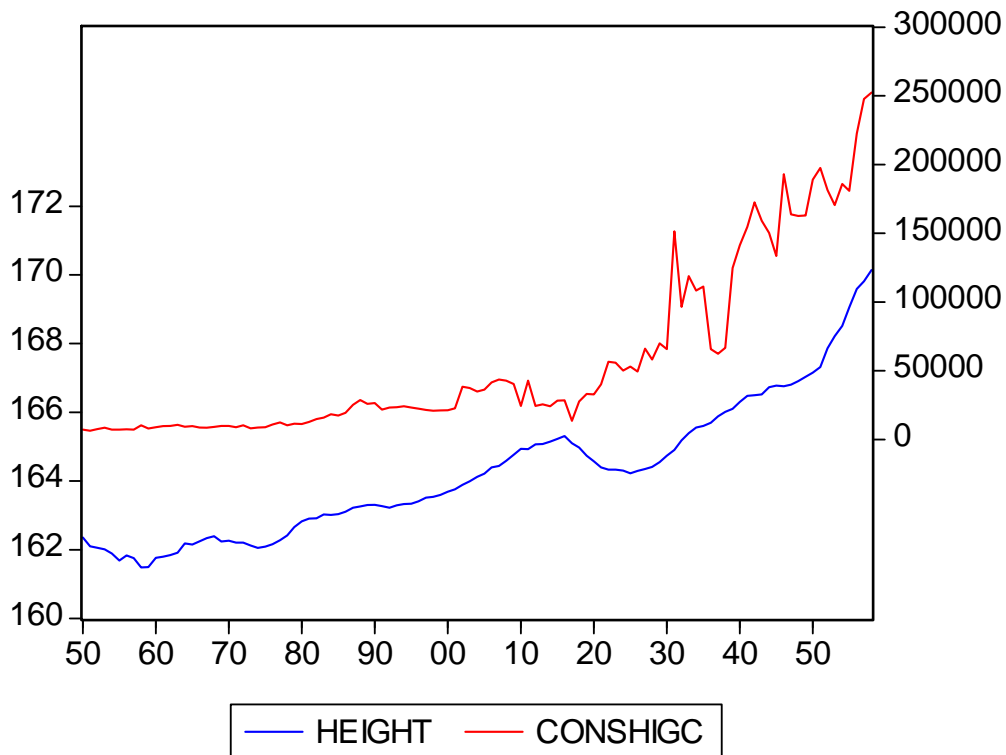

Figure 4: Relationship between height and Mortality rate

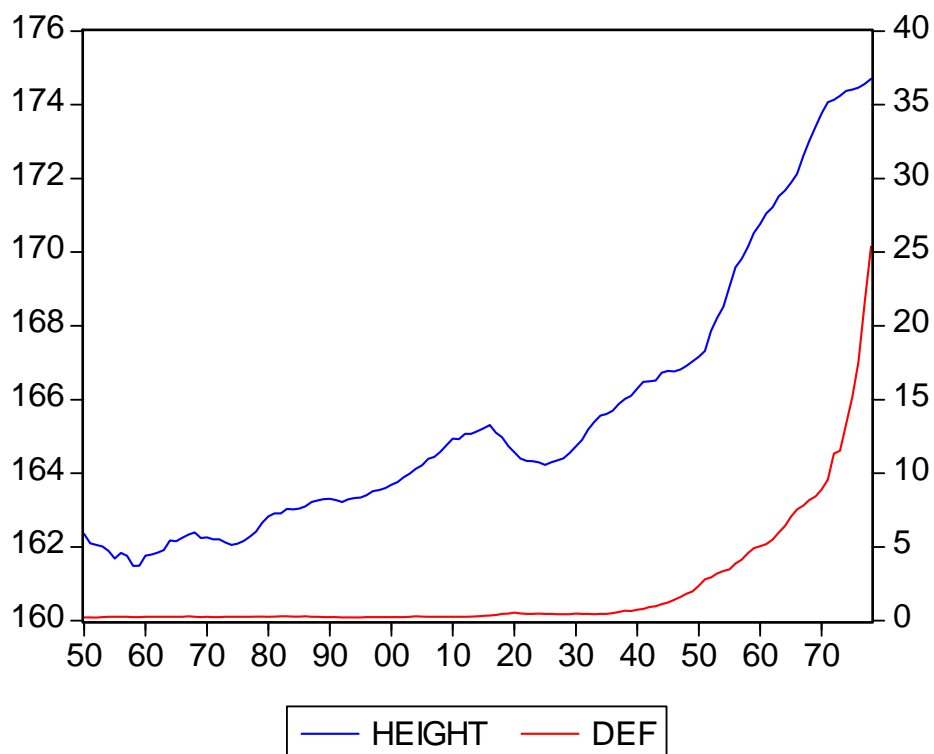**Figure 5: Relationship between height and Real Consumption of hygiene products**

Figure 6: Relationship between height and private consumption deflator

Table 3: Average height and Health Indicators (1850-1978)

	Average Height	Mortality	Consumption of hygiene products	Deflator for private consumption
1850-59	161.87	28.4	0.50	74.36
1860-69	162.08	30.3	0.59	79.43
1870-79	162.25	30.9	0.60	99.45
1880-89	163.06	31.6	1.09	107.93
1890-99	163.38	30	1.26	105.38
1900-09	164.19	25.6	1.87	112.85
1910-19	165.05	23.4	1.33	112.73
1920-29	164.38	19.7	2.39	144.96
1930-39	165.51	17.2	3.99	122.13
1940-49	166.68	13.5	5.97	117.31
1950-59	168.82	9.6	6.97	138.20
1960-69	171.92	8.5	-	-
1970-78	174.30	8.3	-	-

Sources: Height, table 1; mortality, Nicolau (2005); consumption of hygiene products and deflator for private consumption, Prados de la Escosura (2003)

Table 4: Average height and Other Standard of Living Indicators (1850-1978)

	Average Height	Population No Schooling Rate	Openness
1850-59	161.87	61.12	0.66
1860-69	162.08	56.38	0.90
1870-79	162.25	51.14	1.29
1880-89	163.06	51.50	2.34
1890-99	163.38	53.31	3.02
1900-09	164.19	57.23	3.29
1910-19	165.05	49.97	4.21
1920-29	164.38	47.40	3.42
1930-39	165.51	54.62	3.73
1940-49	166.68	33.20	1.76
1950-59	168.82	33.23	4.02
1960-69	171.92	25.12	10.10
1970-78	174.30	17.17	26.23

Sources: Height, Table 1; population no schooling rates, Núñez (2005: 232-236); openness, (Tena, 2005: 628-30)
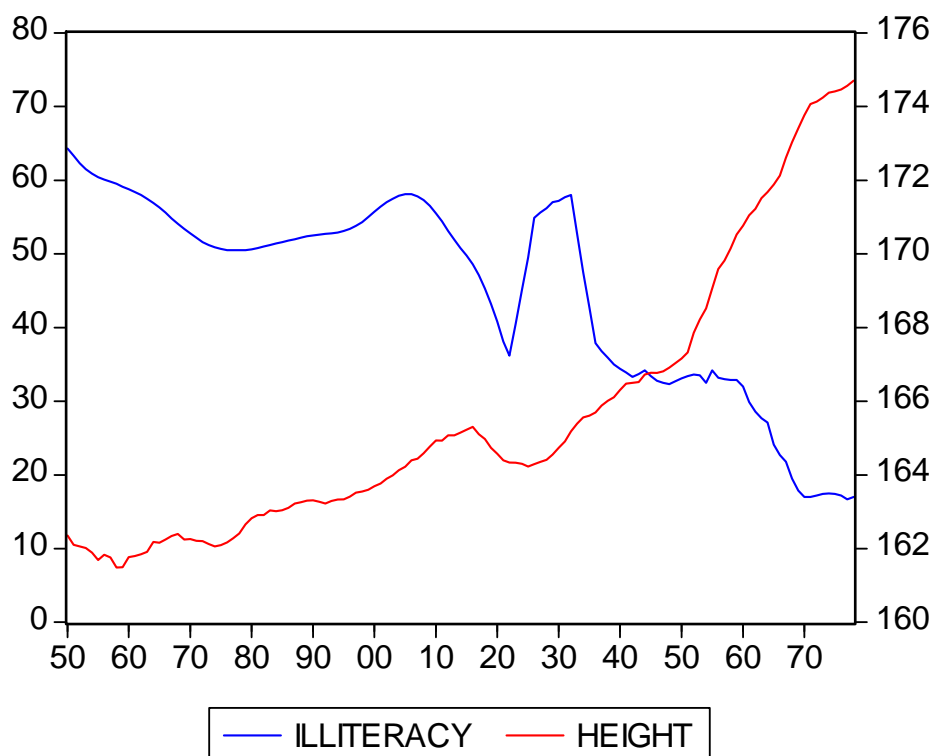
Figure 7: Relationship between height and the percentage of population without schooling.
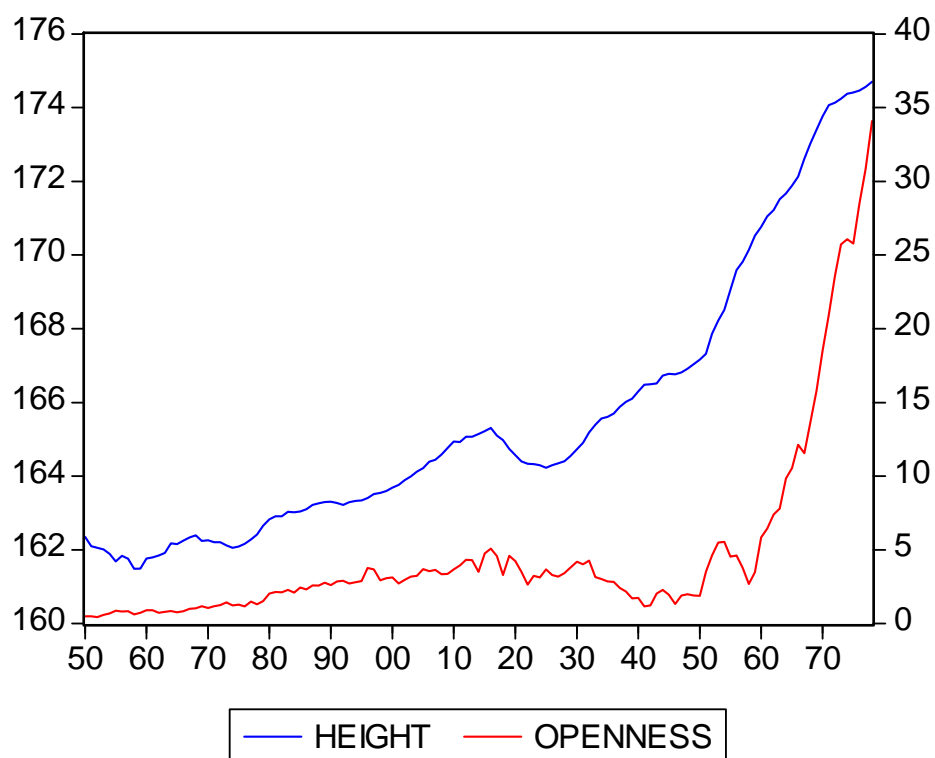

Figure 8: Relationship between height and the grade of openness

Table 5: Unit root tests

	Augmented Dickey-Fuller	*Phillips-Perron*
Height (logs)	1.57	3.07*
GDP pc (logs)	2.34	2.07
Mortality rate	0.31	1.36
Conshig (in logs)	-0.23	-0.36
Deflator (in logs)	4.40	4.34
Population without schooling	-1.15	-0.55
Openness	8.61	8.61

*Indicates rejection of the null hypothesis of unit root test at 95% level.

Table 6: Long-run relationships among Height and their determinants

Long-run relationship	*Dependent variable Height 1850-1958*	*Dependent variable Mortality rate*
Consumption of hygiene products	0.000169* (2.21)	-0.3131* (2.83)
Deflator of private consumption	-0.0044* (2.73)	0.0863* (2.094)
GDP	0.0048* (2.85)	-1.784* (3.79)
Openness	0.0031* (3.49)	-0.14* (2.67)
Constant	-5.09	-9.07

t-ratio between parentheses. * significant 5% level, ** significant 10% level
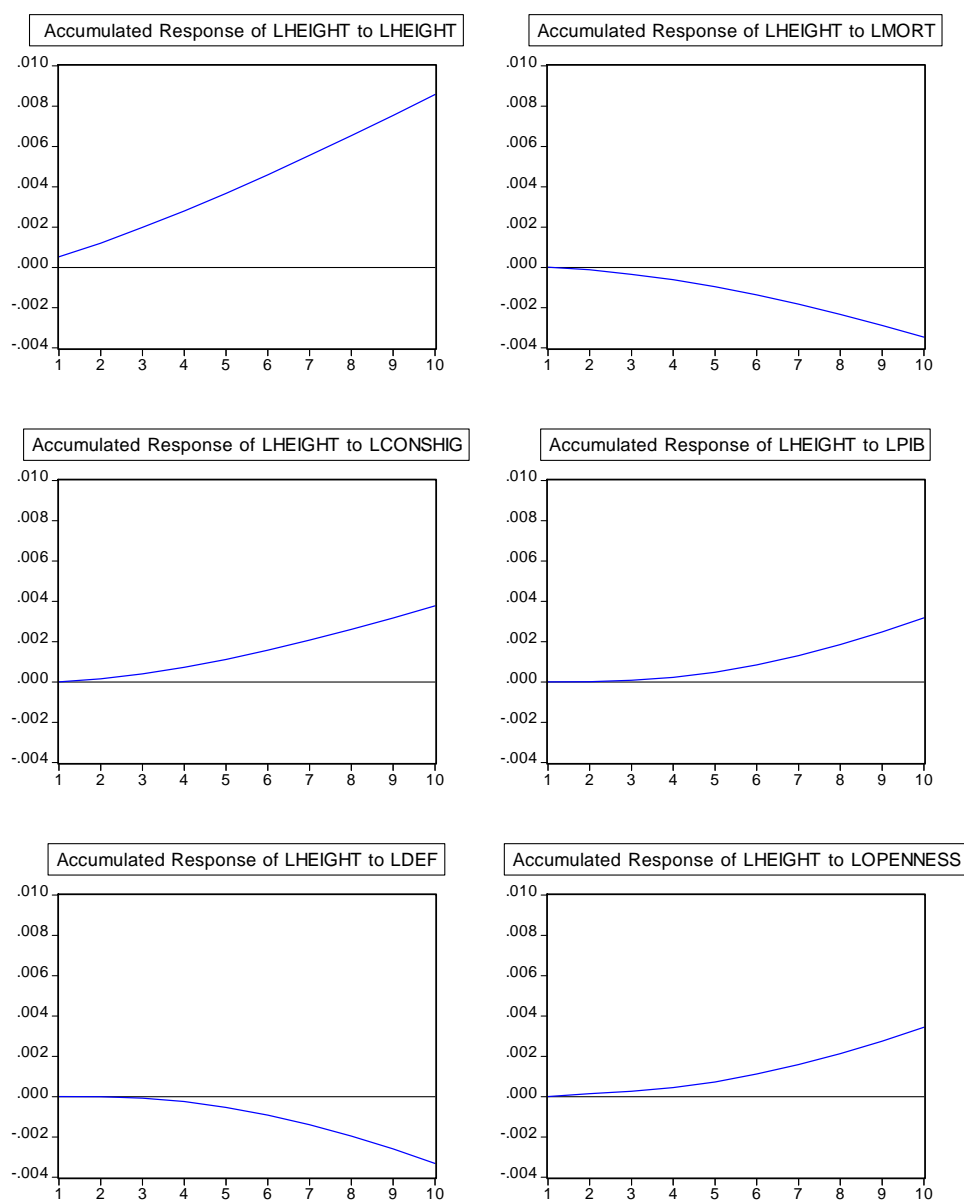
Accumulated Response to Cholesky One S.D. Innovations

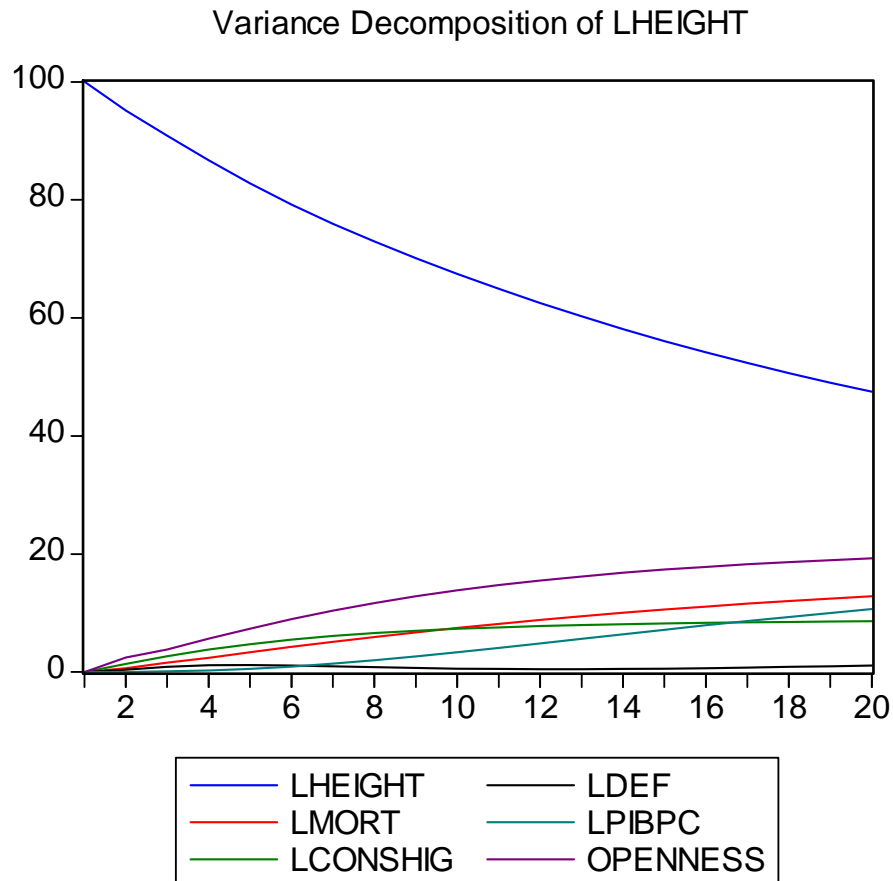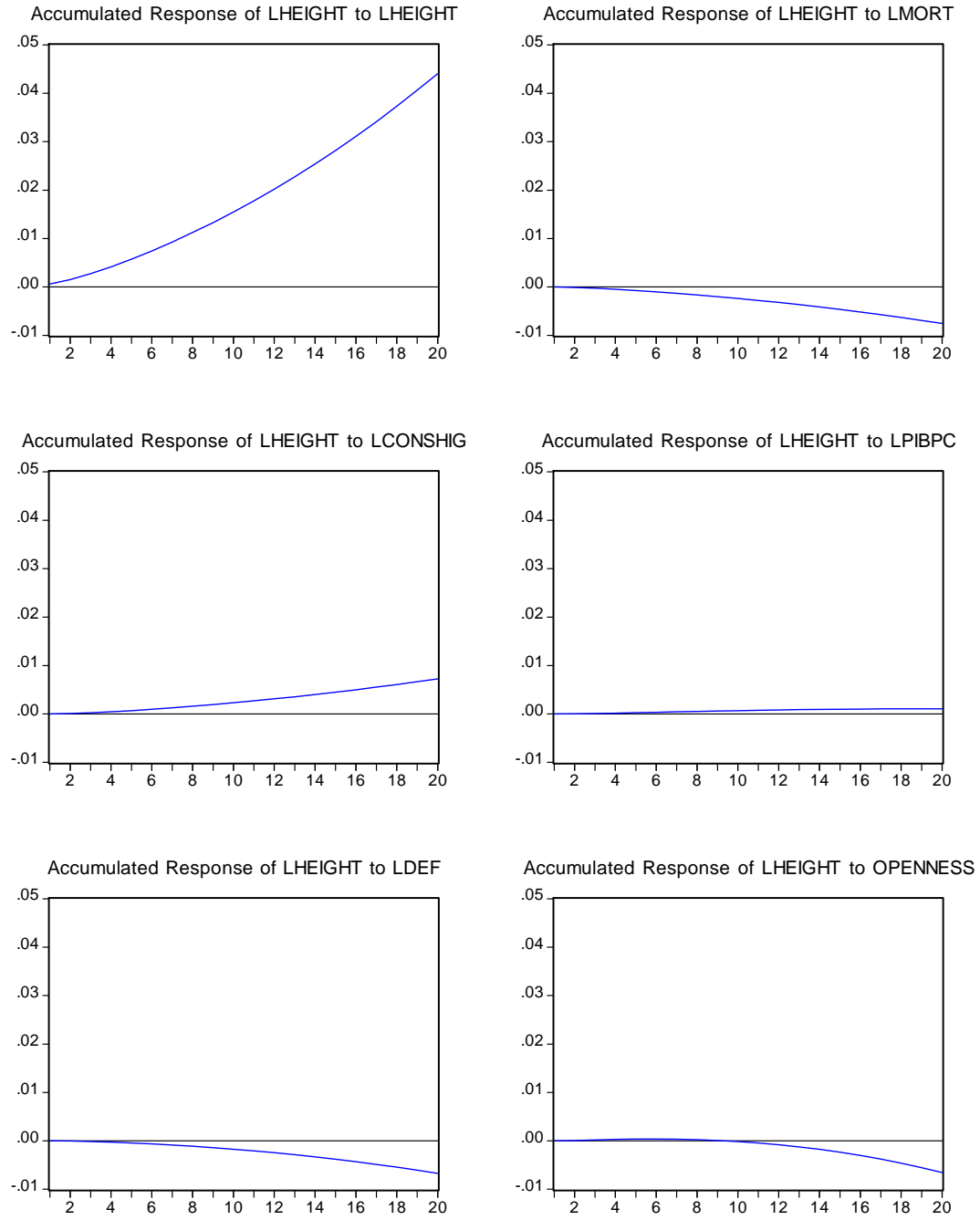**Figure 9: Height Accumulated Impulse Response Functions**

Figure 10: Height Variance decomposition

Table 8: Long-run relationship among Height and their determinants

Long-run relationships	Dependent variable Height	Dependent variable mortality rate
Consumption of hygiene products	0.00016*	-0.3131*
	(1.90)	(2.11)
Deflator of private consumption	-0.000482*	1.7842*
	(2.06)	(1.85)
GDP	-0.00445*	-0.086*
	(2.73)	(3.30)
Openness	-0.003126*	-0.14*
	(3.53)	(2.76)
Constant	-5.09	-9.07

t-ratio between parentheses. * significant 5% level, ** significant 10% level

Accumulated Response to Cholesky One S.D. Innovations

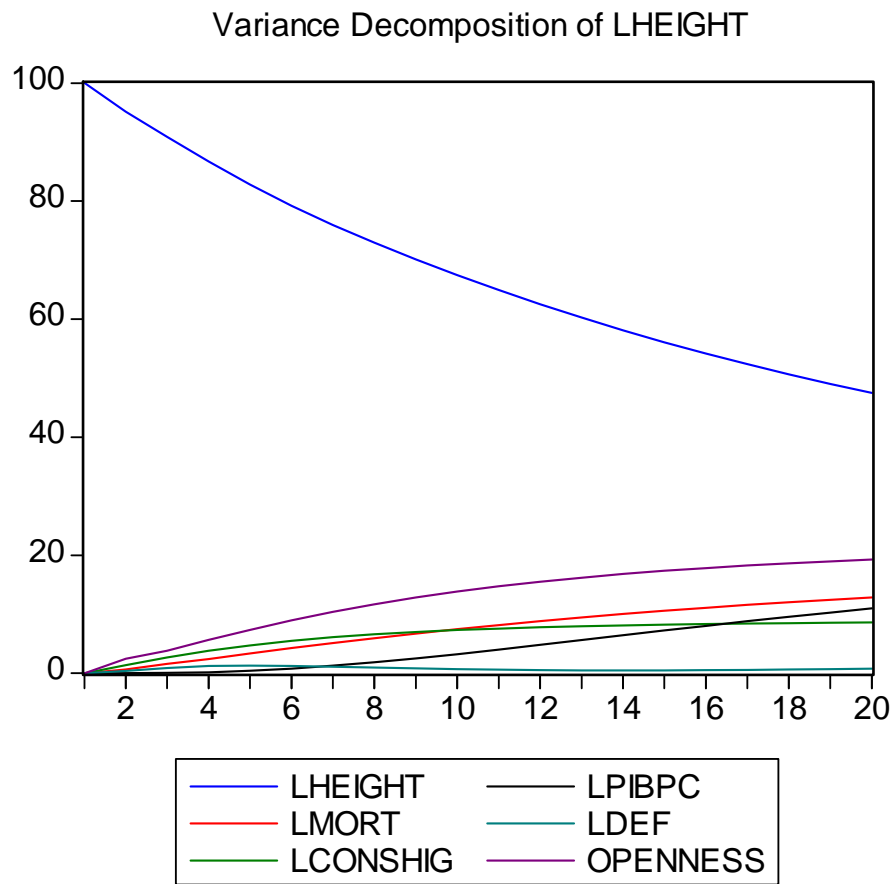Figure 11: Height Accumulated Impulse Response Functions

Variance Decomposition of LHEIGHT

Figure 12: Variance decomposition of height