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ESTIMATION AND EVALUATION OF POTENTIAL OUTPUT DYNAMICS IN AN EMERGING COUNTRY

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Abstract

The aim of the dissertation is to give an overview of some of the most relevant and popular methods suggested for estimating potential output and the output gap. Three alternative methodologies – the Hodrick-Prescott filter, the production function approach and the SVAR approach – are compared and assessed empirically with respect to data representing the economic development of Uruguay in the last twenty years.

Given the recent growth slowdown and abrupt recovery of Uruguay's GDP, the objective is to provide evidence on whether such changes are principally a cyclical shortfall or instead represent a structural shift towards a new growth path. Once the output gaps are estimated, their capacity as indicators of inflationary pressures is assessed through a basic gap model in which the change in inflation is related to the output gap, the money supply and the terms of trade.

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I. Introduction

Potential output and output gap are two variables that have been at the centre of the debate ever since researchers started emphasising the importance of their correct measurement and the consequences of dealing with inaccurate estimations. Not only are they key tools when it comes to evaluating a country's macroeconomic situation and developing macroeconomic forecasting models, but they are also crucial for the conduct of both monetary and fiscal policy.

In the medium term, the estimated potential output provides hints about the pace of sustainable growth and in the short run the output gap becomes a key benchmark against which to assess inflationary pressures. When capacities are not sufficient, they tend to affect price policies of firms and possibly inflationary pressures arise. A level of real gross domestic product (GDP) above the economy's productive capacity over time, i.e. a sustained positive output gap, is indicative of demand pressures, a signal that inflationary threats are increasing and that a policy tightening may be required. A level of real output below potential, i.e. a negative output gap, has the opposite implication, despite recent empirical evidence that suggests that excess demand conditions are more inflationary than excess supply is deflationary. Finally, in terms of fiscal policy, potential output is used to determine cyclically adjusted government budget balances, which work as an indicator of the underlying or structural stance of fiscal policy.

Given that the potential output is not directly observed and that instead estimates need to be inferred from the data, the task of measuring potential output becomes more an "art than a science" (Adams and Coe, 1990). Furthermore, a precise understanding of the output gap – defined as the difference between actual and unobservable potential GDP – depends on the definition of potential GDP. A wide range of different approaches and estimating methodologies have been and are still being developed.

There is no doubt that the methodological abundance – leading to greater diversity and increased sophistication – is beneficial for policymakers. While diversity allows scope for cross-checking estimations, sophistication has improved the researchers' capacity to understand the unstable nature of potential output. Nevertheless, such variety tends to contribute to the uncertainty inherent in the concept. As Cotis, Elmeskov and Mourougane (2004) argue, there is no "right" or unique criterion through which to ensure which estimation is better for the analysis of policy topics. Clearly, the priorities when choosing a methodology depend on the objectives of the researcher and the time horizon selected. If the researcher's interest focuses on recent evolution and short-term forecasts, the most appropriate methods would be those providing accurate estimations at sample end-points. However, a researcher who is interested in long-term trends may be content to have estimates for sub-samples that exclude the latest observations. Similarly, if the objective is an international comparison of potential outputs, the emphasis will be on the applicability across countries, whereas a researcher focusing on a single country may stress greater richness in the economic content. Unfortunately, there is no ideal method capable of satisfying all the desirable requirements; instead, there are a range of alternative methodologies, each with advantages and disadvantages.

Even without the estimation difficulties, the concept of potential output has not yet been well defined, and in various applications the notion of potential output has been used to refer to slightly different concepts. It is the divergence between the alternative perspectives on what can be defined that contributes to the uncertainty surrounding the idea of potential output. The concept can not only be approached either from a physical or economic perspective, but slightly different results also arise based on the estimating methodology that was applied.

In the early 1960s, Okun (1962) defined potential output as the maximum output produced under full employment; more recently, De Masi (1997) redefined it as the maximum level of output that can be sustained without causing inflationary pressures.[1]

In terms of the present dissertation, the potential output will be defined as the level of output achieved when the rates of employment of the economy's installed capacity are "normal". Consequently, potential output is determined by the quantity and efficiency of the available production factors, making it an indicator of aggregate supply capacities. On the other hand, since actual GDP in the short term is mainly determined by aggregate demand, deviations between actual and potential output will be interpreted as a measure of the capacity utilisation of the economy and so as a measure of the disequilibrium between supply and demand.

In order to gauge the extent to which the economy is below or above potential output, three alternative methods are empirically assessed and compared: (i) a Hodrick-Prescott filter, (ii) a production function approach, and (iii) a structural vector autoregression (SVAR) that exploits the relationship between output growth and inflation.

The last section of the dissertation evaluates whether output gaps, given the inevitable underlying uncertainty, are still a useful indicator of inflationary pressures in Uruguay. Following Coe and McDermontt (1997) and Claus (2000), two simple versions of the "gap model" are estimated. Firstly, the change in inflation is related to the level of the three measures of output gap. Under this specification, inflation is expected to rise if the level of real GDP exceeds the productive capacity of the economy over time; logically, inflation will be expected to fall if the gap is negative and remain stable if the gap is zero. The second version of the model relates the change in inflation to the change in the output gap, which implies that the level of inflation will tend to remain stable as long as

[1] The mentioned redefinition coincides with the change in assuming potential output as a stochastic phenomenon instead of deterministic process (Nelson and Plosser, 1982).

the level of the gap remains unchanged. Both an in-sample and out-of-sample forecast evaluation were performed for the first two versions of the model. Finally, in an attempt to extend the process, and given the characteristics of the Uruguayan economy, the gap model is extended to allow money supply and the terms of trade to affect the change in inflation. Overall, the results suggest that the output gap, however measured, provides a good signal of inflationary threats to the monetary authorities. More precisely, when the output gap is positive (or negative) four times out of five the inflation will increase (or decrease) in the next quarter and three times out of five in the next year.

II. Alternative methodologies for estimating potential output

In this section I will examine the methodologies commonly used in the literature for estimation purposes. The aim of this process is not to give an exhaustive list of methods, but rather to review the most popular ones and compare their properties.

Following Chagny and Döpke (2001), the wide range of methodologies can be categorised into four groups: (a) direct methods, namely surveys, (b) non-structural methods, (c) structural methods, and (d) multivariate methods.

II.1. Direct measures of the output gap: Survey data

It is widely accept that, in the short run, supply can be limited by the availability of labour force and capital stock. Thus, if production is subject to constraint it is possible to calculate potential output and the corresponding gap by using business survey data.[2]

[2] The European Commission has gathered a time series for industrial capacity utilisation for the countries that are members of the Euro Zone.

Given this approach, potential output is measured using the effective output, Y_t, and the gap between the available capacities and the level that corresponds to the absence of tensions in the goods market:

$$Y^*_t = \frac{CAP^*}{CAP_t} Y_t \qquad (1)$$

[3]

Despite its simplicity, the method has several limitations. Not only does the amount of data available imply a constraint, but also survey data tends to be subject to definitions, i.e. how to determine the level of utilisation rate that avoids inflationary tensions. Furthermore, since the estimation considers the investment rate to be constant, the method appears to be more appropriate to measuring the evolution of the output gap rather than its level.

II.2. Non-structural methods

The main characteristic of non-structural methods, also known as statistical methods, is the lack of any particular economic structure, and the fact that, instead, they are based on the application of time series analysis. Though parsimonious, they tend to be mechanical, and thus unable to distinguish between the effects of demand and supply shocks on GDP. Furthermore, they ignore all structural properties associated with production, such as availability and quality of factors of production, technology, productivity, etc. – aspects accounted for in methods like the production function approach.

Without any doubt, the main advantage of these methods is the simplicity of the estimation and the little information that is required. However, as Quah (1992) points out, the biggest disadvantage is their inability to incorporate information about the underlying economic structure that allows one to disentangle the

[3] CAP is the utilisation rate, Y* the potential output and CAP* the capacity utilisation coherent with the absence of tensions in the goods market.

relative importance of supply and demand shocks affecting the variable. Furthermore, the lack of an explicit linkage between the resulting measurement and long-term growth makes it impossible to use them for policy advice when the objective of the policymaker is to improve the economy's growth path. Finally, these procedures form a non-specific approach to the nature of the economic cycle, which leads to the use of *ad hoc* assumptions that may alter the measurement. Thus, two researchers using the same method will not necessarily end up with the same estimation.

Among the non-structural methods the following are worth mentioning.[4]

II.2.1. *Linear trend*

The linear trend – the simplest method for estimating potential output – assumes the trend component to be a linear function of time. Defining Y_t as the log of real GDP at time t, β_0 as a constant and *t* as the time trend, the estimation of potential output involves the following linear regression:

$$Y_t = \beta_0 + \beta_1 t + \mu_t \quad (2)$$

The method assumes that GDP can be broken down into a deterministic trend and a cyclical component. Potential output is then given by the trend component, - $\beta_0 + \beta_1 t$ -, and the output gap by the residual element, μ_t.

However, this method implies a constant potential output growth rate at the estimated slope β_1, which excludes the possibility of any supply shock to the system and limits its applicability for policy advice.

[4] The descriptions were heavily based on Changy and Dopke (2001), Cotis, Elmeskov and Mourougane (2004), Brouwer (1998) and McMorrow and Roger (2001).

Moreover, since the trend is considered to be deterministic instead of stochastic, its estimation can bias the output gap by allocating trend components to the cyclical component and thus introducing the possibility of estimating non-stationary gaps.

II.2.2. Split-time trend

Given that a stable linear trend seems unrealistic, the assumption of structural breaks is considered in this method.

Trend output is calculated during each cycle, where the cycle is defined as the period between peaks in economic growth. The specification allows the estimated trend growth to change between cycles, but not within each cycle:

$$LnY_t = \alpha_0 + \sum_{i=1} \alpha_i T_i + \varepsilon_t \quad (3)$$

The main advantage of the split-time trend method is its simplicity once the peaks are detected. Nevertheless, determining the breaks may not be as straightforward as it may appear initially, plus it does not deal with the fact that the trend is assumed to be deterministic between cycles.

II.2.3. Hodrick-Prescott filter

This method is probably the most widely used statistical filter to obtain a smooth estimation of the long-run trend in macroeconomic series. The main reasons are its simplicity and its flexibility in the sense that it can be applied to other series besides real GDP.

Following Billmeier (2004), the Hodrick-Prescott filter (hereafter HP filter) is a linear, two-sided filter that computes the smoothed series by minimising the squared distance between the trend, Y*, and the actual series, subject to a penalty on the second difference of the smoothed series.

Formally, the objective function to be minimised is the following:

$$\min_{\{g_t\}_{t=0,\ldots,T+1}} \quad \{ \sum_{t=1}^{T} (y_t - y^*_t)^2 - \lambda \sum_{t=1}^{T} [(y^*_{t+1} - y^*_t) - (y^*_t - y^*_{t-1})]^2 \} \quad (4)$$

Broadly speaking, the filter implies two steps: (i) minimising the distance between the actual value and trend of the series, and (ii) minimising the change of the trend value.

The penalty or weight parameter, λ, controls the smoothness of the series. A higher λ implies a smoother trend and more volatile gaps, i.e. as $\lambda \rightarrow \infty$ the trend becomes a straight line. Conventionally, λ = 100 for annual data and λ = 1 600 for quarterly data.[5]

Despite its popularity among potential output estimations, the HP filter has its' limitations. Firstly, the filter fits trend through all the observations of the series, regardless of structural breaks that may have occurred. Secondly, the filter as described above is based on observations before and after period t. Thus, in policy contexts, policymakers at the time of decision-making will only dispose of an estimate of the output gap based on a backward-looking evaluation of potential output. Thirdly, there is the possibility of finding spurious cycles for integrated series, and also the shortcoming that long-lasting negative or positive gaps are automatically eliminated by the filter.

[5] Though a justification can be given for choosing such values of λ, the arbitrary nature of their choice is one of the major criticisms of the HP filter.

II.2.4. Baxter-King filter

Baxter and King (1995) developed a filter – also known as the Band-Pass filter – based on moving averages and a spectral analysis.

The idea is that this linear filter eliminates the very slow-moving components – the trend – from those with very high frequency – the irregular component – while retaining the "intermediate" component associated with the business cycle. However, the critical frequency band that has to be allocated to the cycle is exogenously determined.

A positive aspect of this filter is the ease with which a researcher can change the filter construction when the frequency of the data changes. Nevertheless, a practical shortcoming remains: the filter is calculated by moving averages, and so it is impossible to obtain accurate estimations for the most recent observations.

II.2.5. Running media smoothing

This methodology, proposed by Tukey (1977), tries to reduce the smoothness imposed by the HP filter while incorporating structural breaks in the series. The idea is to obtain the median of the values situated in the moving segment of the sample – usually called "window data" – so as to reduce the weighting of the extreme observations and eliminate those that are apart from the majority inside the window.

II.2.6. Wavelets filter

The relevance of this filter is that it allows one to separate the permanent movements from the transitory fluctuations of a series by using a technique known as *Waveshrink.*[6]

Analytically, the filter disaggregates the series into a wave – a wavelet – and a noise according to the following formula:

$$Y_t = Y_t^* + \varepsilon_t \quad (5)$$

where Y_t^* represents the wavelet – i.e. potential output – and ε_t the noise or short-run movements of GDP.

The procedure consists on superimposing functions that represent waves coming from the output. Once such functions are estimated, the coefficients that explain the transitory movements are eliminated, and by using the remaining coefficients, the trend component is reconstructed.

If we were to compare it with the HP filter and the running media smoothing in terms of flexibility, the Wavelets filter would be situated in the middle. Nonetheless, the moment that there are several functions or types of wavelets to choose from, it is not clear enough which should be the criteria of selection.

[6] For an application and a detailed development of the methodology, see Scacciavillani and Swagel (1999).

II.2.7. Unobserved component methods

As implied in the name, these methods aim to approximate unobserved variables – such as potential output or the natural rate of unemployment – based on observed time series.

Two are worth mentioning: the Beveridge-Nelson decomposition and the univariate unobserved component method.

II.2.7.1. Beveridge-Nelson decomposition

Beveridge and Nelson (1981) suggested extracting the trend and cycle from a given time series by making the following two assumptions: (i) the trend is modelled as a random walk, and (ii) the shocks of trend and cycle are perfectly negatively correlated.

The procedure for computing the output gap consists of transforming the given series – real GDP in our case – in a stationary series and then estimating an ARMA model (p,1,q). Then, for each period of the sample, the output gap is defined as:

$$C_t = E_t\,(\Delta y_{t+s} + \Delta y_{t+s-1} + \ldots\ldots + \Delta y_{t+1}) - s\hat{\alpha} \quad (6)$$

where $\hat{\alpha}$ is the constant of the estimated ARMA model.

Given the above specification, the Beveridge-Nelson decomposition is a backward-looking type of filter and, as a result, it exhibits no end-point problems. Yet, it may introduce noise in the estimation, and the possibility of some negative correlation between the cycle and the actual GDP growth cannot be discarded.

II.2.7.2. Univariate unobserved component method

This last non-structural method – estimated with the Kalman filter technique – is based on the assumption that macroeconomic time series are composed of a trend, a cycle and an erratic component that are not observable directly. Nevertheless, these three components could be determined by imposing restrictions in the trend and the cycle process.

Once the restrictions are imposed, the model is rewritten on a state-space representation and estimated with the Kalman filter, as previously mentioned, and maximum likelihood.[7]

Despite its flexibility, significant programming is required, and the results tend to be sensitive to the initial proposed values.

II.3. Structural methods

Distinguishing the structural methods from the non-structural ones is more complex than it might seem initially. Several structural approaches are close to those that simply extract the trend component of the series, and some even use statistical filters as inputs for the estimation. Yet, the main difference arises from the fact that the structural methods are developed from specific economic frameworks. Despite their advantage in giving economic interpretation to the outcomes and being more appropriate for macroeconomic assessment, the information requirements usually become a constraint.

The two most commonly used are the production function approach and the structural vector autoregressive method (SVAR).[8] Nevertheless, it is also worth

[7] For more detail and an empirical estimation, see Changy and Dopke (2004), Clark (1987) and Harvey and Jaeger (1993).
[8] Since both approaches were used for estimation purposes, a detailed description will be developed in the following sections.

mentioning Okun's law: the oldest structural approach to estimating potential GDP.

II.3.1. Production function approach

Contrary to the statistical filters, the production function approach tries to unearth the nature of constraints that limit growth and allows a more direct link to the sources of change in the potential output and output gap. Since it incorporates information concerning capital stocks, working population, trend participation rates, structural unemployment and productivity, there is room for evaluating the effects of structural shocks associated with changes in the evolution of technological progress, capital accumulation and labour force participation. However, a key problem in implementing the production function method is the lack of information available.

The production function approach can be implemented with varying degrees of sophistication and detail. Usually, a simple Cobb-Douglas function with constant returns of scale is estimated on the basis of factor incomes share (Scacciavillani and Swage, 1999).[9] However, the Organisation for Economic Cooperation and Development (OECD) interlink country model applies CES production functions and (Coen-Hickman, 1995) estimate the annual growth model of the US economy endogenising the natural rate of unemployment (NAIRU), the potential labour force and the potential average working hours.

II.3.2. Okun's law[10]

Under the assumption that labour force is the major limiting factor of production, the unemployment rate can be interpreted as an indicator of the output gap.

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[9] This is the approach followed in this dissertation.
[10] The method relies on Okun's (1962) seminar paper.

This indirect method suggests that estimating potential output is possible based on historical data and the underlying relationship between the output and the employment gaps implied in Okun's law.

The relationship is as follows:

$$(U_t - U^*_t) = -\alpha\,(Y_t - Y_t^*) \quad (7)$$

where U represents the unemployment rate and 1/α the so-called Okun coefficient.

Given the empirical regularity found by Okun – a 1% increases in the output gap goes hand in hand with a 0.3 percentage point decrease in the cyclical unemployment rate – the cyclical component of real GDP is associated with the cyclical unemployment rate.

Yet, critiques are numerous. Firstly, both potential output and the equilibrium unemployment rate are not directly observed. Secondly, the relationship assumes unemployment to be stationary, which could be true for economies like that of the United States, but not necessarily for others. Chagny and Dopke (2001) show that in most of European economies, the unemployment rate is non-stationary. Thirdly, the Okun coefficient can be a problem in itself. A frequently found low coefficient could be explained by the lagged adjustment of employment to production. In the medium term, the value should be around 0.7–0.8, given that employment tends to grow to maintain productivity in its long-term trend.

II.3.3. *Structural VARs*

The SVAR methodology, put forward by Blanchard and Quah (1989), Shapiro and Watson (1988) and King et al. (1991), combines time-series methods with economic theory to distinguish between permanent and temporary movements of output. The method identifies structural shocks and structural components on the basis of a limited number of economic restrictions imposed on an estimated VAR.

The procedure stems from the traditional Keynesian and neoclassical synthesis, which identifies potential output with the aggregate supply capacity of the economy and the cyclical fluctuations with changes in aggregate demand. Thus, the potential output is estimated by aggregating – to a linear trend – successive permanent shocks that affect the growth rate of actual GDP series, while the transitory shocks determine the business cycle.[11]

The main advantages of the approach are the following: (i) it allows a better economic interpretation of potential GDP variations, (ii) it also allows the estimation of the gradual transmission of a permanent shock to the potential output and the transitional dynamics that take place after permanent shocks, (iii) it provides the possibility of deriving confidence intervals, which give a measure of the uncertainty surrounding the estimates of the output gap and the potential output, and (iv) the results are based on econometric estimates without the arbitrary setting of smoothing parameters and without experiencing the end-sample problems that most of the non-structural methods do.

Among the disadvantages, we can mention the higher data requirements and the risk of obtaining a potential GDP series that closely resembles the actual series if the correlation between GDP and the other variables considered is weak. Moreover, the intervals of confidence are usually too wide and too sensitive to both the sample and the model's specification.

[11] The methodology and long-run identifying restrictions are discussed in detail in the following sections of the dissertation.

II.4. Multivariate methods

The ongoing criticism of the mechanical aspect of the non-structural methods and the data requirements of the structural ones led to the development of multivariate methodologies. Such methods aim to introduce structural relationships – like Okun's law or the Phillips curve – to the non-structural approaches so as to estimate the permanent component of the series with a higher degree of certainty.

Following Miller (2002), the advantage is that, given that the structural relationships introduced usually consider variables such as inflation, unemployment and installed capacity, the results become more consistent with the empirical evidence.

II.4.1. Multivariate HP filter

Proposed by Laxton and Teltow (1992) and Butler (1996), this method aims to add economic information to the previously mentioned HP filter. Such information can come from either economic relationships or indicators of capacity utilisation.

Two arguments are proposed by these authors: (i) researchers usually have insufficient knowledge of the determinants of supply shocks on which to base the analysis of the structural methods, and (ii) distinguishing between supply and demand shocks tends to be more helpful in terms of policy advice than distinguishing between transitory and permanent components.

Combining both aspects and introducing the residuals of a structural economic relationship – Phillips curve or Okun's law – in the minimisation problem is how the multivariate version of the HP filter was derived.

II.4.2. Multivariate Beveridge-Nelson decomposition

Evans and Reichlin (1994) introduced the new approach to the Beveridge-Nelson decomposition process mentioned previously among the univariate methods.

The assumption of the tendency being a random walk is retained, but the stochastic shocks are now defined as a linear combination of the existing changes between real GDP and other variables containing relevant information for estimating the long-run output. For example, a change in output correlated with a change in employment would indicate a supply shock, while a change in output correlated with a change in consumption would indicate a demand shock. As Dupasquier (1999) mentions, the potential output is then defined as the level of output that is reached after all transitory dynamics have died out.

II.4.3. *Multivariate unobserved components models*

Again, the aim of this method is to incorporate additional equations so as to enrich the univariate methods' estimations. Gerlach and Smets (1999) apply this methodology by considering the relationship among potential output, inflation, output gap and interest rate.

II.4.4. *Cochrane decomposition*

Finally, Cochrane (1994) developed his decomposition method based on permanent income theory. Associating consumption with the permanent component of output, he estimates potential output.

A two-variable autoregressive vector – real GDP and consumption – is applied for the calculations. Given that the permanent income theory implies that consumption follows a random walk and that output and consumption are co-integrated, the output's fluctuations that exceed those implicit in the consumption's evolution are considered to be transitory (Gallego and Johnson, 2001).

Nevertheless, it should be borne in mind that there is little empirical evidence that supports the permanent income theory. More precisely, Noya, Lorenzo, Grau and Perez (1996) prove that the theory does not hold in the Uruguayan economy, where the evolution of consumption cannot be detached from the relevance of liquidity restrictions. As a result, consumption cannot be smoothed over time, and so current consumption and income are no longer independent.

Table 1 summarizes and classifies the previously mentioned alternative methodologies for estimatin potential output

Table 1: Alternative methodologies for estimating potential output

Direct methods	Non-structural methods	Structural methods	Multivariate methods
- Survey data	- Linear tendency - Split-time trend - Hodrick-Prescott filter	- Production function approach	- Multivariate HP filter
	- Baxter and King filter - Running media smoothing - Wavelets filter	- Okun's law	- Multivariate Beveridge-Nelson decomposition
	- Unobserved components methods: - Beveridge-Nelson decomposition - Univariate unobserved components method	- Structural VARs	- Mutilvariate unobserved Components models - Cochrane decomposition

II.5. Methodologies commonly applied in central banks and international organisations

The objective of this section is not only to evaluate the popularity of the methods mentioned above, but also to emphasise that due to the uncertainty of the estimation, the common method is to consider more than one approach. Table 2 summarises such methods.

Table 2: Methodologies commonly applied in central banks and international organizations

	Central Bank of Canada	Central Bank of England	European Central Bank	IMF	OECD	CBO
Linear trend	X					
Split-time trend					X	
Production function	X		X	X	X	X
HP filter	X	X		X	X	
Multivariate HP filter	X					
Univariate unobserved components models		X				
Beveridge-Nelson filter			X			
Structural VARs		X	X			

IMF = International Monetary Fund

CBO = Congressional Budget Office

Two main conclusions can be extracted: (i) the most frequently used methods are the HP filter and the production function approach, and (ii) the tendency to employ several methodologies so as to check results is evident.

II.6. <u>Potential output estimations for the Uruguayan economy</u>

Several papers have been written on the subject of growth in the Uruguayan economy, e.g. Bucacos (1999; 2000), De Brun (2000; 2004), and Noya, Pereira y Prieto (2003), to mention a few. However, the main focus has been on growth accounting rather than estimating the output gap.

Bucacos (2001) stresses the importance of measuring potential output not only in terms of medium- and long-term growth, but also because of its key relevance when it comes to economic analysis and policy advice. For estimating purposes, he considers three methodologies: split-time trends, the HP filter and the production function approach. For the first methodology, quarterly data is applied, while the HP filter and the production function approach are base on annual data. The samples are from 1975–2000 and 1960–2000, respectively. The results obtained by the three methods are very close, although a higher volatility of the output gap was found using the HP filter.

More precisely, real GDP seems to have grown under its potential from 1981 to 1985 and from 1993 to 2000, while inflationary pressures seem to have been significant for the rest of the period. The estimated potential trend indicates a sustainable growing path around an annual average of 3,2%, which implies that for the last years the Uruguayan economy has been growing below its full capacity.

More recently, Cabrajal, Lanzilotta, Llambi and Velazquez (2007) present a preliminary estimation of potential output by applying the production function approach, the HP filter and the Kalman filter. The sample considered was 1986Q1–2006Q1. Again, regardless of small differences, there is evidence of a high correlation among the alternative estimations; for example, all three methods agree on real GDP exceeding potential output in 2006. Yet, the Kalman filter shows a lower deviation of real GDP with respect to the long-term trend, the production function approach reflects the widest output gap and the highest estimated peak is achieved when using the HP filter.

Similar to the papers mentioned at the beginning of this section, the HP filter and the production function approach will be applied in this dissertation. Thus, the conclusions derived by the authors mentioned above will function as a benchmark for comparing the results achieved. The extension proposed by this work is precise the data employed in the production function and estimate potential output using a structural VAR – which was not yet used for the Uruguayan economy.

III. The production function approach

Prior to estimating the potential output under the production function approach, both the theoretical background and the data requirements are revised. This method was chosen mainly for two reasons: (i) its flexibility and advantages (specially, if compared to alternative non-structural methodologies), and (ii) its popularity among central banks and international organisations such as the IMF.[12]

The method explicitly models output in terms of input factors, generally by means of a Cobb-Douglas production function with constant returns to scale. Thus, it specifies and estimates the production process by linking capital, labour and total factor productivity (TFP) to real GDP.

Following Bucacos (2001) and De Mesi (1997), potential output is calculated as the level of output that results when the rates of capacity utilisation are "normal", i.e. when labour is consistent with the natural rate of unemployment and TFP is at its trend level.

The procedure does not require modelling the demand and supply of capital, labour or TFP. However, it implies the following assumptions: (i) in the short run, the potential levels of capital and labour can be determined by the behaviour of unemployment relative to its natural rate and the fluctuation of GDP around its normal level, and (ii) the growth of the factors of production considered for projecting potential output can be based on the interpretation of macroeconomic trends (De Mesi, 1997).

When justifying the election of the production function for estimating purposes, I referred to the advantages of this method, yet further discussion is relevant.

[12] "IMF research on estimating potential output has mainly concentrated on developing and applying the production function approach for industrial countries" (De Masi, 1997).

Firstly, given that the link between output and inputs is clearly evidenced through the measuring process, the production function approach allows for the decomposition of output growth in terms of the contributions of capital, labour and TFP. Therefore, as De Mesi (1997) states, it is possible to trace the impact of past, current and projected disturbances on the levels of potential output. However, Coe and McDermott (1996) argue that despite the advantage of explicitly identifying the sources of growth, studies commonly focus on capital and labour, while leaving TFP largely unexplained. Secondly, due to the approach's flexibility, a researcher can introduce different assumptions concerning technology, changes in the quality of labour and capital, changes in macroeconomic policies and so on. For instance, in the presented estimation, labour is adjusted by quality – through the introduction of a human capital index – and by the emigration that has been affecting the Uruguayan economy recently. With respect to policy changes, Gallego and Johnson (2001) expand the approach for identifying the factors that explain growth by estimating a system of equations in which the production function is one of them. These authors introduce structural factors such as the syndicate rate, unemployment insurance, labour laws, the rate of investment in R&D, demographic characteristics and the taxation system.

Analogous to all the methodologies, the production function approach also has drawbacks. The main and most obvious one is the data requirements; i.e. in order to have an accurate estimation of the potential output, a key factor is the reliance on filtered factor input series. However, capital stock is particularly difficult to measure and update, labour data tends to be inconsistent in long samples, and both the natural rate of unemployment and the TFP are non-observable variables. This is the reason why filters such as the HP filter constitute a first step in the estimation process. Furthermore, Cerra and Saxena (2000) also argue that the simplicity of a Cobb-Douglas production function may not capture the complexity of the real production and technological process.[13]

[13] See Bolt and Van Els (1998) for an estimation under a CES function.

In terms of this dissertation, a traditional Cobb-Douglas function is considered, i.e the assumptions of diminishing rates of returns, marginal rates of substitution among factors equal to one and the Inada conditions hole.[14] Bucacos (2001) also considers the same production function, arguing that the economic characteristics of the Uruguayan economy are well reflected by the function. Thus, by applying the same assumption, it will be possible to check the consistency of the results.

The relationship considered is the following:

$$Y_t = F(K_t,\ H_t\, L_t,\ A_t) = A_t.\ (H_tLt)^{\alpha}.\ K_t^{\beta} \quad (8)$$

with Y_t being the actual output, K_t the capital stock, H_tL_t the labour force adjusted by quality and A_t the TFP.

Assuming constant returns of scale: $\alpha + \beta = 1$; under perfect competition or at least under enough competition so that the factors are paid their productivity, α corresponds to the share of labour and $\beta = 1 - \alpha$ to the share of capital income[15].

Equation (8) shows that current output is related to current capital stock. Teixeira da Silva (2002) argues that, for estimation reasons, the periods should be adjusted in a way that current output is determined by the previous period's capital stock. Such a lagged structure is explained by the fact that investment needs one period before materialising into an increase in the economy's productive capacity.[16]

[14] The existence of constant returns to scale for the case of Uruguay will be proved later in the analysis.
[15] Although the assumption of constant returns of scale is standard in the literature, the increasing returns to scale are also becoming more and more acceptable.
[16] This author's argument is taken into account when estimating the capital stock using the permanent inventory method.

Since TFP is not directly observable, it is usually derived as a residual from the above equation, i.e. it is calculated by subtracting the contribution of capital and labour to actual GDP once expressed in log form:

$$tfp_t = y_t - \alpha h_t l_t - (1 - \alpha)k_{t.} \quad (9)$$ [17]

Given the way it is measured, the TFP estimation poses many of the challenges and uncertainties inherent in the potential output. If it is true that real GDP deviates from the level determined by the factors inputs, then the difference is ascribed to TFP. As a result, externalities that are not captured by the behaviour of capital and labour or factors that cannot be compensated for by market mechanisms will affect TFP measurement.[18]

Once capital, labour, TFP and the factors shares are calculated, potential output is estimated by subtracting trend variables in the production function along with actual capital:

$$Y^*_t = A^*_t \,.\, (HL_t^*)^{\alpha} .\, K_t^{(1-\alpha)} \quad (10)$$

Y^*_t corresponds to potential output, A^*_t to the TFP trend – usually determined by the HP filter – and HL_t^* the level of qualified employment consistent with the NAIRU. Notice that the capital stock is the only series that is not detrended. This is because the maximum potential contribution of capital is directly given by the full utilisation of the existing stock in the economy.[19]

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[17] The variables in small caps are in logs.

[18] This is why TFP – commonly known as the "Solow residual" – is said to be a "measurement of our own ignorance".

[19] For a more elaborate approach, see Everaert and Nadal de Simone (2003).

III.1. Estimating physical capital stock

The capital stock series is estimated within the macroeconomic measuring framework of the national accounts system. Thus, all the installed capital goods that determine the productive capacity of the economy and that are included in the gross fixed capital formation series of the national accounts will be considered in the measurement.[20]

The definition applied in this work follows the one used by the OECD (2001): "tangible or intangible assets produced as output from processes of production that are themselves used repeatedly, or continuously, in processes of production for more than one year".

As for most Latin American countries, Uruguay lacks an updated measurement of the available capital stock in the economy. Perez (2003) summarises the indirect procedures commonly used in different economies for estimating capital stock series: the perpetual inventory method, the Harberger method, physical assets inventory and composed physical indexes, to mention a few. However, ESA95 recommends the perpetual inventory method proposed by Hirsleifer (1970) – henceforth PIM – for the calculation of the stock of fixed assets whenever direct information is missing.

Capital stock is calculated as the sum of gross fixed capital formation in the previous period net the economic depreciation of which the service life is not yet expired, i.e.

$$K_t = (1 - d)^t K(0) + \sum(1 - d)^t I_{t-1} \quad (11)$$

[20] Notice that the reason why capital stock is calculated based on the gross capital formation is because stocks are the ultimate result of flow accumulation.

where K_t is the capital stock in time t, K(0) the initial capital stock, I_{t-1} the gross capital formation in t-1 and d the depreciation rate. If only two periods are considered, then equation (11) is simplified to:

$$K_t = I_t + (1 - d) K_{t-1} \qquad (12)$$

Yet, the problem associated with the estimation of K(0) is not avoided.

Given that expected service life differs with the type of asset, the stocks should be estimated separately and only then added up. In the case of Uruguay, the assets were grouped into three categories: constructions, machinery and equipment, and plantations, which ensured consistency with the gross fixed capital formation presented in the national accounts.

The stock for construction and machinery and equipment was derived using: (i) Harberger's estimations (1971) as the initial stocks, (ii) quarterly gross fixed capital formation from the national accounts, and (iii) a 2,5% and 8% annual rate of depreciation for construction and machinery and equipment, respectively.[21] Because of missing data, the stock of plantations was calculated based on the 1980, 1990 and 2000 agricultural census.

Quarterly gross fixed capital accumulation is presented in constant prices for 1983, while Harberger's estimation is expressed in 1961 prices. Thus, a change of base was needed in order to consolidate the estimation, and for that purpose, the implicit price indices of 1978 – in both 1961 and 1983 prices – are required. The latter are calculated as the ratio between 1978's gross investment in current and constant prices, base 61 and 83.

[21] The same depreciation rates were considered by Bucacos (1997) and Carbajal, Lanzilotta, Llambi and Velazquez (2007).

Once the indices are calculated, the obstacle is linking and conciliating, – both laterally and temporally –, the series of gross capital formation with base 83. Since 1971, the basing years for the series presented in constant prices were changed three times; as a result, the data is divided into three sub-samples:

(i) 1970–1983, base 78;

(ii) 1983–1998, base 83; and

(iii) 1988 onwards, base 83, due to the abovementioned revision done in 1988.

The objective is to obtain a long and consistent series for gross investment starting from 1970 and expressed in 1983 prices. Although the detail reconstruction of the series is the most precise alternative among the ones proposed by Hexeberg, the data requirements explain why indirect methods are applied instead. The procedure used in the dissertation follows the statistical techniques suggested by the national accounts system. More precisely, based on Ponce (2004), the method applied is the variation rate. Given k and $k + h$ as base years and defining C^t_k and C^t_{k+h} as the constant priced values of period k and $k + h$ at time t, the linked values for $t = k + h - 1$ are derived from equation (13):

$$C_{k+h}^{t=k+h-1} = C_{k+h}^{t=k+h} \times C_k^{t=k+h-1} / C_k^{t=k+h} \quad (13)$$ [22]

The national accounts system ensures a temporal and sectorial consistency scheme for the different macroeconomic variables. However, once the updated time series are put together into a new serie with base 83, the consistency and additive principle is broken; i.e. a residual arises from the difference between aggregate gross investment and the series classified by type of investment. In

[22] Notice that the linking procedure should be done from the data presented in the latest revision backwards.

order to recover the transversal consistency, a modification of the Denton procedure (1971) is performed using Matlab.[23]

The resulting initial capital stocks for construction and machinery and equipment B83R88[24] are presented in Table 3.

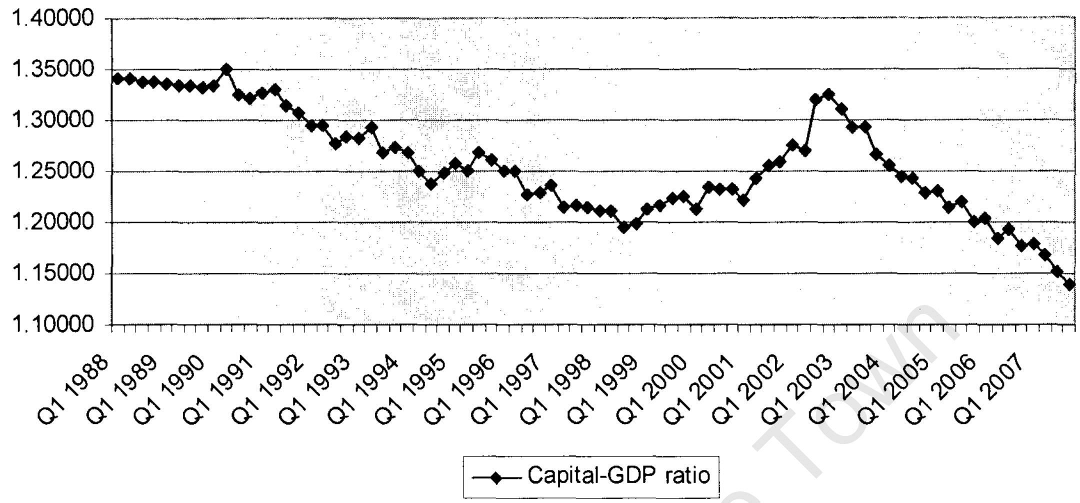
Table 3: Initial capital stock - (Constant prices of 1983)

	Construction stock	Machinery and equipment stock
1978	399 720	95 216

Figure 1 show that the capital-to-GDP ratio has been declining for the last decades, despite the peak in 2002–2003, which can be explained by the sharp decrease in real output. Notice, however, that the decline in the ratio for the last quarters is mainly due to the strong increase in GDP and not so much to an actual decrease in capital formation.[25]

[23] Through this procedure, the residuals are smoothly distributed along the sample. See Ponce (2004) for further details about the methodology.
[24] The national accounts were revised in 1988, so B83R88 stands for "prices for 1983 revised in 1988".
[25] More precisely, Centro de Investigaciones Economicas (CINVE) stated in its analysis that gross investment grew in 2007 at an annual rate of 16,5%.

Figure 1: Capital-to-GDP ratio in logarithms, 1988–2007



In general terms, the composition of the capital stocks has stayed relatively stable, with a small increase of machinery and equipment and a corresponding decrease in the stock of plantations. Such behaviour is consistent with the increments in the level of imports of capital goods of the last few years.

III.2. Estimating human capital stock

When it comes to estimating human capital, there are two aspects that need to be mentioned. Firstly, given that the inputs of the production function should be expressed as physical units, an ideal estimation of the labour force would be total working hours. Naturally, data is insufficient or non-existent, so a good proxy is the number of working individuals. Secondly, the figure for labour force should be adjusted by quality in order to capture its real contribution to the productive capacity of an economy.

In order to obtain an estimation of the Uruguayan human capital stock that is as accurate as possible, the series was adjusted by the significant emigration wave of the last periods and by a human capital index reflecting the quality of the labour force.

III.2.1. Labour supply

The figure for the economically active population resulted from multiplying the working-age population – defined by the National Statistics Institute as those aged 14 or more – by the quarterly activity rate.[26]

Following Bucacos (1999), omitting the unemployment rate in the measurement may bias the productivity levels calculated later, especially if the unemployment rate is as high as it was during part of the sample.[27] Yet, the fact that the distribution of the economically active population by level of education did not distinguish between employed and unemployed placed a big obstacle. Thus, the limit of the assumption is recognized, but the priority was set on the coherence between labour force and the human capital index.[28]

Potential labour input is taken to be the level of employment consistent with the natural rate of unemployment, or, following Denis, McMorrow and Roger (2002), the non-accelerating inflation rate of unemployment:

$$L^*_t = L_t\,(1 - NAIRU) \qquad (14)$$

Despite adding elements of discretion, the natural rate of unemployment can be calculated by HP filtering the observed unemployment rate.[29]

Given the mentioned problem of data availability, only the activity rate was smoothed by the HP filter; i.e. the L^*_t considered in the estimation equals the working-age population multiplied by the filtered activity rate.

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[26] Both series are provided by the National Statistics Institute, INE: www.ine.gub.uy. The working-age population was corrected by the National 2004 Census data.
[27] See Teixeira (2002) for further discussion.
[28] Bucacos (1999) performs a sensibility analysis of the labour demand and concludes that omitting unemployment does not affect the measurements significantly. Plus, there seems to be no trend to unemployment over the period considered.
[29] Billmeier (2004) uses a more sophisticated filtering procedure that includes structural assumptions based on economic theory.

III.2.2. The emigration phenomenon

After ten years of economic growth, the Uruguayan economy began a slow-down phase that resulted in the financial and economic crisis of 2002. The break in economic evolution and the magnitude of the recession affected, among other things, the migratory flow.

Between 2001 and 2007 more than 100 000 habitants emigrated, according to the National Census data. Ninety per cent of these emigrants were in the working-age range, and if we take into consideration that the country's population at the time was three million people, the figure becomes alarming.

Despite the fact that the National Census is still in its initial stages and there is no information about the level of education of the emigrants, their educational profile is considered to be "high" and "medium high". According to Pellegrino and Vigorito (2003), the percentage of individuals living overseas with 12 or more years of education is much higher than the percentage of the residents.[30] Table 4 summarises the distribution of educational level among the emigrating population in 2002.

[30] See Pellegrino and Vigorito (2003) for a further discussion of the emigration wave and its economic impact.

Table 4: Level of education among emigrants (%), 2002

Primary education	6,7
Secondary education 1st stage and/or technical[31]	24,1
Secondary education 2nd stage	30
Tertiary education[32]	34,2
No answer [33]	5
	100

Source: Pelegrino and Vigorito (2003) and survey data, World Bank (2002)

Table 5: Percentage of individuals with 12 or more years of education by country of residence

Year	USA	Canada	Argentina	Brazil	Paraguay	Venezuela	Uruguay
1990	61,8	77,6	30,4	32	51,2	47,9	23,5
2002	81,2	n/a	40,2	47,8	61,8	64,3	26,7

Source: Pellegrino and Vigorito (2003)

Table 5 compares the percentage of Uruguayan emigrants with 12 or more years of education living abroad with those living in Uruguay. As Pellegrino and Vigorito (2003) conclude, the emigration phenomenon has been selective in terms of quality: a higher proportion of the emigrants had university degrees, while those with primary education were the minority. Naturally, such a reality is expected to impact on the quality and supply of the labour force, and, as a result, on the

[31] Secondary 1st stage corresponds to the first four years of high school and secondary 2nd stage to a bachelor's degree. Technical education was added to the secondary 1st stage cohort because workers completing secondary education tend to perceive higher returns.
[32] Includes military training, scholastic degrees (teachers and professors) and university.
[33] This category is eliminated from the total.

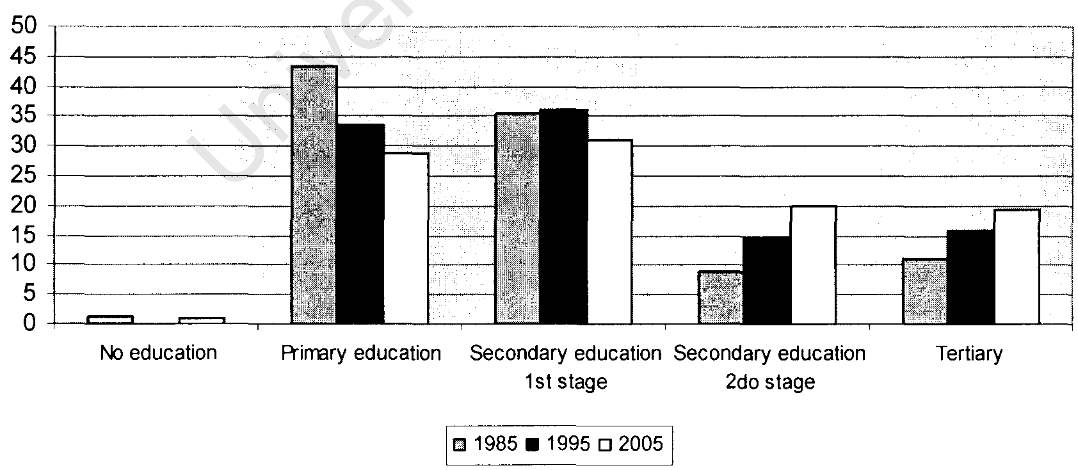
economy's growth path. Thus, the phenomenon's characteristics will be considered when calculating the human capital index.

III.2.3. *Human capital index*

The high level of schooling in the labour force and the speed at which this was achieved has always characterised Uruguay.

In the mid-1980s, almost 45% of the economically active population had only completed primary education, while in the mid-1990s, this figure had reduced to 30%, and the majority of the workers possessed either technical or secondary level education. Despite the relative importance of the number of workers with technical qualifications remaining stable, in 2004–2005 an increase in the proportion of those with secondary and tertiary education was observed. Figure 2 shows the transition.

Figure 2: Economically active population and distribution by level of instruction, 1985–2005



Several studies have been done with the objective of endogening the significance of technological change, explaining the changes in the economy's productivity and linking human capital with economic growth. Wolff (2000) argues that one of the main sources of growth among OECD countries is the level of education in the labour force. More precisely, he concludes that increments in human capital led to increments in productivity and that the convergence of productivity among countries was explained by the convergence of the level of education. Nevertheless, other empirical works have found that economies with high levels of schooling did not exhibit growth rates that were as high as expected. Thus, the link between growth and education cannot be generalised for all economies, and specific analysis is recommended.

III.2.3.1. *Definition of human capital*

Defining human capital is almost as complex as measuring it. According to Noya Pereira and Prieto (2003), human capital is associated with the characteristics and potential abilities intrinsic to each individual. Once involved in the production process, the worker's characteristics and abilities will determine his/her corresponding flow of current and future income. In this context, Torello and Casacuberta (1997) define human capital as the stock of the productive capacity among the economy's potentially active individuals. Broadly speaking, human capital can be defined as productive wealth embodied in labour, skills and knowledge.

Human capital is not restricted to formal education; on the contrary, it is a multidimensional concept. Thus, informal education, mental and physical capacities, inborn abilities and "learning by doing" formations should also be considered. Yet, the definition needs to be limited so as to make it operational, and this is usually done by focusing on education and its economic returns. The underlying idea is that at an early age individuals need to decide the amount of investment he or she wants to make in education, knowing that its return has a lag of 12–20 years.

In this section, the stock of human capital for the Uruguayan economy is measured and the outcomes are compared to those presented in earlier empirical works.

Given that individuals differ in terms of capacities and levels of education, the simple aggregation of working individuals or working hours should not be considered a good proxy of the production factor labour. Instead, human capital indices should be constructed as a weighted average of individuals, with the human capital being the weighting factor.

Two dimensions are commonly considered when calculating the indices: (i) income and (ii) level of education.

Indices based on income are based on the assumption that workers with higher levels of human capital are paid higher wages.[34] This procedure is generally known as the labour income-based index or LIB, and it associates wage divergence with productivity differences. Because wages are affected by other factors such as demand and supply, Mulligan and Sala-i-Martin (1995) suggest dividing the worker's wage rate by a numeraire that captures the effect of a representative worker with no human capital.[35] This method was discharged in the case of Uruguay because the labour market is not competitive enough to guarantee that wages reflect the average productivity of work. Due to the bargaining power of syndicates, changes in the wage rates are likely to be a biased measurement of the change in human capital.[36]

Based on a cross-country analysis, Barro and Lee (1993) emphasise the advantages of considering the level of education when measuring human capital. However, the underlying limitation is that the divergence among workers'

[34] Buchelli (1990) studies the empirical regularity for the case of Uruguay.
[35] For an application of the Mincer equations, see Torrello and Casacuberta (1997) and Carbajal, Lanzilotta, Llambi and Velazquez (2007).
[36] Such decision goes in line with the conclusions presented by Torello and Casacuberta (1997) and Risso and Stroch (2002).

productivity is directly proportional to the years of schooling, i.e. a worker with ten years of education would be considered ten times more productive than a worker with no education. A way of dealing with this shortcoming is to consider the gross and net enrollment rate. This is calculated by "dividing the number of students of a particular age group enrolled in all levels of education by the number of people in the population in that age group" (OECD, 2007). Nehru (1995) goes further and applies the perpetual inventory method, using the enrolment rate and the mortality rate as proxies for investment and depreciation.

II.2.3.2. Human capital measurement

Following Collins and Bosworth (1996), the labour supply adjusted by quality and emigration is calculated through equation (15):

$$Ht = \sum_{1988Q1}^{2006Q4} \sum_{j=1}^{5} Wj * Pjt \qquad (15)$$

where Ht is the human capital at time t, P_{jt} the proportion of active individuals – at time t and with level j of education – on Uruguay's economically active population and Wj the returns that workers within the different educational categories obtain in the labour market.[37]

The calculation was based on the microdata provided by the Encuestas Continuas de Hogares (ECH) collected by the National Statistic Institute (INE).[38] Until 1997, the ECH collected information on the population in towns and cities with more than 900 inhabitants; since 1998, the sample was limited to towns and cities with more than 5 000 inhabitants. In order to have a similar coverage for all the period, the data of small towns for the years before 1998 was dropped. As only 12% of the population lives in towns with less than 5 000 inhabitants, the

[37] The impact of emigration is considered by subtracting emigrants from the economically active population. Furthermore, since emigrants are distributed by level of education, the selectivity of the phenomenon and its impact on the economy's human capital are also taken into account.
[38] The ECH is a one-shot urban monthly survey.

results obtained with this sample can be interpreted as results for the whole country. Plus, the Economic Commission for Latin America and the Caribbean's statistical analysis of its implications in terms of socioeconomic results concluded that the inclusion or exclusion of the periphery had little effect on aggregated data.

The human capital index is calculated in two stages: (i) we classify the economically active population – previously adjusted by the emigrational phenomenon – into the different educational categories, and (ii) we define the pondering factors that make the aggregation possible.

The ECH present educational data disaggregated in nine categories: no education, primary, secondary 1st stage, secondary 2nd stage, technical formation, scholastic degree or mastery, military training, university and others. However, the categories were reduced to five so as to be consistent with the empirical work previously done for Uruguay, as shown in Table 6.

Table 6: Levels of education

No education
Primary
Secondary 1st stage and/or technical education
Secondary 2nd stage
Tertiary

After defining the different levels of education, a scale was built such that an additional year of education has an exponential increase in the associated return. The pondering factors were defined based on those applied by Risso and Stroch (2003), Bucacos (1998), Noya, Pereira and Prieto (2003) and Carbajal, Lanzilotta, Llambi and Velazquez (2007).[39]

[39] All the mentioned papers apply weighting averages, W_j, which are in line with those used by Collins and Bosworth (1996). Based on Amarante and Arim's (2003) paper, Carbajal, Lanziolotta,

The scale considered in the dissertation goes from 1 to 3, with 1 being the return obtained by workers within the lowest educational category and 3 the return of those with the highest human capital.

Table 7: Worker's return based on education, W_j

No education	1
Primary	1,3687
Secondary 1st stage and/or technical education	1,8966
Secondary 2nd stage	2,5625
Tertiary	3

Figure 3 show the evolution of the different cohorts over the period analysed. The results indicate a decrease in people in the lower categories – no education and primary – among the economically active population, and an increase of the presence of workers with secondary and tertiary formation. Notice, however, that the relative participation of tertiary education has declined in the most recent periods due to the impact of emigration and its selectiveness when it comes to human capital.

Llambi and Velazquez (2007) ran Mincer equations considering experience indices, their squares, the individual's gender and age, type of occupation under the CIUO 88 classification, sector of activity, a dummy for part-time or full-time job, etc., and confirmed the values of W_j..

Figure 3: Economically active population by level of education

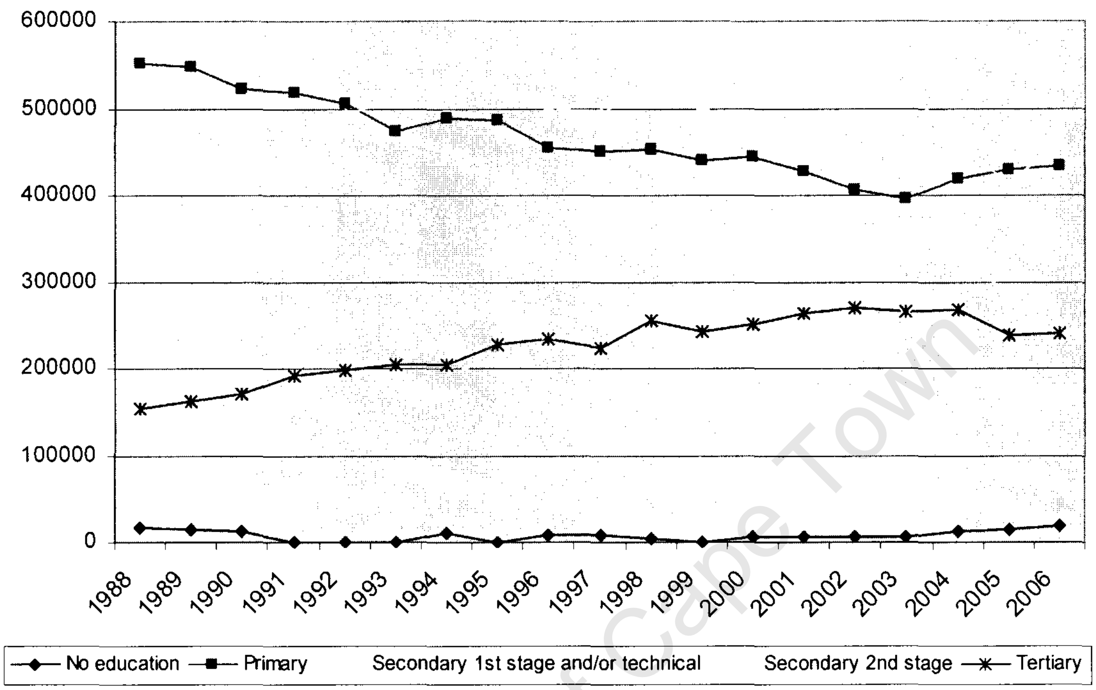


Table 8 compares our core results with those obtained in the empirical analyses previously done for Uruguay. Classifying the various studies based on the two main dimensions of human capital – income and education – two groups can be distinguished: (i) Torello and Casacuberta (1997) and De Brun (2004), who apply the LIB index, and (ii) Bucacos (1999), Noya, Pereira and Prierto (2003) and Risso and Stroch (2002), who apply the Collins and Bosworth procedure.

Table 8: Human capital: Comparison by author and sub-sample

	Torello & Casacuberta	Dissertation	Difference
1988–1995	1,80%	1,00%	0,80%
1986–1995	-2,80%	0,33%	-3,13%

	Bucacos	Dissertation	Difference
1981–1985	0,80%	0,11%	0,69%
1985–1998	0,80%	0,84%	-0,04%
1988–1995	1,79%	1,00%	0,79%

	De Brun	Dissertation	Difference
1991–1997	2,40%	0,91%	1,49%

	Risso & Storch	Dissertation	Difference
1981–1985	0,38%	0,11%	0,27%
1985–1998	1,13%	0,84%	0,29%
1986–1995	1,15%	0,82%	0,33%
1988–1995	1,23%	1,00%	0,23%
1991–1996	1,01%	1,04%	-0,03%

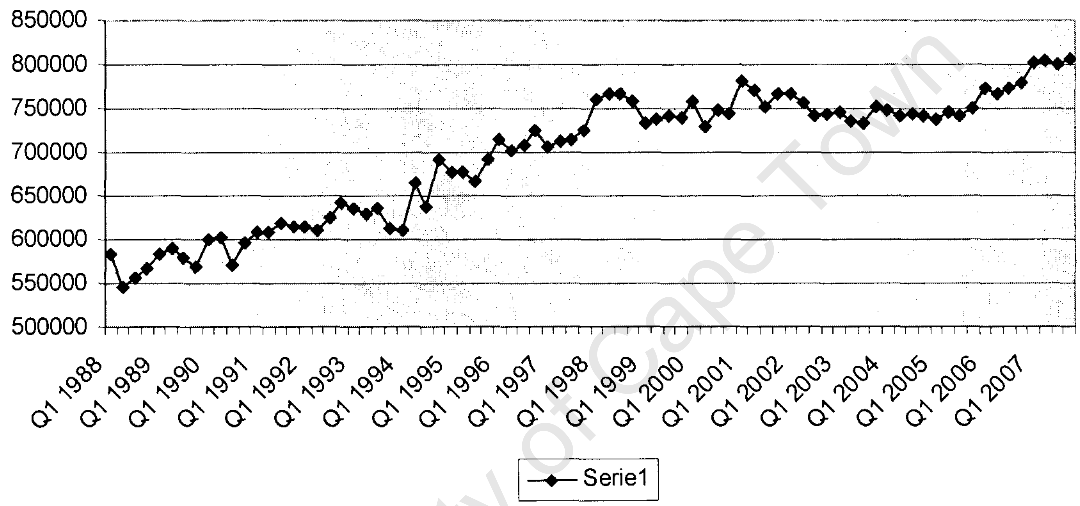
	Noya, Pereira, Prieto	Dissertation	Difference
1981–1985	0,64%	0,11%	0,53%
1985–1998	0,57%	0,84%	-0,27%
1986–1995	0,62%	0,82%	-0,20%
1988–1995	0,62%	1,00%	-0,38%
1991–1996	0,60%	1,04%	-0,44%
1980–1989	0,65%	0,25%	0,40%
1990–1999	0,54%	0,90%	-0,36%

The similarities and divergences of the results depend on the sub-sample and, naturally, on the method considered. As expected, my results differ from those of

Torello, Casacuberta and De Brun and are more in line with the results of the other authors mentioned.

Finally, Figure 4 presents the evolution of the labour input considered for the estimation.

Figure 4: Human capital stock, 1988–2007



III.3. *Estimating potential output and previous considerations*

In this section, the potential output and output gap series are presented, together with the analysis required prior to the estimation.

The first step is to study the stationarity of the series. The techniques commonly used are the Augmented Dickey Fuller and the Perron-Phillips tests. However, Perron (1989) proves that when a series has undergone a permanent change either in the slope or the intercept at some point during the analysis of stationarity, the standards ADF tests tend to show non-stationarity when in fact stationarity applies. Given the presence of both: shifts and trend breaks in the analysed series, the innovational outlier model with H_0: $\alpha = 0$ was performed.[40]

From the test results, I do not reject the null hypothesis of unit roots in levels, but not in first differences. Consequently, the three series considered in the estimation – real GDP and human and physical capital – are I(1).

Bucacos (1999) argues that due to the existence of stochastic trends in the factor and output series, the analysis should incorporate co-integration techniques. The economic interpretation of a co-integrating vector is that if the series are linked in an equilibrium relationship in the long run, then they should move together and so their difference should be stable, i.e. stationary, despite the fact that the series are in themselves non-stationary. Applying Johansen and Joselius' (1994) co-integrating methodology, the existence of a long-run relationship between real GDP and the human and physical capital stock was verified. Furthermore, since the series show a high degree of crossed correlation and seem to be synchronised, a co-integrated relation without lags was considered.

Table 9: Correlation coefficients

	Real GDP	**Physical capital**	**Human capital**
Real GDP[41]	1.000	0.781	0.867
Physical capital	0.781	1.000	0.917
Human capital	0.867	0.917	1.000

The specification considered evidences that the long-run elasticity of physical capital is lower than the one found for human capital.[42] The estimated coefficients are 0.37 and 0.63, respectively, which are in line with the range

[40] $Y_t = \mu + \beta t + \theta DU_t + \gamma DT_t + \delta DTB_t + \sum \alpha_i \, \Delta y_{t-i} \, \varepsilon_t$, where DU denotes shifts, DTB outliers and DT changes in the trend.
[41] The variables were expressed in log form and the real GDP was seasonally adjusted.
[42] A Wald test was performed to check the constant returns to scale assumption.

commonly accepted in empirical works. Collins and Bosworth (1996) states that: "a plausible range for the physical capital share is between 0.3 and 0.4". With regard to the Uruguay economy, Bucacos (2001) finds an α of 0.3 and a β of 0.6. Analogously, the results provided by De Brun (2004) are 0.28 and 0.72, while Carbajal, Lanilotta, Llambi and Velazquez (2007) find values of 0.31 and 0.69.

The core results curve is as follows:

Table 10: Potential output: Production function approach

Dependent variable: real GDP

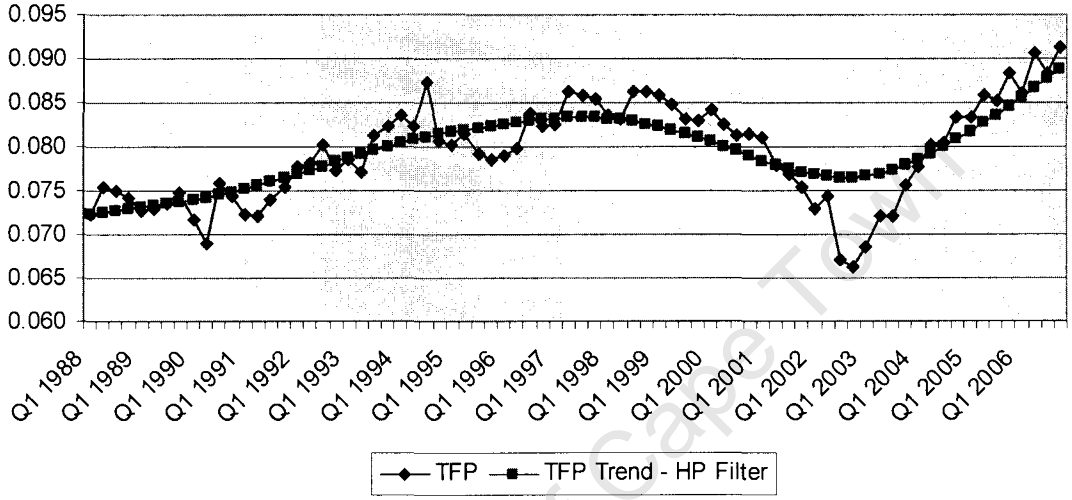
Sample: 1988Q1–2007Q4

Independent variables	**Coefficients**	**t-Statistic**	**Prob**
Human capital	0.678607	4.836565	0.00000
Physical capital	0.321393	n/a	n/a
D91 Q1	0.030187	3.319605	0.00140
D02 Q4	-0.084012	-6.536289	0.00000
T93 Q1	0.002664	5.854967	0.00000
T99 Q1	-0.005996	-9.344063	0.00000
Adjusted R-squared	0.8983	S.E. of regres	0.0185
Akaike info criterion	-5.0699	S.S. Resid	0.0239
Schwarz criterion	-4.8859	F-stat	123.723
Durbin-Watson stat	1.6438	Prob(F-stat)	123.723

Notes: (1) The series are expressed in logs and the real GDP was seasonally adjusted. (2) The variables Di are dummy vs reflecting a break in the level of the Series; i.e, D91Q1 is a break in the level of the output in the first quarter of 1991 (3) Analogously, Ti correspond to trend breaks, i.e. T93Q1 reflects a brak in the trend for the first quarter of 1993 (4) Based on Wald test, the assumption of constant returns to scale was imposed: coef (HK) = 1 – coef(PK)

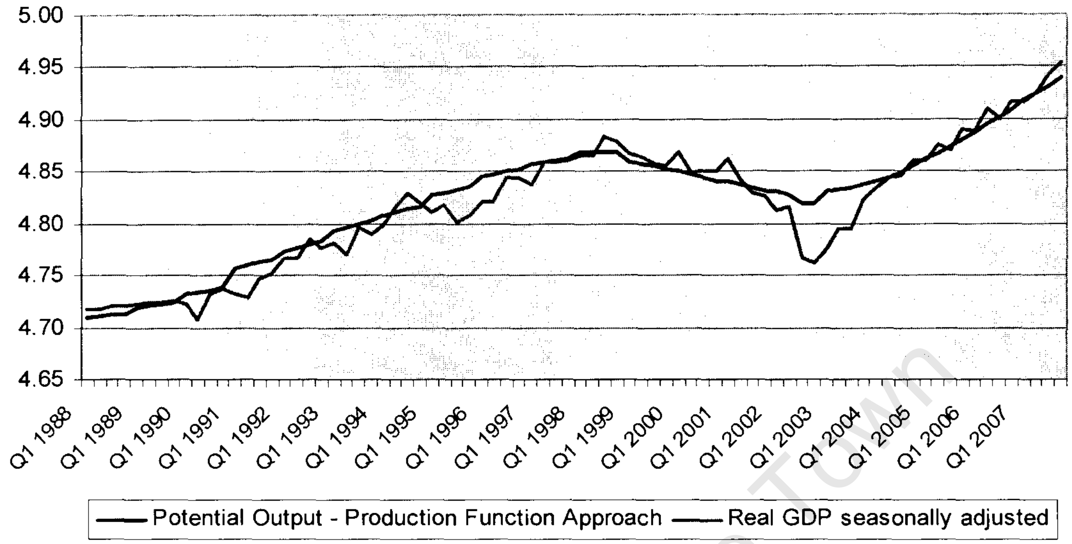
Having estimated the shares of labour and capital income, TFP is calculated as a residual and the log trend TFP is obtained by appropriately smoothing the series using an HP filter.

Figure 5: Total factor productivity, 1988–2007



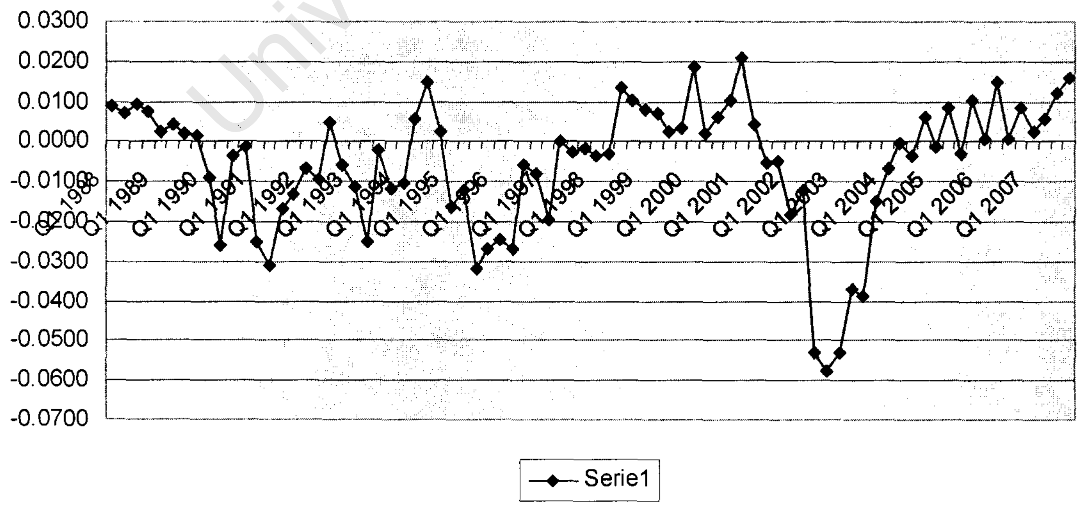
Once capital, labour, TFP and the factors shares are calculated, potential output is estimated by subtracting trend variables in the production function along with actual capital – equation (10).

Figure 6: Potential output under the production function approach, 1988–2007



Defining the output gap as the difference between real GDP and potential output, Figure 7 shows its evolution throughout the sample analysed. As previously mentioned, a negative gap implies that the economy is growing below its possibilities, while a positive gap is synonymous of inflationary pressures.

Figure 7: Output gap under the production function approach, 1988–2007



The estimated output gap shows an irregular behaviour, with successive peaks and lows. However, it can be concluded that for most of the period considered, the Uruguayan economy has been growing below its potential path. From the beginning of the sample until the early 1990s, real GDP closely follows the long-run output, while from the mid-1990s the divergence between the two series becomes evident, reaching a trough in which output was nearly 3% below potential. The subsequent growth quickly lifted output above potential in the second half of 1998, reaching a surplus of 2% in the first quarter of 2001 and averaging 1% above potential form 1998Q3 to 2001Q2. Due to the combined effects of the Brazilian and Argentinean recessions, a strong slow-down phase followed. The negative gap widens in 2001 and its greatest extent – 15% – is reached in the last quarter of 2002, when the economy was going through one of the worst recessions of the country's history. Nevertheless, due to the significant and quick economic recovery of the last three years, the economy has been facing inflationary threats for over seven quarters. More precisely, at the end of the sample, real GDP seems to exceed the potential output in by 3,7%, and if the predicted growth for 2008 is considered, this figure increases to 5%.

The presence of structural breaks – 1993 and 1999 – explains the existence of three different cycles: the first two had a duration of five and six years, respectively, while the third has been extended to eight years, and it is yet not clear whether it has come to an end or not.

The long-run growth trend for the entire sample was estimated at 2,4% annual average. In the mid-run, due to the presence of breaks, different rates were achieved: 3,9% (1988Q2–1993Q1), 2,6% (1993Q2–1999Q1) and 2,1% (1999Q2–2007Q4).

IV. The SVAR methodology and the applied model

The second measurement of potential output is obtained using a structural VAR approach based on simple theoretical aggregated supply–demand models and the assumption that nominal shocks are neutral in the long run. The idea is to estimate such a model in a VAR form, using economically founded restrictions to identify the shocks of the system, and to decompose the output series into its permanent and transitory components. Once these figures are obtained, the shocks can be applied to construct the series of the potential output and output gap.

Structural VARs (SVARs) are an extension of the traditional VAR methodology, with the only difference being that SVARs identify a set of independent disturbances by means of restrictions provided by economic theory rather than atheorical restrictions.

The VAR approach was proposed by Sims (1980) and became a significant tool in empirical analysis. Its popularity arose from the debate among economists throughout the 1970s concerning the true underlying structure of the economy and from Luca's critique, which stated that changes in policy altered the structure of econometric models.

Sims's VAR approach has the desirable property that all variables are treated symmetrically and, as a result, it is capable of dealing with the fact that econometricians tend to impose "incredible identification restrictions" in order to derive parsimonious structures. Sims's critique stated that the researcher not only chooses which variables are to be included as determinants in each equation, but also decides whether the variable should be treated as exogenous or endogenous. The VAR approach, however, attempts to allow the data determine its true structure by making all variables endogenous.

The problem is that because the coefficients in the system are unknown and the variables have contemporaneous effects on each other, the structural model is underidentified, and thus there is no way of uniquely estimating the parameters. It is possible to transform the structural system into a reduced-form representation where the variables are expressed as functions of their lags and, as a result, the standard VAR representation can be estimated applying ordinary least squares. Consequently, the reduced-form disturbances of the reduced-form VAR can be used to recover the structural shocks. Yet, the recovery requires the identification of the elements in the matrix of contemporary coefficients that link structural shocks with the estimated reduced-form errors. It is in the imposition of a structure to the system where the traditional and the structural VARs differ. While the traditional VAR proposes the Choleski decomposition, the SVAR derives the identification restrictions from economic theory.

Using the Choleski decomposition, the residuals are separated into orthogonal shocks by imposing restrictions based on the ordering of the variables; i.e. the first variable responds only to its own shock, the second variable to the first and second variables's exogenous shock, and so on. The resulting structure is a lower triangular matrix where all the elements above the diagonal are set equal to zero. Despite the Choleski decomposition provides the $(n^2 - n)/n$ restrictions required for the exact identification of the system, there can be n! possible orderings, and so the VAR results are sensitive to the imposed ordering when the reduced-form errors are highly correlated.

Cooley and LeRoy (1985) criticise the VAR approach, saying that "it implies a particular type of recursive contemporaneous structure for the economy which is not consistent with economic theory". This kind of critique led to the development of the SVAR method. Sim (1986), Bernanke (1986) and Blanchard and Watson (1986) use economic theory to impose short-run restrictions – in the sense that shocks are considered to have transitory effects – to recover the structural residuals. Alternatively, given that long-run restrictions tend to be more consistent with macroeconomic theory and less questioned, Shapiro and Watson (1988) and Blanchard and Quah (1989) consider the shock as having permanent effects on certain variables of the system. Previously, based on a VAR for output and unemployment, Blanchard and Quah (1989) identify structural supply and demand disturbances by assuming the former to have permanent effects on output, while the latter has only transitory effects. As Cerra and Saxena (2000) point out, the analysis can be extended to include temporary nominal shocks by including a price variable that is affected by nominal shocks both in the long run and the short run.

The approach considered in the dissertation follows Shapiro and Watson (1988) and Blanchard and Quah (1989), with the exception that inflation is considered instead of the unemployment rate variable. This is mainly for two reasons: (a) the relationship between Uruguayan output and unemployment may have been disrupted as a consequence of ongoing emigration, and (b) the consistency of the data through the studied period is questionable.

The estimation relies on the long-run restrictions on the GDP series: aggregate supply shocks are assumed to have permanent effects on the level of output, while aggregate demand shocks and temporary aggregate supply shocks have only transitory effects. The interpretation given to the fluctuations – permanent effects as supply shocks and transitory effects as demand shocks – is motivated by the traditional Keynesian perspective of economic cycles. The presence of nominal rigidities explains why demand shocks have an impact over output only in the short run, fading away as the rigidities gradually disappear. The identification process is illustrated below.[43]

[43] The theoretical explanation is based on Enders (2004), Misas and Lopez (1998) and St Amant and Norden (1997).

The structural model is expressed in an infinite moving average form, where the variables considered in the vector X_t – in our case real GDP growth and annual inflation – are expressed as a linear combination of current and past structural shocks (e_t):

$$X_t = S_0e_t + S_1e_{t-1} + \ldots = \sum_{i=0}^{\infty} S_i e_{t-i} \qquad (16)$$

where S(L) = $\sum_{i=0}^{\infty} S_i L^i$ is a matrix of polynomials in the lag operator and e_t a vector of structural shocks. In the analysed bivariate system, equation (1) can be specified as:

$$\begin{aligned} \Delta y_t &= \sum_{k=o}^{\infty} S_{12}(k)e_{1t-k} + \sum_{k=0}^{\infty} S_{12}(k)e_{2t-k} \\ \Delta\Pi_t &= \sum_{k=o}^{\infty} S_{21}(k)e_{1t-k} + \sum_{k=0}^{\infty} S_{22}(k)e_{2t-k} \end{aligned} \qquad (17)$$

The shocks e_{1t} and e_{2t} are assumed to be independent and white noises, which leads to a covariance–variance matrix that is normalised to the identity matrix:

$$\Omega = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

i.e. it is assumed that $E[e_t] = 0$ and $E[e_t\, e_t'] = In$, with n being the number of variables included in the VAR.[44]

Since the structural shocks are not observed, an appropriate[45] autoregressive reduced-form VAR is first estimated in its unrestricted form so as to recover the structural model:

[44] Cerra and Saxena (2000) question Clarida and Gali's assumption of pure uncorrelated supply, demand and nominal shocks by saying that technological progress identified as a supply shock may simultaneously increase demand owing to an increase in wealth or that an increase in government productive spending associated with demand shocks could also have long-run supply-side effects.

$$X_t = \theta(L)X_{t-1} + \varepsilon_t \quad (18)$$

with ε_t being the vector of estimated residuals.

Since all the equations in the system share the same matrix of regressors, the reduced-form model's estimation amounts to applying ordinary least squares separately to each equation after including the optimal number of lags and eliminating the serial correlation in the residuals.

Given that X_t is stationary, the reduced-form model can be inverted using the Wold decomposition, resulting in a reduced-form moving average process:

$$X_t = C(L)\varepsilon_t \quad (19)$$

where $C(L) = (I - \theta(L)L)^{-1}$.

The variance-covariance matrix for the vector of the reduced-form innovations, ε_t, is $E[\varepsilon_t, \varepsilon_t'] = \Omega$. From the previous equations, it follows that the structural innovations are a linear transformation of the reduced-form innovation:

$$\varepsilon_t = S(0)e_t \quad (20)$$

and that:

$$S(0)E[e_te_t']S(0)' = \Omega \quad (21)$$

$$C(L) = S(L)S(0)^{-1} \quad (22)$$

The long-run covariance matrix of the reduced form is given by:

---

[45] Residuals are multivariate white noise.

$$C(1)\,\Omega C(1)' = S(1)S(1)' \qquad (23)$$

This relationship suggests that the matrix S(0) can be identified with an appropriate number of restrictions on the long-run covariance matrix of the structural form. The equations above identify $n(n + 1)/2 = 3$ elements of the matrix, hence the remaining $n(n - 1)/2 = 1$ need to be identified.[46] Following Misas and Lopez (1998) and based on Blanchard and Quah's approach, the remaining restriction is provided by assuming that aggregate demand or nominal shocks have permanent effects only on the price level. Such an assumption implies that demand shocks have only temporary effects on output and that the accumulated effects of such demand shocks on output is zero.

Notice that the advantage of using Blanchard and Quah's approach is that instead of imposing contemporaneous restrictions, it allows the data to determine the short-run dynamics based on a particular long-run model. In particular, the potential output is not restricted to following a random walk. The relevance of this derives from the difficulty in reconciling the assumption of potential output being a random walk with the idea that the permanent component of GDP is partly driven by technological shocks.

In the model considered for estimation purposes, the three equations with the four unknowns are:

$$Var(e_{1t}) = S_{11}^2(0) + S_{12}^2(0) \qquad (24)$$

$$Var(e_{2t}) = S_{21}^2(0) + S_{22}^2(0) \qquad (25)$$

[46] Assuming a lower triangular matrix is the common procedure in empirical analysis. However, the matrix can be assume to have a different representation, given the variables of the model, provided that the hypothesis of demand shocks having no permanent effect on output holds. For an application of a different matrix, see Keating (1992).

$$Cov(e_{1t}, e_{2t}) = S_{11}(0)^*S_{21}(0) + S_{12}(0)^*S_{22}(0) \qquad (26)$$

The additional restriction required for the full identification of the system is given by the assumption made previously:

$$\left[1 - \sum_{k=0}^{p} \theta(k)\right] S11(0) + \sum_{k=0}^{p} \theta(k) S21(0) = 0 \qquad (27)$$

Letting the first element of the vector X_t be the growth rate of the real output in logs, -Δy_t-, we can then say that real output is equal to:

$$\Delta y_t = \mu_t + S^p{}_1(L)e^p{}_t + S^c{}_1(L)e^c{}_t \qquad (28)$$

where $e^p{}_t$ is the vector of permanent shocks affecting output, $e^c{}_t$ is the vector of shocks with transitory effects on output, μ_t the deterministic trend in output and $\{S^p{}_1(L), S^c{}_1(L)\}$ the parameters that reflect the dynamics of these shocks.

Since potential output corresponds to the permanent component of output in the system, the change in potential output growth can be estimated using the vector of supply shocks:

$$\Delta y_t^* = \mu_t + S^p{}_1(L)e^p{}_t \qquad (29)$$ [47]

This is the level to which output reverts when demand shocks and temporary supply shocks die out. Consequently, the output gap is defined as the part of output purely explained by transitory shocks.

[47] With μ_t being the linear trend in the actual output series.

IV.1. Data and previous considerations

The estimation was done using the 1988Q4–2007Q4 sample, and the data was taken from international financal statistics of the IMF and the Central Bank of Uruguay.

A bivariate SVAR that exploits the relationship between output growth and inflation is applied.[48] The aim when selecting the variables in the model is to include as much information as possible when identifying the structural components of interest. However, introducing several variables besides real GDP leads to a rapid loss of degrees of freedom, given the large number of parameters to be estimated. Furthermore, this restriction becomes crucial when the sample is small: the larger the number of variables, the more likely one is to select insufficient lags, leading to systematic errors in the estimation of the structural components (DeSerres, Guay and St-Atmant, 1995).

Output is measured by real GDP and presented in a logarithmic scale based on the Ermini-Hendry test and the Schwarz-Bayesian criterion. The annually quarter inflation rate was calculated based on CPI quarterly data.

Unit root tests were applied to the data so as to determine the order of integration of the variables included in the model.[49] A series is said to be integrated of order d, denoted I(d) if the series becomes stationary after differenced d times. The augmented Dickey-Fuller and the Phillips and Perron Z_α tests were performed. The tests fail to reject the null hypothesis of unit root in levels of both output and inflation, but do reject the null hypothesis that a unit roots exists in their growth rates. Thus, both tests confirm the widely accepted view of GDP and changes in prices being difference-stationary processes at conventional levels of

[48] A similar methodology is used by Scacciavillani and Swagel (1999) and by the Central Bank of England for estimating potential output.
[49] This will determine whether a reduced-form representation in levels or in first differences is required.

significance.[50] St Amant and Norden (1997) note that inflation is better characterised as being I(1), since assuming inflation to be stationary would imply that it has to return to a constant mean, whatever the actions of the monetary authorities. On the contrary, if inflation is stationary in first differences, changes in prices are allow to vary with factors such as the monetary authorities' preferences, the political environment, and the costs and benefits of targeting a certain inflation rate.

The presence of unit roots in the explanatory variable can generate spurious regressions if a VAR is estimated in levels; thus, the variables included should be the first difference of real GDP and inflation to ensure the stationarity of the system. Nevertheless, stability is confirmed given that all the eigen values lie inside the unit circle.

When referring to the disadvantages of the SVAR methodology, I mentioned the risk of obtaining a potential GDP series that closely resembles the actual series if the correlation between GDP and the other variables considered is weak. Yet, in this case the correlation coefficient shows a negative correlation between the variables of 45%.

Including a sufficient number of lags to avoid serial correlation in the residuals is crucial, as using a lag structure that is too parsimonious can significantly bias the estimation of the structural components (Clauss, 1999). The optimal lag length was chosen based on the Akaike (AIC), the Shwarz (SIC) and the Hannan-Quinn (HQ) information criteria. The information criteria do not coincide in the required lags to avoid systematical errors. As a result, the number of lags considered – four – was chosen so that the estimated residuals verified the multivariate white noise and normality tests, as well as the lag exclusion test.

[50] Notice that the decomposition of the logged GDP and the consequent potential output estimation cannot be carried out if the series was stationary.

Table 11: Selection order criteria

Selection order criteria

Sample: 1990q3 2007q4 Number of obs = 66

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	347.196				9.8e-08	-10.4605	-10.4343	-10.3941
1	396.685	98.979	4	0.000	2.5e-08	-11.8389	-11.7603	-11.6399
2	400.297	7.2234	4	0.125	2.5e-08	-11.8272	-11.6961	-11.495*
3	408.427	16.259	4	0.003	2.2e-08	-11.9523	-11.7688	-11.4878
4	413.205	9.5562*	4	0.049	2.2e-08*	-11.9759*	-11.7399*	-11.3787

Endogenous: lrealgdp_growth deltainflation

Exogenous: cons

Having determined the optimal lag length and imposed the identification restrictions on the long-run multipliers for structural shocks, the SVAR model is estimated.[51] Notice that this is possible because each shock is assumed to have a permanent effect on at least one of the variables and there is no co-integration for the variables in the X_t vector (Keating, 1992).

To investigate the plausibility of the identification scheme regarding the proposed model for Uruguayan data, the impulse response function and the variance decomposition analysis were considered.

For a coherent measurement of the potential output to result from the SVAR, the empirical founding should be such that a positive supply shock leads to a permanent increase in the level of GDP – i.e. a smaller output gap and a fall in prices – while a positive demand shock leads to higher prices and a higher level

[51] To identify the structural disturbances driving the system, a long-run neutrality restriction is imposed; i.e. it is assumed that the impact of changes in the inflation rate on changes in real output is zero in the long run.

of output that dissipates in approximately three years.[52] Thus, the asymptotic properties of the impulse response functions are consistent with the intuition suggested by economic theory and provide evidence that the shocks affect the variables as theory predicts.

[52] Recall that the estimation is constrained so that there is no permanent effect of demand on output.

Figure 8: Impulse response functions under SVAR estimation

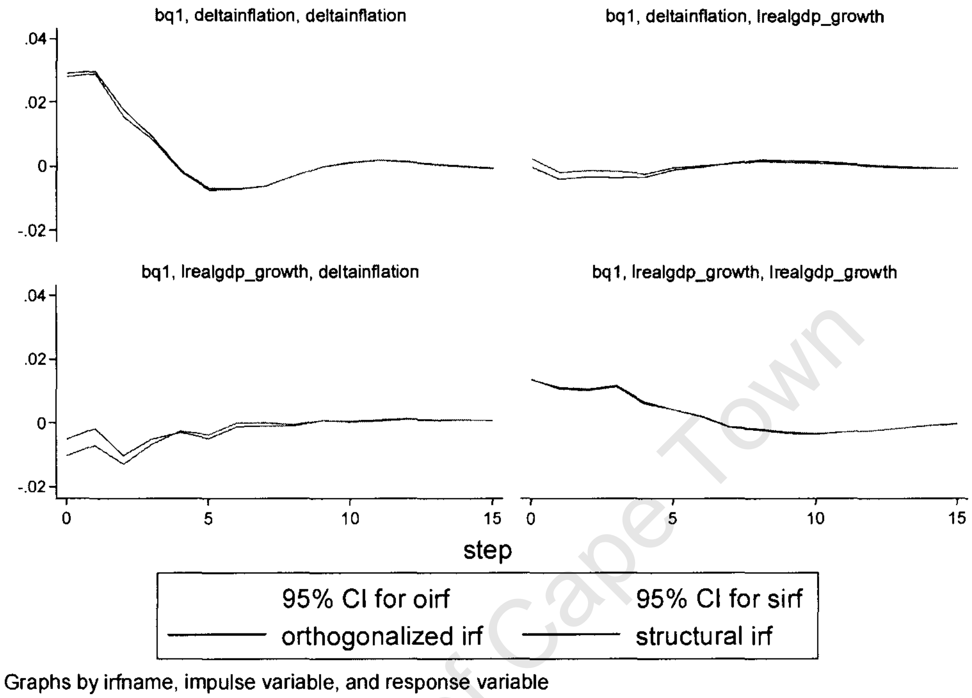
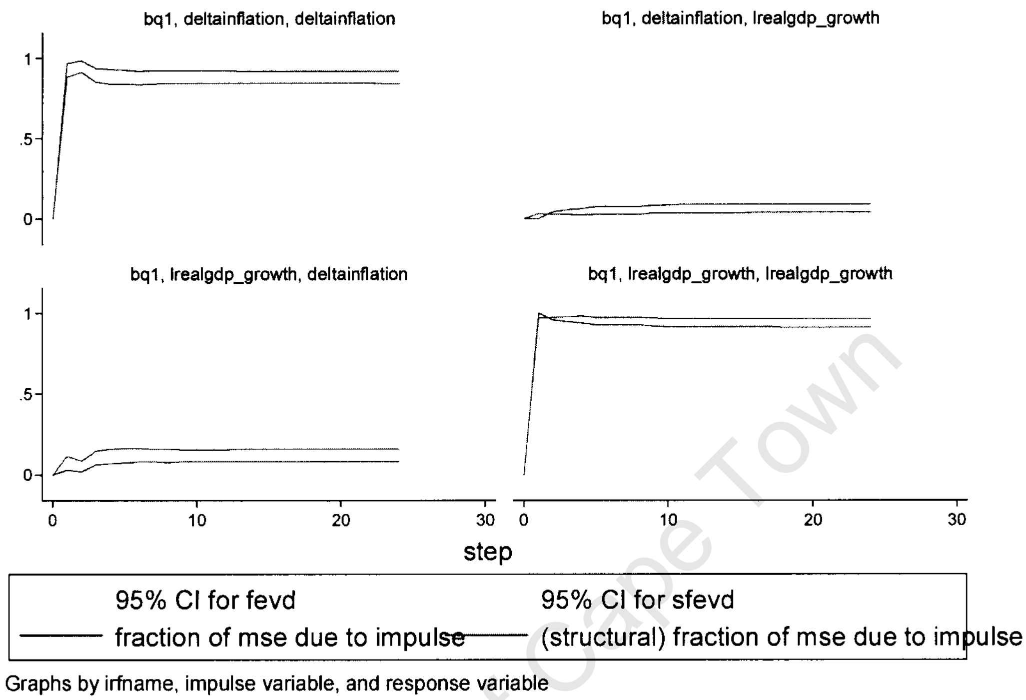


Figure 9: Variance decomposition



The variance decomposition presented in Figure 9 indicates the relative importance of the different shocks when considering alternative time horizons. Because of the restriction that demand shocks have no permanent effect on output, the proportion of output variance explained by aggregate demand shocks is significantly less than the variance explained by supply shocks; the opposite is true for the nominal side of the economy.[53]

IV.2. *Estimation of potential output using the SVAR*

Within the baseline bivariate SVAR model, the development of real GDP growth can be decomposed into the following components: (a) the deterministic trend, (b) supply shocks, and (c) demand or nominal shocks.

[53] The shocks were assumed to be uncorrelated, so the proportion of output variance caused by the sum of both shocks is always equal to 100% (Enders, 2004).

As derived from the theoretical framework, the potential output series is given by the deterministic component of the model and the impact of supply shocks. Thus, the potential output growth can be estimated as:

$$\Delta y_t^* = \mu_t + S^p{}_1(L)e^p{}_t \quad (30)$$

where $e^p{}_t$ is the vector of permanent shocks affecting output, $S^p{}_1(L)$ the parameters that reflect the dynamics of such shocks and μ_t the deterministic trend of actual GDP.

In order to determine $\mu_{t,}$ the following regression was run, and four structural breaks were found.

Table 12: Deterministic trend of real GDP

Dependent variable: LRGDP
Sample: 1988Q1–2007Q4

Variable	Coefficient	Std. error	t-Statistic	Prob.
Trend	0.003073	0.000148	20.70059	0.0000
T91Q1	0.001199	0.000206	5.821765	0.0000
T99Q1	-0.00144	0.000568	-2.536337	0.0134
T03Q1	0.004082	0.000856	4.77001	0.0000
D02Q1	-0.085032	0.006818	-12.47117	0.0000
C	4.703612	0.003885	1210.742	0.0000
R-squared	0.943351	Mean dependent var		4.8114
Adjusted R-squared	0.939305	S.D. dependent var		0.0560
S.E. of regression	0.013786	Akaike info criterion		-5.6546
Sum squared resid	0.013304	Schwarz criterion		-5.4706
Log likelihood	220.876	F-statistic		233.1366
Durbin-Watson stat	1.223826	Prob(F-statistic)		0.0000

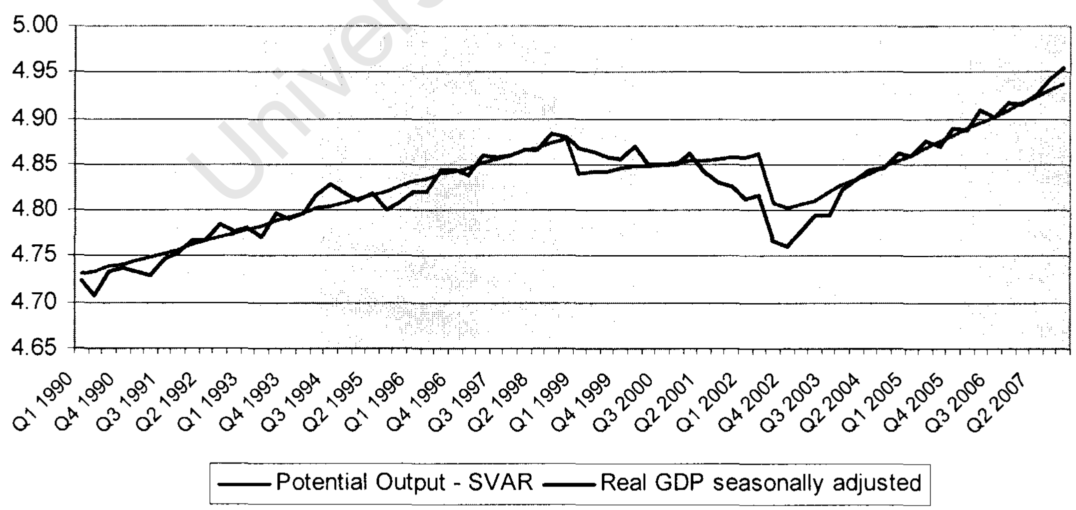
As before, the results suggest the presence of three breaks in the trend: one in 1991Q1, another in 1999Q1 and the third in 2003Q1. With respect to level breaks, only the break in 2002Q1 seems to be significant.

Given the estimated trend and corresponding breaks, the potential output series for the Uruguayan economy can be constructed by adding the structural shocks derived from the SVAR estimation.

Within this framework, the output gap is given by the fraction of GDP movements explained by nominal shocks. Its estimation can be done either directly through the estimated shocks with a temporary effect on output or simply by the difference between actual GDP and potential output, both expressed in logarithmic form.

Figure 10 plots actual output and the estimate of potential output from the SVAR estimation, and Figure 11 presents the corresponding output gap.

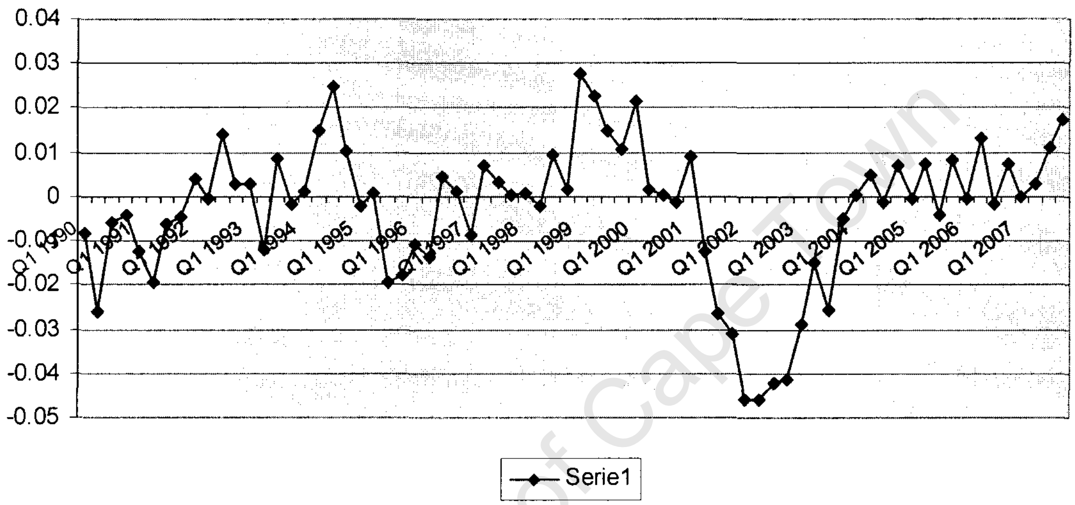
Figure 10: Potential output, SVAR estimation, 1990–2007



The estimated potential output – which in the VAR model is associated with productivity shocks – shows a productivity growth during the early and mid-

1990s. This is followed by a subsequent levelling off until 2002, when the potential output started decreasing, due to the recession that struck the economy. Finally, from 2004 onwards the graph suggests a gradual productivity recovery.

Figure 11: Output gap, SVAR estimation, 1990–2007



The output gap graph shows a similar behaviour to the gap resulting from the production function estimation. For most of the period considered, Uruguayan real GDP has been either below its potential path or at its long-run output. As before, the negative gap widens in 2001, but in this case, the minimum is reached in the second quarter of 2002 instead of the last quarter and is not as pronunciated. Nevertheless, a break in the potential growth of the economy is also observed. The estimates of the SVAR model suggest that for the last three to four years the Uruguayan economy has been functioning mostly in excess of demand. The inability of productive capacity to meet demand has been leading to increasing inflationary pressures, but these are less pronounced than the pressures experienced in the early and late 1990s.

V. Comparison between the three alternative estimations

Together with the production function approach and the SVAR bivariate model, the potential output for the Uruguayan economy was also estimated using the HP filter. The results are presented in Figures 12 and 13.

Figure 12: Potential output, HP filter, 1988–2007

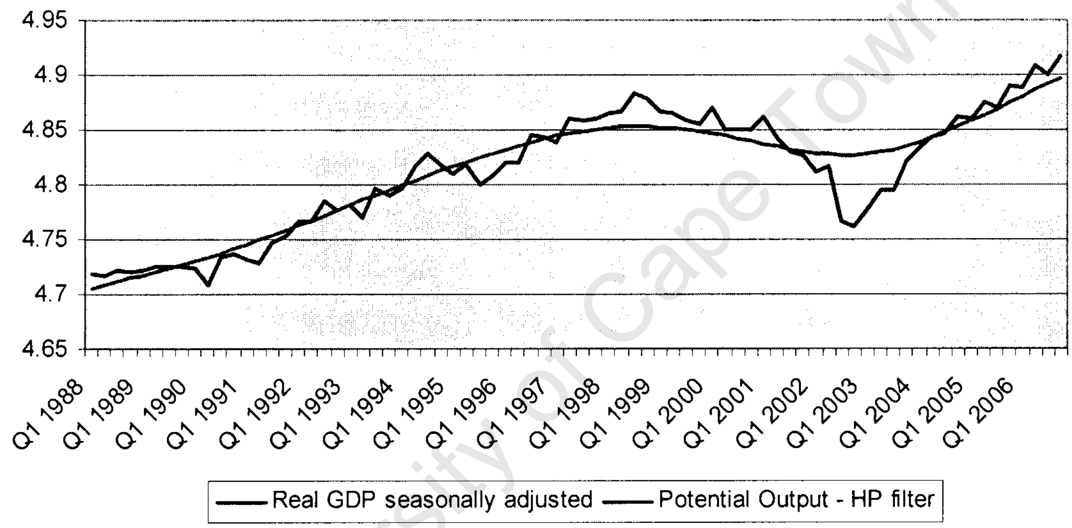
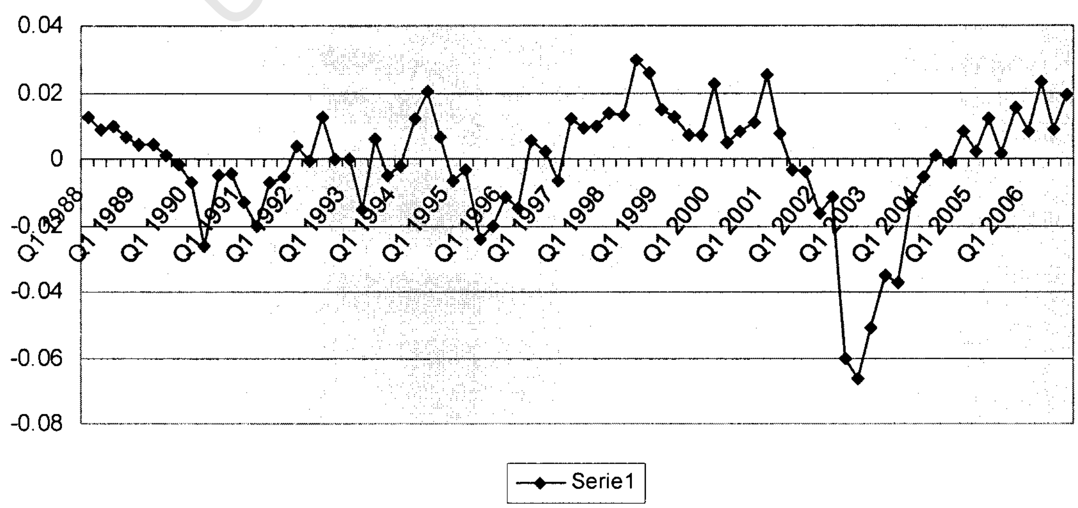
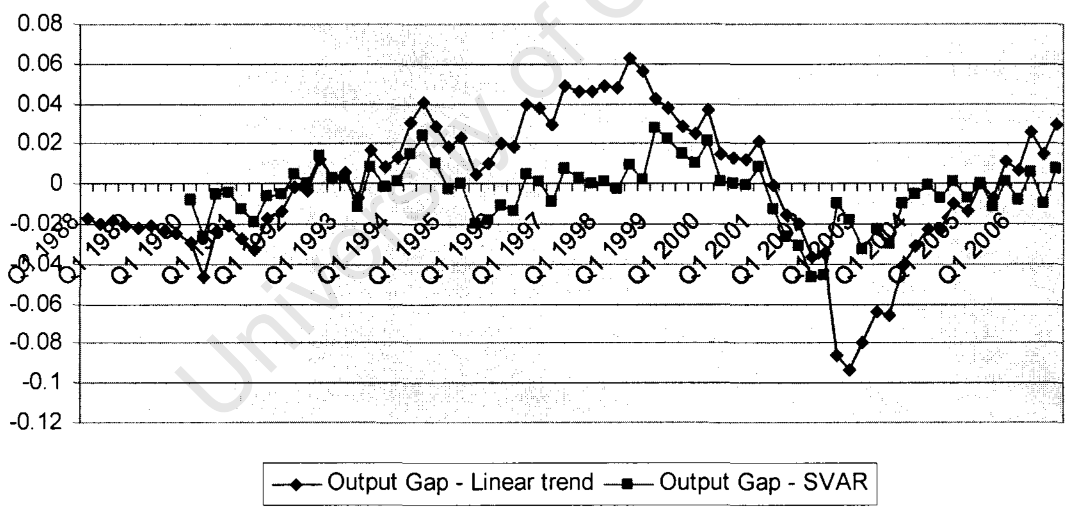


Figure 13: Output gap, HP filter, 1988–2007



According to Chagny and Dopke (2001), the most striking advantage of the SVAR methodology is that it provides a strong critique of univariate detrending methods. The distinction made between nominal shocks affecting the output gap and supply shocks impacting on the potential output clarifies why univariate methods may be misleading. As Chagny and Dopke mention, univariate filters will take any positive supply shock hitting an economy as an increase in the output gap rather than as a change in the potential output. However, this is not in line with economic reasoning since, by definition, supply shocks should not affect the output gap. Such an argument is illustrated in Figure 14, where the output gap calculated under a simple deterministic trend is compared with the SVAR gap obtained taking into account both supply and demand shocks.

Figure 14: Supply shocks and output gaps, 1988–2007



The deterministic trend interprets the increase in production at the beginning of the 1990s as a demand shock. Thus, it indicates serious inflationary pressures, while the SVAR approach gives supply shocks a much more significant role, resulting in a smoother output gap.

Furthermore, Baxter and King (1995) argue that univariate filters such as the HP filter become inaccurate at the beginning and end of the samples. For this reason, discarding three years of quarterly data at both ends of the sample is usually recommended. Obviously, this is a serious limitation to policymakers aiming to estimate the current level of output gap and detect inflationary threats.

In the case of Uruguay, the three alternative output gap estimations indicate a high correlation for the period under analysis.[54]

Table 13: Cross-correlations, sample 1990Q1–2007Q4

	HP filter	Production function	SVAR
HP filter	1.00	0.96	0.80
Production function	0.96	1.00	0.77
SVAR	0.80	0.77	1.00

Based on the descriptive statistics provided in Table 14, a comparison between the three different gaps can be drawn. Despite the small difference, the SVAR estimation shows the lowest standard deviation for Uruguayan output growth with respect to its long-run trend. Because it imposes a higher degree of smoothness on the potential output, the HP filter implies the largest gap of the statistical techniques for 2002Q4; i.e. the minimum value of the gap is achieved under the HP estimation, while the SVAR predicts the smallest decrease of actual GDP with respect to its potential level. Again, the maximum is reached with the HP filter, which confirms the belief that univariate filters take any positive supply shock hitting an economy as an increase in the output gap rather than as a change in potential output.

54 Note that the sample was restricted to 1990Q1–2007Q4 due to data availability for the SVAR estimation.

Table 14: Descriptive statistics: Output gap, sample 1990Q1–2007Q4

	HP filter	Production function	SVAR
Std. deviation	0.018665	0.017092	0.015976
Maximum	0.029614	0.020452	0.027545
Minimum	-0.066132	-0.05795	-0.046121

Table 15 summarises the results of the annual output gap from the HP filter, the production function and the SVAR, starting from 1991. Annual potential output is calculated as the sum of potential output in the four quarters of each year and the output gap as the deviation of annual output from the sum of the corresponding four quarters of real GDP. Given that several breaks were detected in the evolution of potential output, the growth rates are presented by sub-sample.

The three different approaches used to measure potential output in Uruguay vary somewhat from year to year, but yet the results remain consistent. They all capture similar increasing and decreasing paths, despite the fact that the estimated positive and negative rates under the HP filter are smoother than the ones estimated by the alternative methods.

Between 1991 and 1998 potential output grew at an average annual rate of 3,45–4%, depending on the method considered. After 1999 the three methodologies estimate a decline in the Uruguayan long-term path with an average negative annual growth rate of 2%. Due to the structural break in 2003, the downward-sloping path is reversed and growth rates of 4% and 5% evidence the economy's recovery of the last years. Finally, regardless of the inaccuracy that the estimations may face at the end of the sample, the three methodologies coincide in the fact that for the last quarters of 2007 real GDP is situated above the economy's potential output

Table 15: Estimates of potential output and the output gaps (growth rates of actual and potential output in %)

	Actual output	potential Output		
	Real GDP	HP filter	Production function	SVAR
1991–1998	4,39	3,43	3,95	3,95
1999–2002	-4,62	-1,48	-2,52	-2,02
2003–2007	7,01	4,68	4,93	4,65
		Output gap		
		HP filter	**Production function**	**SVAR**
1991–1998		0,96	0,44	0,44
1999–2002		-3,25	-2,16	-2,72
2003–2007		3,42	2,08	2,56

Note: A positive output gap indicates an output above potential and a negative gap an output below potential.

Deciding which of the measurements is the most appropriate for the Uruguayan economy requires making a judgement on the pace and importance of the structural changes that occurred both in the country and the region. Nonetheless, all the estimations – especially the production function and SVAR – indicate that the slowdown in output between 1999 and 2002 stems from slower growth of the potential output rather than from a cyclical retrenchment.

VI. Testing the gap model

In this last section the focus is on evaluating whether the three previously calculated output gaps are good indicators of inflationary pressures for the Uruguayan economy.

It is widely accepted that inflation is closely related to the pace of economic activity; nonetheless, further analysis is necessary in order to determine the actual link between these variables. Following Coe and McDermontt (1997) and Claus (2000), two simple versions of the "gap model" are estimated. Firstly, the change in inflation is related to the level of the output gap. Under this specification, inflation is expected to rise if the level of real GDP exceeds the productive capacity of the economy over time, i.e. if the output gap is positive for long periods. Logically, inflation will be expected to fall if the gap is negative and remains stable if the gap is zero. The second version of the model relates the change in inflation to the change in the output gap, implying that the level of inflation will tend to remain stable as long as the level of the gap remains unchanged. There are two reasons why the change in inflation is considered instead of the level: (a) I failed to reject the null hypothesis of unit root in the level and (b) it was convenient to remove the mean shifts in the inflation due to the presence of both high inflation and price stability regimes.

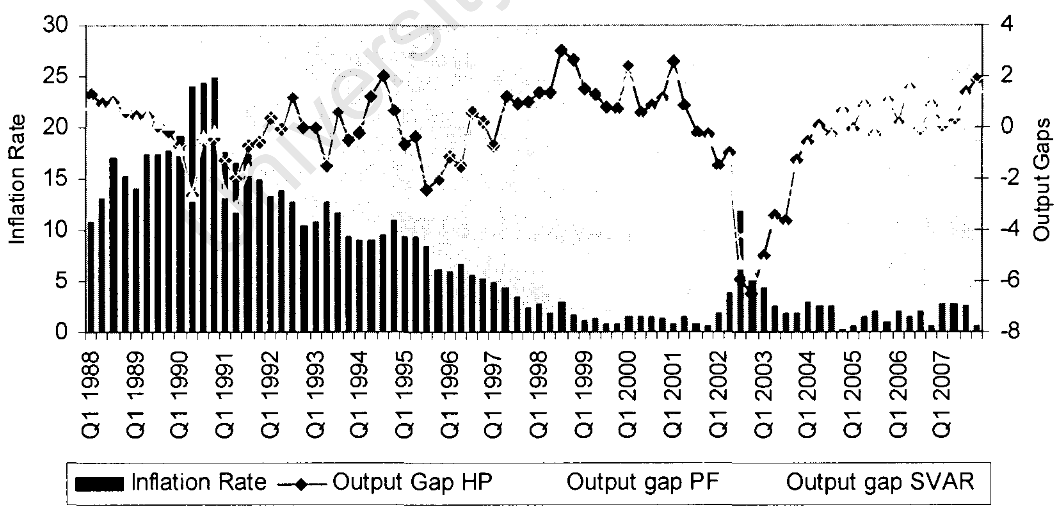
As Coe and McDermont (1997) argue, the gap model has proven to be a useful tool for policy analysis due to the impact of economic policies on the output gap; i.e. while structural policies will generally affect potential output, monetary and fiscal policies will affect actual GDP. Although inflation will depend on other factors such as changes in import prices, indirect taxation, inflation expectations, labour market policies and/or wage formation, output and the unemployment gap remain at the centre of almost all inflation models.[55]

[55] See, for example, Masson, Symansky and Meredith (1990).

There are many studies for industrialised countries that empirically support the gap model presented in this dissertation. However, for developing countries, the studies have been few. In the case of Uruguay, the fact that monetary policy is transitioning towards an inflation-targeting regime and that the Uruguayan economy has faced and is actually facing periods of hyper- and relatively high inflation is what justifies the question of whether the gap model is applicable or not.

The three different measures of output gap exhibit a trajectory inverse to that exhibited by the inflation rate. Thus, the results suggest a negative relationship between the variables in the stages of both growth and recession; particularly, in periods of high inflation, the output gap and prices have a symmetrically opposite behaviour. This is even more evident after the currency devaluation of 2002 when the significant negative output gap, explained by the magnitude of the recession, led to significant inflationary pressures.

Figure 15: Inflation rate and output gaps



PF = production function

The visual evidence of a relationship between inflation and the estimated output gaps can be assessed by testing the two simple versions mentioned previously.

The time series properties of the data are examined so as to determine the order of integration of the included variables.[56] The results from the tests suggest that the null hypothesis of a unit root in the level of output gap can be rejected for the three alternative measures and that annual inflation is a difference-stationary process at conventional levels of significance.

Following Coe and McDermott (1997) and Claus (2000), the first specification of the gap model is defined as:

$$\text{Model 1:} \quad \Delta\pi_t = \alpha_1 + \sum_{k=o}^{p} \beta_{1k} GAP_{t-k} + \varepsilon_{1t} \qquad (31)$$

where π_t is the annual logarithmic difference of the consumer price index, GAP_t the logarithmic difference between actual and potential output, ε_t the stochastic disturbance term and Δ the first difference operator. To avoid imposing the constraint that the non-inflationary level of the output gap is exactly zero, a constant, α_1, is included.

This simplified model is derived from an inflation-expectations-augmented Phillips curve with adaptive expectations:

$$\pi_t = \alpha_1 + \pi_{et} + \sum_{k=0}^{p} \beta_{1k} GAP_{t-k} + \varepsilon_{1t} \qquad (32)$$

where π_{et} is inflation expectation at time t and with $\pi_{et} = \pi_{t-1}$ due to the adaptive expectation assumption. Such an assumption allows us to focus on the role of

[56] The augmented Dickey-Fuller (1984) and the Phillips-Perron Z_α statistic tests were performed. The results can be found in Appendix I.

the output gap as a determinant of the change in inflation and interpret the gap coefficients as semi-elasticities.[57]

Note that under an inflation-targeting regime the main issue is not the level of inflation in itself, but whether the inflation rate is above or below its target. As Claus (2000) states, if the inflation regime is credible, the mean of the inflation rate will coincide with the target, the first difference will approximate deviations of inflation from the target, and thus inflation expectations will coincide with the targeted rate.

Model 2 relates the change in inflation to the change in the output gap, which makes it a special case of model 1. The change version of the gap model can be represented by the following equation:

$$\text{Model 2} \qquad \Delta\pi_t = \alpha_2 + \sum_{k=o}^{p} \beta_{2k} \Delta GAP_{t-k} + \varepsilon_{2t} \qquad (33)$$

The main difference between the models relies on the constraints imposed by the latter: (i) the coefficients of the level of the considered gaps should alternate in sign, and (ii) the pairs β_{10} and β_{11}, β_{12} and β_{13}, and so on should total zero.[58]

Using the Akaike (1973) and the Schwarz (1978) information criteria, the preferred lag length was determined. For both models and the three output gap measures, the optimal lag length was found to be 6, with the exception of model 2 under the SVAR, where the lags were set equal to 5. Thus, model 1 and model 2 were estimated with the corresponding number of lagged variables; an F-test, which tests the included lagged terms for significance at the 10% level, was also considered so as to confirm the lag-length selection.

[57] The β_{1k} coefficients can be interpreted as a percentage point change in inflation implied by a one percentage point output gap.
[58] Notice that model 1 also allows both the level and the change in output gap to affect inflation. In such a case, some of the β coefficients would be negative, though their sum would be positive.

To evaluate the models and determine whether the output gaps are a significant determinant of inflation or not, F-tests that the β_{ik} for i = 1,2 are jointly significantly different from zero were performed, as well as the following diagnostic tests on the regressions residuals: (i) a test for normality based on a Lagrange multiplier test for joint skewness and kurtosis proposed by Jarque and Bera (1980), (ii) the White test (1980) and the modified Breush and Pagan test (1979) for homoskedastic errors, and (iii) a Lagrange multiplier test for serial correlation.[59]

The F-tests indicate that both the level and the change of all three output gaps are a significant determinant of the change in inflation. More precisely, the level of the gap – model 1 – explains between 20–32% of the total variance in inflationary pressures over the sample period. From the results of model 2, it appears that including the first difference of the output gaps increases the percentage of the HP gap from 0,31 to 0,34, but it remains almost unchanged for the production function and SVAR gaps.

The levels of the alternative output gaps have a significant impact on the change in inflation: the sum of the β coefficients is positive – though close to zero – and they alternate in sign, although less than for the SVAR gap.[60] Overall, the results suggest that the three measures of the output gap appear to be good indicators of inflationary pressures when considered in terms of levels. Based on the results presented in Appendix III, the production function exhibits the lowest root mean square, followed by the SVAR gap; i.e. model 1's performance is best when the gap considered is estimated using the production function approach. This is also true when the change in output gap is introduced in the regression instead of the level. However, the estimation results with the constraint implied by model 2

[59] The LM test indicates that the null hypothesis of no serial correlation is rejected at conventional levels of significance for most of the equations. Claus (2000) also rejects the null hypothesis for all eight equations. The results are presented in Appendix II.

[60] The fact that the estimated coefficients are all positive suggests that the change in inflation is more related to the level than the change in the output gap. On the contrary, when the coefficients alternate in sign, but their sum is positive, it implies that both the level of and the change in the gaps may be relevant.

suggest that the change specification may work slightly better than model 1.[61] This is confirmed by the number of times that the output gap correctly predicts, in-sample, the direction of the inflationary pressures. The level of the output gap predicts whether inflation is accelerating or decelerating 71% of the time. On the other hand – except when using the HP filter, where the figure remains the same – the percentage increases to 76% when the change in inflation is considered. Despite the high percentage achieved, it should be taking into account that this test tend to be "naïve" in the sense that it does not distinguish whether the forecast was slightly wrong or completely misleading.

The residual diagnostic tests suggest that the gap model may be oversimplified if only the inflation and the estimated gaps are included, yet there is no evidence suggesting a significant specification error.[62] Based on the results summarised in Appendix II, the Jarque and Bera tests suggest that the residuals under the SVAR estimation are not normally distributed and the null hypotheses of homoskedastic errors are rejected for some of the equations.[63] This finding is consistent with Claus (2000).

Figure 16 plots the actual and in-sample predicted change in inflation given the three alternative estimations; i.e. the HP filter, the production function and the SVAR gaps. In line with Claus (2000), annual averages are plotted, despite the fact that the estimation was done using quarterly data. The reason is not only for ease of illustration, but also – as Claus argues – the persistence of the output gap makes the series in annual frequency a better indicator of inflationary pressures.[64]

[61] Such a conclusion is in line with Claus (2000) and Coe and McDermott (1997).
[62] The residuals form the equations are essentially white noises.
[63] Under the SVAR estimation, the recession of 2002 is considered an outlier. This is the reason why the null hypothesis of normal distribution is rejected; otherwise it would not be the case.
[64] Notice, however, that annual output gap calculated as the average of quarterly measures allows one to incorporate new information as soon as it is available and so tends to be more accurate.

Figure 16 (a) presents the results from model 1, where the contemporaneous and lagged gaps in levels were considered for the forecast. Figure 16 (b) plots the results from model 2, which uses the changes in the gap as explanatory variables.

Figure 16 (a): Gap model 1, 1991–2007

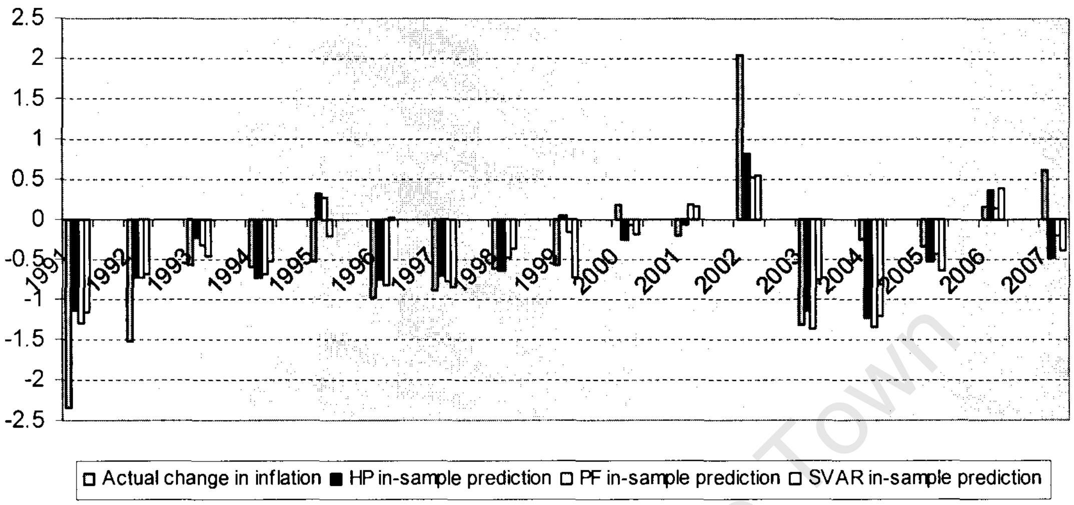
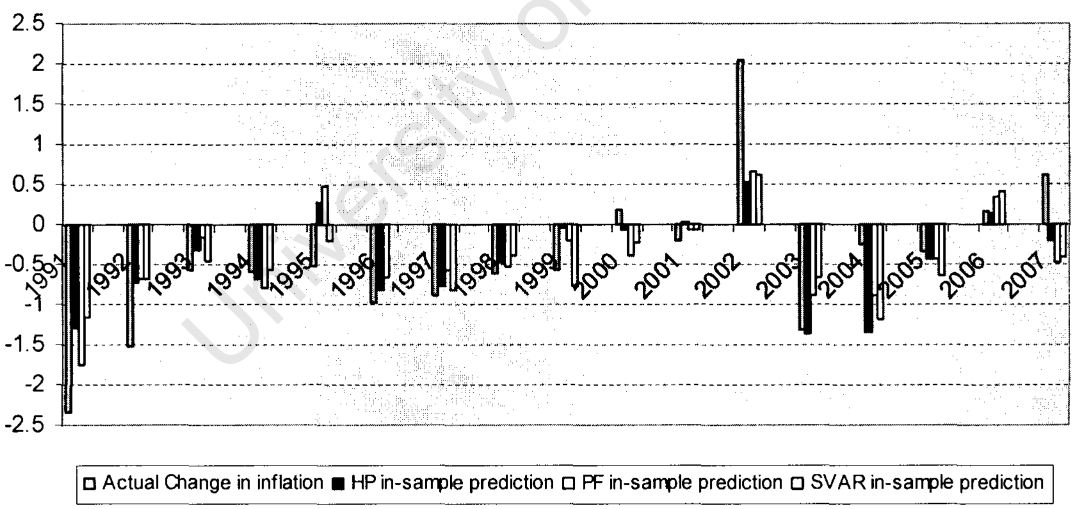


Figure 16 (b): Gap model 2, 1991–2007



Regardless of some exceptions, the plots indicate that the actual and predicted inflation tend to move in the same direction for all the alternative gap estimations. Thus, the findings confirm that the overall output gap constitutes a good indicator of inflationary pressures.

For 2000 and 2007, the three versions of model 1 failed to identify the increasing inflationary pressures; i.e. the model predicts a drop in inflation, while actual inflation increased. In 1995 the predicted and actual inflation go in opposite directions, except for the SVAR estimation; something similar occurs in 2001, but in this case both the production function and the SVAR estimates of the output gap are the exceptions.

Given that the residual tests suggest that the gap model may be oversimplified, two new specifications were analysed. Following Coe and McDermott (1996), the gap model is extended to allow money supply and the terms of trade to affect the change in inflation. While the direct link between terms of trade and inflation may be clearer, in most inflation models the money supply seems to have no direct impact on inflation. Nevertheless, given that the gap model includes the output gap, an indirect effect of money supply over inflation – through its impact on the inflation expectations – could be present. The effects of these new explanatory variables are analysed using two additional models.

The third model incorporates the real money gap; i.e.

$$\Delta\pi_t = \alpha_3 + \sum_{k=o}^{p} \beta_{3k} GAP_{t-k} + \sum_{k=0}^{p} \gamma_{3k} RMGAP_{t-i} + \varepsilon_{3t} \quad (34)$$

where the real money gap is measured as the log difference of the real money supply and the HP filtered series. For the lag length selection, the same procedures are applied, but with the only constraint that both the output and the real money gap should enter with the same number of lags.

Finally, model 3 is extended by including the percentage change in the terms of trade.[65] Thus, model 4 is given by equation (35):

$$\Delta \pi_t = \alpha_4 + \sum_{k=o}^{p} \beta_{4k} GAP_{t-k} + \sum_{k=0}^{p} \gamma_{4k} RMGAP_{t-i} + \sum_{k=0}^{p} \rho_{4k} TOT_{t-i} + \varepsilon_{4t} \quad (35)$$

Notice that by including a variable reflecting the quarterly growth rate of the terms of trade, we allow commodity shocks and exchange rate changes to have a direct effect on inflation.[66]

The results for models 3 and 4 are presented in Appendix IV. The new specifications explain more than one third of the variance of the change in inflation, and the residual diagnostic tests indicate that models 3 and 4 work slightly better than models 1 and 2. Furthermore, both models correctly predict the direction in the change of the inflation rate 82% of the time.

[65] The series is constructed as the ratio between the price indexes used by the central bank when deflating the exports and imports in the national accounts. Given that the deflating series of services is not available for the entire sample, the terms of trade series is restricted only to goods.

[66] Given the fact that Uruguay is a highly dollarised economy and that its exports are mainly commodities, model 4 can be expected to perform better in capturing the behaviour of the inflation rate. Furthermore, CINVE's analysis of the evolution of prices in Uruguay concluded that one of the main reasons for the increase was the international inflationary pressures related to commodity prices.

Figure 17 (a): Gap model 3, 1991–2007

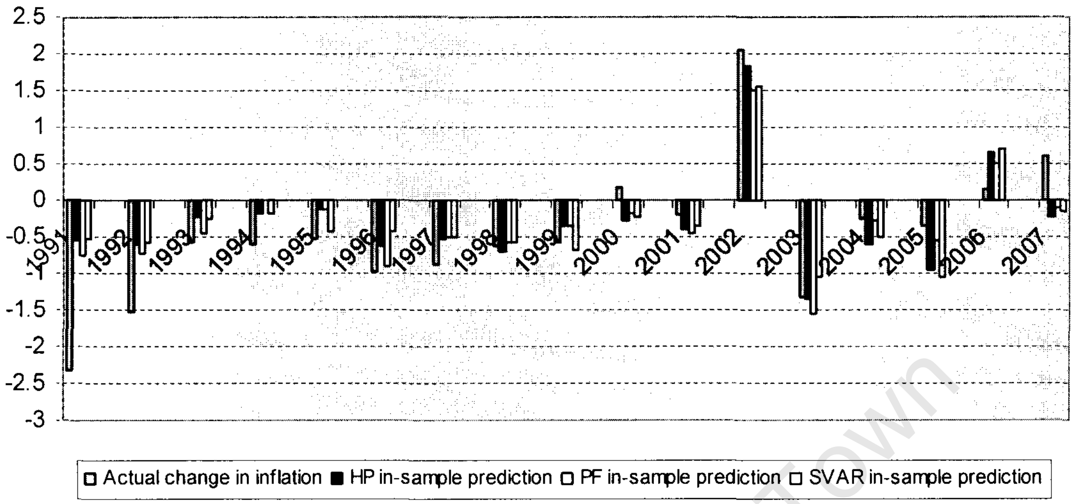
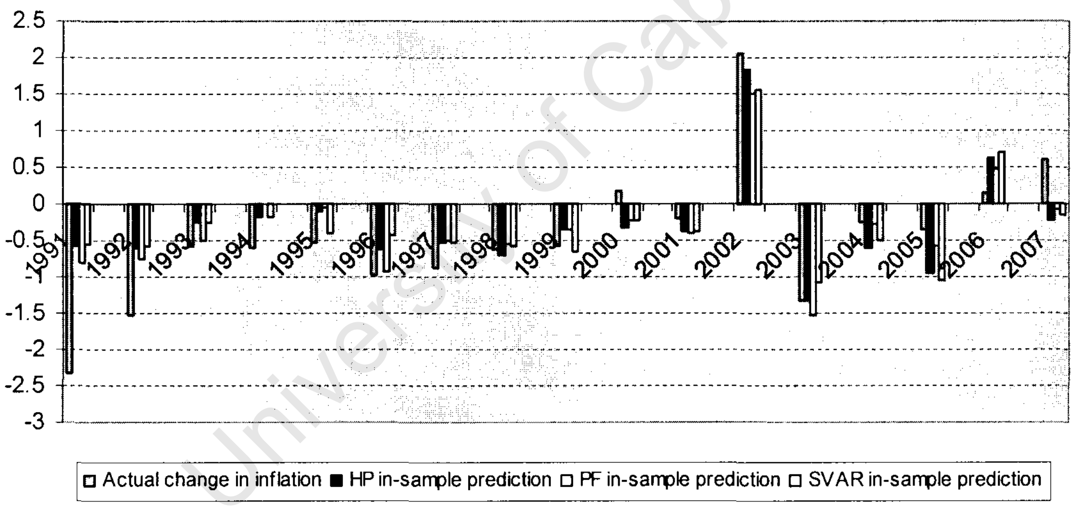


Figure 17 (b): Gap model 4, 1991–2007



Figures 17 (a) and (b) present the actual and predicted change in inflation under the new specifications. As before, although the estimated gap models do a rather good job of predicting inflation, it should be taken into account that other factors such as import prices, taxes and random shocks may be as important as the actual output gap. Naturally, the richer the model, the better its ability to predict will be[67].

As Claus et al. argue, the fact that the output gap seems to explain the inflation within sample does not necessarily mean that it will be a useful tool for real-time forecasting. In order to assess the prediction performance outside of the sample, a VAR model is estimated including both the change in inflation and the output gaps. Thus, the change in inflation will be allowed to depend on past realisations of the output gap as well as on its own past realizations; so will the output gaps.[68]

Following Claus et al. the reduced-form VAR is given by equation (34):

$$X_{it} = \phi(L)X_{it-1} + \varepsilon_{it} \quad (36)$$

where X_{it}, – a covariance stationary process – represents both models, i.e. X_{1t} = [$\Delta\pi_t$, output gap_t]' and X_{2t} = [$\Delta\pi_t$, Δoutput gap_t]', ε_{it} is a vector of random disturbances and $\Phi(L)$ is a polynomial lag operator.[69]

The VAR model is first examined by the in-sample results. The F-tests show that the coefficients on the output gap are jointly significantly different from zero, which confirms the previous conclusion of the output gap being a significant determinant of inflation. In line with Claus et al.'s findings, the R^2 for the inflation equation in the VAR – regardless of the gap considered – is higher than for the single equation estimation and the magnitude of the error is smaller. Hence, it suggests that the past changes in inflation are also an important determinant of current inflation. Despite the promising results, the diagnostic tests still detect

[67] A good alternative to be followed in the future is to incorporate a Bayesian Model Averaging (BMA) to identify the variables that contribute to the variation in inflation apart from the output gap.
[68] The money supply and the terms of trade were not considered in the out-of-sample forecast so as to avoid introducing noise in the estimation.
[69] The number of lags in this case was set equal to 5 for both models and for the three alternative output gap measures.

some mis-specification, even though the VAR estimation seems to work better.[70] Therefore, it should be taken into account that past inflation and the output gap alone may not completely explain the inflationary pressures in the Uruguayan economy.

Given that the variance decomposition of the change in inflation is defined as the percentage of the in-sample forecast error that is accounted for by the output gap at different horizons, it can be a significant source of information about the relative influence of the output gap. Thus, if a large fraction of the variance of the change in inflation is explained by the innovations in the output gap, it can be concluded that the output gap is an important factor when explaining inflationary pressures.

Table 16: Variance decomposition of the change in inflation (% of forecast variance explained by innovations in the output gap 20 quarters ahead)

Output gaps	Model 1	Model 2
HP filter	43	25
Production function	35	21
SVAR	18	15

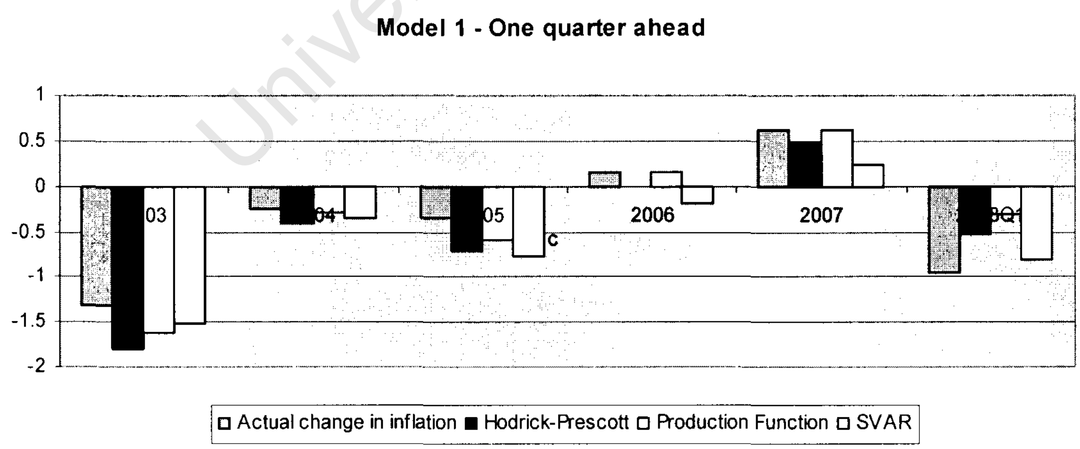
Table 16 show the variance decomposition as a percentage of the variance in the forecast error of the change in inflation that can be attributed to an innovation in the alternative measures of the output gap. The forecast horizon is set at 20 quarters and the results indicate that approximately between 15% and 40% of the variance in the change of inflation can be explained by the level of output gap. Notice that for all three gaps, the levels seem to explain a larger fraction of the forecast variance of the change in inflation rather than their first differences.[71]

[70] For example, the null hypothesis of no autocorrelation in the residuals is not rejected for most of the cases.
[71] The higher figure under the HP filter can be explained by the inherent volatility of the resulting output gap, given the way this filter is calculated.

To evaluate the usefulness of the gap model for forecasting in real time, a time varying coefficient approach is applied over a period of 13 years or 52 quarters. The forecasting performance of the model focuses on the last five years and the analysis is done for one and four quarters ahead. The technique implies a rolling sample where the forecasts are initially estimated for the period 1990Q1–2002Q4. The coefficients estimated for such a sub-sample are then used to forecast the change in inflation and the output gap one quarter ahead, which are used again to predict the following quarter and so on up to four quarters, if that is the case. Once the forecasts are obtained, the model is rolled forward one quarter, re-estimated, and the change in inflation and the output gap are forecast four quarters ahead following the same procedure; the process is then repeated until the last observation. The one quarter ahead forecast is obtained analogously.[72]

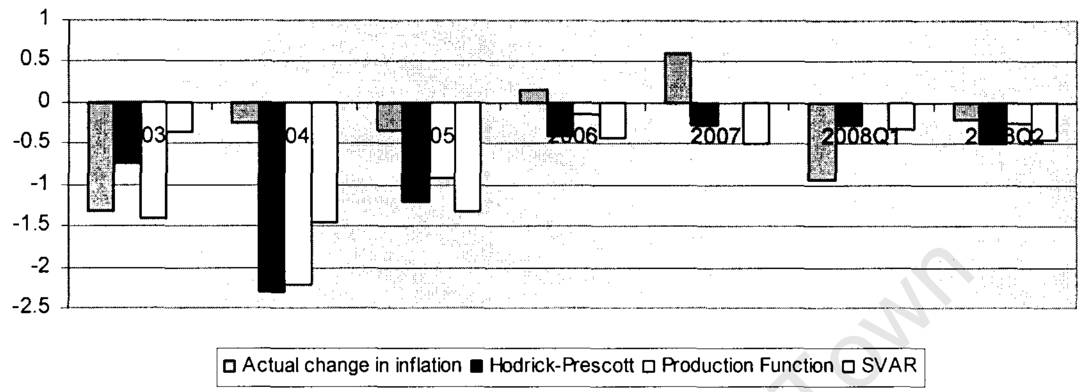
The out-of-sample forecast performances for both models 1 and 2 are illustrated in Figure 18.[73]

Figure 18: Actual and out-of-sample forecast

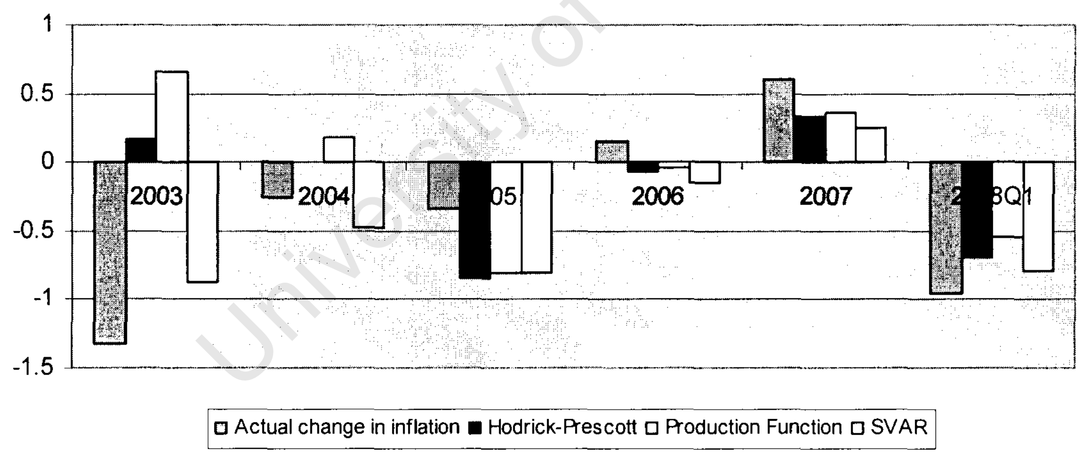


[72] See Claus et al. for a forecast for six and eight quarters ahead and a detailed explanation of the process.
[73] As before, the frequency considered for the estimation is quarterly data, but the results are presented in annual averages. The different bars correspond to the actual change in inflation and the change predicted by the HP filter, production function and SVAR gaps, respectively.

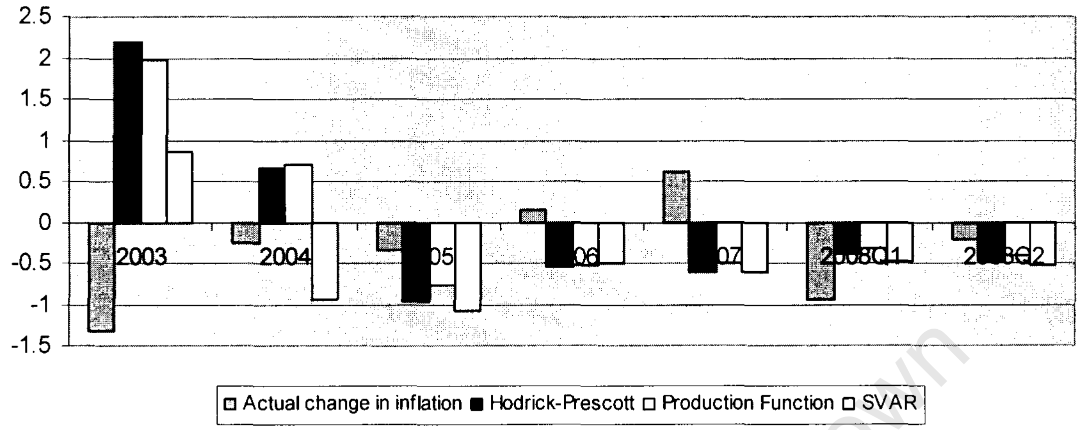
Model 1 - Four quarters ahead



Model 2 - One quarter ahead



Model 2 - Four quarters ahead



Once more, the results suggest that the output gap is a good indicator of the inflationary pressures, and, as a result, it seems to provide a useful signal for monetary authorities.

As previously, Table 17 shows the percentage of occasions when the output gap correctly predicts the change in inflation, but in this case in an out-of-sample forecast and only for the period 2003Q1–2007Q4.

Table 17: Out-of-sample forecasts of inflationary pressures (number of times correctly predicted in %)

One quarter ahead	Model 1	Model 2
HP filter	80	70
Production function	90	65
SVAR	80	75

Four quarters ahead	Model 1	Model 2
HP filter	50	35
Production function	60	35
SVAR	55	50

In both models, actual and forecast inflation tend to move in the same direction. Nonetheless, based on the number of times the models correctly predict the change in inflation, the level of output gap – model 1 – appears to be a better predictor of the accelerating or decelerating behaviour of prices. Naturally, the out-of-sample forecast performance deteriorates as the forecasting horizon is extended. More precisely, when the output gap is positive four times out of five, inflation will increase in the next quarter and three times out of five in the next year. The inverse is true for a negative gap and a decreasing inflation rate.

VII. Conclusions

Given the sharp decline and abrupt recovery of Uruguay's GDP in the last few years, three alternative measures of output gap were estimated in order to gauge the extent to which the economy is performing at below or above potential, as well as to provide evidence on whether such changes are mainly cyclical shortfalls or structural shifts towards a new growth path.

Despite the theoretical and empirical divergence among the different approaches, the three output gaps share similar increasing and decreasing patterns, which explains the observed high level of correlation. Throughout the 1990s, potential output grew at an average annual rate of 3,5–4% until the decline in Uruguay's long-term path led to a negative annual rate of 2%. Due to the structural break in 2003, the downward sloping trend is reverted and growth rates of 4–5% indicate the economy's recovery in the last quarters. Regardless of the inaccuracy that the estimation may face at the end of the sample, the three methodologies coincide in the fact that for the last quarters of 2007 real GDP is situated above its potential, leading to inflationary pressures.

The last section of the dissertation evaluates whether the output gaps, given the inevitable underlying uncertainty, are still a useful indicator of inflationary pressures in Uruguay. Following Coe and McDermontt (1997) and Claus (2000), two simple versions of the "gap model" were estimated. Firstly, the change in inflation is related to the level of the three measures of output gap. Under this specification, inflation is expected to rise if the level of real GDP exceeds the productive capacity of the economy over time; logically, inflation will be expected to fall if the gap is negative and remain stable if the gap is zero. The second version of the model relates the change in inflation to the change in the output gap, which implies that the level of inflation will tend to remain stable as long as the level of the gap remains unchanged. In an attempt to extend the analysis and given the characteristics of the Uruguayan economy, the gap model was extended to allow money supply and the terms of trade to affect the change in inflation. Overall, the results suggest that the output gap, however measured, provides a good signal of inflationary threats to the monetary authorities. More precisely, when the output gap is positive (negative) four times out of five, inflation will increase (or decrease) in the next quarter and three times out of five in the next year.

Finally, a series of conclusions can be extracted from the previous results: (i) accelerating prices are, in general, an indication that the economy is overheating, (ii) reducing inflation generally requires implementing restrictive macroeconomic policies that temporarily reduce the growth of real output, and (iii) inflation does not only depend on the output gap, but also on factors such as changes in indirect taxes, exchange rates shifts, commodity price shocks, import prices, labour market policies and institutions that affect wages formation. As a result, while estimates of output gap were found to be good indicators of inflationary pressures, they should be analysed together with other indicators when it comes to practical policy implementation. The use of the Principal Components Analysis, -more specifically [FA]VARs- , would not only extract the comon factors seen among the different measurements but also improve the estimation technique since it would allow for example the use of the factor's lags as additional regressors. Finally, an extension would be the use of data from other South American countries with similar characteristics allowing a panel analysis like the PANIC approach, panel VARS and FAVARs. Thus, this dissertation opens up new avenues for future research.

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Appendix

I. Tests for integration

Variables	Augmented Dickey-Fuller		Phillips-Perron Zα test	
	no trend	**trend**	**no trend**	**trend**
Inflation	-2.18 (12)	-1.05 (12)	-1.54	-1.25
Δinflation	-1.95 (11) **	-3.18 (11) *	-4.11 ***	-4.23 ***
Output gap HP	-2.55 (11) **		-2.88 ***	
Output gap Production Function	-2.15 (11) **		-2.83 ***	
Output gap SVAR	-2.33 (11) **		-2.94 ***	
Real Money Gap c.	-2.82 (11) ***		-3.10 ***	
Terms of trade c.	-2.43 (12) ***		-10.91 ***	

*** H_0 of a unit root is rejected at the 1 % level

** H_0 of a unit root is rejected at the 5 % level

* H_0 of a unit root is rejected at the 10 % level

a. All the test regressions include a constant

b. A lag-length selection is used that tests the included lagged terms for significance at the 10 percent level. The initial number of lags is set to equal to three times the seasonal frequency, 12.

c. These variables are includes when the models are extended

II. Testing the Gap Model: Model 1 and Model 2

Output Gaps	lag length	Gap Coefficients Sum	Sign	F-test	R-squared	Test for normality	test for homoscedastic errors
Model 1							
Hodrick-Prescott	6	0.07	-++++-+	3.71 ***	0.31	1.704	3.67 *
Production Function	6	0.14	-++++-+	3.92 ***	0.34	1.887	5.32 ***
SVAR	6	0.00	-+-+-++	1.83 **	0.20	12.02 ***	1.94 *
Model 2							
Hodrick-Prescott	6	0.73	-++-+--	4.14 ***	0.34	1.07	3.28 *
Production Function	6	0.57	++-++-+	3.73 ***	0.33	1.67	3.99 **
SVAR	5	0.62	-++++-	2.18 **	0.21	14.91 **	1.28

*** Ho is rejected at the 1 percent level

** Ho is rejected at the 5 percent level

* Ho is rejected at the 10 percent level

a. The lag length was determined using the Schwarz (1987) information criterion and an F-test that tests the included lagged terms for significance. The maximum number of lags was set equal to the double seasonal frequency, ie 8.

b. Ho: the gap variables jointly have no effect on the change in inflation

c. The test for normality is based on a LM test for joint Skewness and kurtosis proposed by Jarque and Bera (1980)

d. The null hypothesis of a linear model with homoskedastic errors was tested using the White test (1980) and Breush and Pagan test (1979)

Note: LM test suggest that the null hypothesis of no serial correlation is rejected at conventional levels of significance for most of the equations.

III. Forecast evaluation

Model 1	Hodrick-Prescott	Production Function	SVAR
Root Mean Squared Error	0.0106	0.0097	0.0097
Theil Inequality Coeff	0.5339	0.4614	0.4629
Bias Proportion	0.0000	0.0000	0.0000
Variance Proportion	0.3906	0.2755	0.2776
Covariance Proportion	0.6094	0.7245	0.7224
Model 2			
Root Mean Squared Error	0.0108	0.0093	0.0095
Theil Inequality Coeff	0.5342	0.4503	0.4628
Bias Proportion	0.0000	0.0000	0.0000
Variance Proportion	0.3912	0.2542	0.2703
Covariance Proportion	0.6088	0.7458	0.7297

IV. *Testing the Gap Model:* Model 3 and Model 4

Output Gaps	lag length	Gap Coefficients Sum	Gap Coefficients Sign	Money gap coefficient Sum	Money gap coefficient Sign	Terms of trade Sum	Terms of trade Sign	F-test	R-squared	Test for normality	Test of heteroskedasticity
Model 3											
Hodrick-Prescott	2	0.01	-++	0.02	--+	N/A	N/A	6.17 ***	0.37	2.38	1.15
Production Function	2	0.26	-++	-0.07	--+	N/A	N/A	6.89 ***	0.40	3.03	0.9
SVAR	2	-0.02	--+	0.05	--+	N/A	N/A	5.07 ***	0.32	2.63	2.02 **
Model 4											
Hodrick-Prescott	2	0.02	-++	0.014	--+	0.014	-++	3.97 ***	0.38	2.93	1.34
Production Function	2	0.20	-++	-0.07	--+	0.028	-++	4.51 ***	0.41	3.98	1.04
SVAR	2	-0.03	-+-	0.04	--+	0.000	-+-	3.28 ***	0.33	2.85	1.43

*** Ho is rejected at the 1 percent level

** Ho is rejected at the 5 percent level

* Ho is rejected at the 10 percent level

a. The lag length was determined using the Schwarz (1987) information criterion and an F-test that tests the included lagged terms for significance. The maximum number of lags was set equal to the double seasonal frequency, ie 8.

b. Ho: the gap variables jointly have no effect on the change in inflation

c. The test for normality is based on a LM test for joint Skewness and kurtosis proposed by Jarque and Bera (1980)

d. The null hypothesis of a linear model with homoskedastic errors was tested using the White test (1980) and Breush and Pagan test (1979)

Note: LM test suggest that the null hypothesis of no serial correlation is rejected at conventional levels of significance for most of the equations.

V. *Forecast evaluation*

	Hodrick-Prescott	Production Function	SVAR
Model 3			
Root Mean Squared Error	0.010435	0.009872	0.010083
Theil Inequality Coeff	0.488385	0.447907	0.462554
Bias Proportion	0.0000	0.0000	0.0000
Variance Proportion	0.27335	0.227276	0.243331
Covariance Proportion	0.72665	0.772724	0.756669
Model 4			
Root Mean Squared Error	0.010431	0.009818	0.010064
Theil Inequality Coeff	0.488076	0.444228	0.461239
Bias Proportion	0.0000	0.0000	0.0000
Variance Proportion	0.272977	0.223349	0.241861
Covariance Proportion	0.727023	0.776651	0.758139