

3 DOUBLE-CONDITIONED POTENTIAL OUTPUT*

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Abstract

The central argument of this paper is that both – internal and external – equilibria should be taken into account in the estimation of potential output. If only the data on inflation, unemployment rate, and wages are used for its evaluation, no certainty exists that such a level will correspond to a stable foreign trade balance.

Our attempt is based on the following methodological assumptions:

- the potential output is concomitantly associated with a constant inflation and sustainable relative foreign trade balance (ratio of net export to gross domestic product);
- all supply shocks affect this level, potential output being, therefore, a variable indicator;
- consequently, the output gap reflects exclusively the demand pressure.

The proposed computational algorithm is based on the use of orthogonal regressions. It is exemplified on seasonally adjusted quarterly statistical series of variables characterizing the Romanian transition economy; this application shows that the estimated output gap **does** contain significant regular and irregular cyclical components.

Key words: Potential Output, Output Gap, Orthogonal Regression, Cycle.

JEL classification: C 22, E 23, E 32.

1. Introduction

The current literature reveals some reasonable controversies over the concept of “potential output”. On the one hand, this is an “invisible” indicator, which cannot be unequivocally estimated. Several computational algorithms were proposed, each of them generating different results, sometimes even contradictory ones. On the other hand, the question cannot be simply avoided or ignored. The analysts and especially

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the policy-makers need to know, with a reasonable approximation, what is a desirable level of the real GDP, in the proximity of which a given economy does not register major disequilibria and is developing in a predictable manner.

The volume of studies regarding this matter is already sizeable and it continues to rise. While the present paper does **not** aim at evaluating extensively this literature, I will emphasize some issues which are, in my opinion, particularly important for our approach below.

1. The first one concerns the observed indicators to which the potential output is related. Inflation is, by far, the most frequently considered variable, either in theoretical researches, or in empirical analyses (including the building of macro-models).

The “Phillips Curve”-“Okun’s Law” combination was for a long time, the main accepted paradigm (Galli, G., D. Terlizzese, I. Visco, Elmeskov and Pichelmann; Fair 1994; Karbuz; Mankiw 1995; Kawasaki; de Bondt, van Els and Stokman; Frisch; Kichian; Akerlof, Dickens and Perry; Schorderet; Abel and Bernanke; Proietti, Mussoy and Westermanny; Gerlach and Yiu; Ögünç and Ece).

The NAIRU investigations have considerably extended this line of research (Layard, Nickell and Jackman; Staiger, Stock and Watson 1996 and 2001; Allen, Hall and J. Nixon; Holden; Whelan; Stiglitz; Blanchard and Katz; Gordon 1997 and 1999; Duarte and Andrade; Black and Fitzroy; Chaney; Stockhammer; Herz and Röger; Bårdsen and Nymoer; Nymoer).

The NAWRU version has focused on the correspondence between the output gap and wages as a main component of the production costs as well as of inflation (Elmeskov; Elmeskov and MacFarlan; Ball; Holden; Duarte and Andrade; Johansen; Nymoer).
The AWSU approach has explored the same connection using the share of wages in value added (Gordon 1996, Holden and Nymoer).

In conclusion, until now, the relationship between potential output and inflation has had priority. This is undoubtedly one of the most relevant expressions of the global economic environment. Nevertheless, it focuses primarily on the internal dimension of the issue.

The foreign trade balance is also a very important symptom of the state of an economy, reflecting the external side of equilibrium. This problem had not been completely disregarded in the literature, but it was discussed chiefly on the premises that the price index and the current trade balance are linked together by a stable clearing mechanism, which induces an univocal correlation between them (Layard, Nickell and Jackman; Holden). Obviously, domestic inflation and foreign trade balance interact on several levels through exchange rates, wages, import prices, other production costs, which are all factors of economic competitiveness. But this interdependence is mediated by the institutional framework, by the shifting behaviours of firms and households, by the changing macroeconomic policies, and by the unstable international environment. Consequently, we do not have enough reasons to believe that a constant (even low) inflation is typically associated with a medium-to-long run sustainable net export. On the contrary, a lot of historical examples show that variable or steady price indices combine – during a representative period - with quite different configurations of the foreign trade balance (deficit, surplus, near zero). In this



field, there are many influencing factors, whose analysis goes beyond the scope of the present research.

I have only considered and stressed these circumstances as fundamental facts. Therefore, we cannot ascertain unequivocally that a potential output derived from data on inflation, unemployment rate and wages, will correspond to a stable foreign trade balance (or, for that matter, to a zero net export). This paper attempts to include explicitly, not only the movement of domestic prices, but also the evolution of net export in the determination of potential output. In other words, both – internal and external – equilibria will be simultaneously involved in the estimation of the discussed indicator.

Consequently, the potential output is the output level associated with:

- constant inflation, and
- constant relative foreign trade balance, represented by the ratio of net export to gross domestic product.

To outline both these two features we will further call this a **double-conditioned potential output**.

2. The temporal stability of the potential output is another essential question. The theory and practical applications evolved towards a flexible interpretation. If initially only the long-run definition of potential output was considered, (according to the natural growth rate), subsequently, its medium and short-run levels definition have been investigated; (for example, as a weighted average of the long-run and previous statistical levels (Holden) or, lately, as the soft concept of *time-varying NAIRU* (Gordon 1999). Due to this evolution, the concept became more amenable to empirical research, but, at the same time, the distinction between the potential output and the actual GDP was blurred

2.1. In fact, the question to ask should be: “How does the potential output react to both demand and supply shocks?”

a) On the supply-side, according to the traditional expectations-augmented Phillips curve, inflation depends on its past level, on deviation of the output from its own natural rate (inflationary gap), and on supply shocks (Mankiw). This refers to the short-run supply shocks, because the long-run ones intrinsically affect the equilibrium of the economic growth. But, there are many changes with permanent effects that gradually penetrate into economy (Kichian). In other words, there is a big class of long-run shocks, which consist of step by step accumulated short-run shocks. The difficulty to distinguish unambiguously between the short and long term supply-shocks is aggravated by the hysteresis phenomenon, which is often present in the labour market (Elmeskov and MacFarlan; Krugman; Bellmann; Blanchard and Pedru; Calmfors; Karamé; Betcherman; Gordon 2003). As a result, it seems realistic to accept that the potential output incorporates all supply shocks - positive or negative - irrespective of:

- their temporal influences (on short or long term),
- spatial sources (internal or from abroad), and
- nature of their impulses (technological developments, variation in quality of human capital, modification of market environment, changes in institutional framework, and so on).

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In this interpretation, the potential output is clearly changing value, not only in the long run, but on the medium and short term horizons as well. Therefore, it is related to Gordon's time-varying NAIRU.

b) Unlike the supply shocks, the demand ones act preponderantly on short run. There are, of course, shifts in preferences which could profoundly influence the structure of demand. Nevertheless, such modifications become observable only during extended periods, in any case longer than the possible duration of a given level of the potential output. This assumption would need a more detailed examination, but, for the time being, it will be adopted as such. Thus, we will consider that demand shocks affect only real output, the potential output remaining neutral to this type of changes. In other words, the difference between actual and potential outputs reflects exclusively a demand pressure. Such a statement could appear as an extreme simplification. However, it eliminates the uncertainties implied by the inclusion of supply-shocks among inflation determinants, separately from the output gap. In the author's opinion, the concept becomes thus more consistent with its original paradigm.

2.2. The dependence of potential output on supply-shocks not only in the medium-to-long run, but in the short run as well, has a key methodological implication. No matter how it is built, the computational algorithm must explicitly include either parameters that are stable during the period considered representative for a given potential output, or include more flexible parameters.

Under these circumstances, another question becomes noteworthy. Is there any difference between potential and actual outputs, from their variability point of view? It seems plausible to state that the potential output is less volatile than the actual one, at least by the strength of the fact that the last one is conditioned not only by the supply shocks, but by the demand ones, too. Thus, the usual hypothesis stating that the potential output stays constant during two successive intervals (especially when these are relatively short) cannot be rejected. It will be also adopted in the scheme described below.

3. During the last decades the literature on the estimation methods of potential output has been very rich. Two approaches are dominant:

- the first one is global, in that potential output is determined as an aggregate indicator, on the basis of series of actual gross domestic product (as such or in combination with other variables);
- the second one is structural, emphasising the main factors determining potential output and using a wide variety of production functions.

3.1. The global estimation has evolved tremendously, from a simple specification, towards more and more sophisticated algorithms (Beveridge and Nelson; Nelson and C.Plosser; Watson; Stock and Watson; King and Rebelo; Harvey and Jaeger; Kuttner; Baxter and King; Cogley and Nason; Mankiw; Conway and Hunt; Gerlach and Smets; de Brouwer; Driver, Greenslade and Pierse; Duarte and Andrade; Gerlach and Yiu; Guarda; Domenech and Gomez; Logeay and Tober; Rennison). They also employed various methods, such as: linear time trends, univariate and multivariate filters, unobserved components models.



The great advantage of these methods consists in the possibility of approximating the potential output directly from statistically defined indicators, to which it is related. Using only these methods, we can generally define the projections by extrapolating the identified characteristics of the past series. As a result, there are serious difficulties to integrate the globally estimated potential output into larger predictive macromodels.

3.2. As a solution to this drawback of global (empirical) models, the structural approach emerged as the obvious alternative. It is centred on the neo-classical production function models (Kawasaki; Ekstedt and Westberg; Zaman 2001 and 2002; Denis Mc Morrow and Röger; Rööm; Proietti, Mussoy and Westermanny). Without any doubt, such an approach is closer to micro-foundations and, moreover, may generate – under adequate investment and labour force relationships – more reliable forecast. However, it is not immune to other drawbacks:

a) Irrespective of the difficulty in compiling a consistent time series representing capital itself, there is an even more problematic issue of estimating a rate of capacity utilization consistent with an unobservable indicator such as potential output. For this reason, most models containing production functions do not include such a rate.

b) Natural (normal) employment (or unemployment) also cannot be directly approximated using available data. This explains why the methodologies based on production functions define it on the basis of global (empirical) estimates (most of all NAIRU or NAWRU). Sometimes, the elasticity of output with respect to the labour input is determined imposing its equivalence with the share of wages in added value, which is a questionable solution.

3.3. A mixed approach is also possible. It integrates the core relationship, which derives from a global (empirical) estimation into a system, containing not only a production function, but domestic absorption, export and import, and other macroeconomic determinants.

3.4. There are also some notable attempts at comparing different procedures using equations of inflation that include – apart from the output gap - some supply shock variables:

- changes in the relative price of imports, in the relative price of food and energy, and in the real exchange rate (Gordon 1997);
- unit labor costs and import prices adjusted for tariffs (de Brouwer);
- real oil prices and real import prices (Driver, Greenslade and Pierse).

Rennison used also Monte Carlo techniques to evaluate alternative output gap estimators.

4. Concluding this introductory section, the central methodological assumptions of the present study are the following:

- the potential output is interpreted as double-conditioned, which means the equilibrium level of potential GDP corresponds to both a constant inflation and a sustainable net export;
- all supply shocks affect this level, potential output being, therefore, variable;
- output gap reflects exclusively the demand pressure.

II. Computational Algorithm

1. The global (empirical) estimation of potential output starts with the definition of the two above-mentioned conditions: the price index equation and the relative foreign trade balance equation.

The inflation is determined as follows:

$$P=P(-1)*(Y/Y_p)^\beta \quad [1]$$

where P are prices, Y – actual output at constant prices, Y_p – potential output expressed in the same prices as actual one, all variables expressed in indices (of course, with the same temporal reference). According to the theory, the coefficient β is positive due to straightforward reasons detailed in Appendix I.

Using the logarithms (small letters), the relationship [1] becomes

$$\Delta p = \beta * (y - y_p) \quad [1a]$$

The second condition may be represented as follows:

$$n_x = a + \gamma * (y - y_p) \quad [1b]$$

where n_x is the ratio of net export to GDP. Generally speaking, γ is negative: domestic demand pressure resulting in a positive output gap stimulates imports and, subsequently, induces a deterioration of the foreign trade balance. Nevertheless, if the economic growth is based on improving productive competitiveness and/or on a pro-export active policy, a positive correlation between Y (or $(y - y_p)$) and n_x is likely to exist, at least temporarily.

The constant term in [1b] can be interpreted as being the level of a relative foreign trade balance (possible under given international circumstances, including capital markets) around which the economy tends to stabilise in the given period.

Obviously, $Y=Y_p$, $P=P(-1)$, $n_x=a$, and $\Delta p=0$ describe the steady state, corresponding to the mentioned characteristics of the double conditioned potential output.

Normally, these features could be formalised in other more sophisticated ways. I would prefer the simplest expression, and not only for computational reasons. In such a straightforward format, the weaknesses (or eventual strengths) of the approach proposed here may be easier to identify.

2. The stochastic expressions of the relationships [1a] and [1b] are:

$$\Delta p = \beta * (y - y_p) + \varepsilon_p \quad [2a]$$

$$n_x = a + \gamma * (y - y_p) + \varepsilon_n \quad [2b]$$

It is assumed that both, ε_p and ε_n , are “white noise”.

From [2a] and [2b], we can derive two estimates for the potential output. One of them observes price restriction (y_{pp}) and the other one corresponds to the foreign trade balance condition (y_{pn}).

$$y_{pp} = y - \Delta p / \beta + \varepsilon_p / \beta \quad [3a]$$



$$y_{pn} = a/\gamma + y - n_x/\gamma + \varepsilon_n/\gamma \quad [3b]$$

If the potential output simultaneously presumes constant inflation and stable relative foreign trade balance, then [3a] and [3b] have to be equal ($y_{pp} = y_{pn} = y_p$), which means:

$$a/\gamma + \Delta p/\beta - n_x/\gamma + \varepsilon = 0 \quad [4]$$

where $\varepsilon = (\varepsilon_n/\gamma - \varepsilon_p/\beta)$, again a "white noise".

Two regression-pairs are thus possible:

$$\Delta p = a_1 + b_1 * n_x + \varepsilon_1 \quad [4a1]$$

$$a_1 = A\Delta p - b_1 * An_x \quad [4a2]$$

where $a_1 = -a * \beta/\gamma$, $b_1 = \beta/\gamma$, $\varepsilon_1 = -\varepsilon * \beta$, and corresponding averages $A\Delta p$ and An_x , or

$$n_x = a_2 + b_2 * \Delta p + \varepsilon_2 \quad [4b1]$$

$$a_2 = An_x - b_2 * A\Delta p \quad [4b2]$$

where $a_2 = a$, $b_2 = \gamma/\beta$, and $\varepsilon_2 = \varepsilon * \gamma$, and An_x and $A\Delta p$ with the same significance.

As it can easily be shown, the separate regressions [4a1] and [4b1] are not reversible, except in the trivial case when the coefficient of correlation between Δp and n_x is equal to unity.

The problem becomes more complex when we cannot establish a reliable causal relationship between the given variables. In other words, when we do not know what coefficient, b_1 or b_2 , should be used to estimate β and γ .

3. Such reversibility means that the relationships [4a1] and [4b1] have to be valid at the same time with [4a2] and [4b2].

Setting the error terms aside, we have:

$$\begin{aligned} \Delta p &= a_1 + b_1 * n_x = a_1 + b_1 * (a_2 + b_2 * \Delta p) = a_1 + b_1 * a_2 + b_1 * b_2 * \Delta p = \\ &= A\Delta p - b_1 * An_x + b_1 * (An_x - b_2 * A\Delta p) + b_1 * b_2 * \Delta p = \\ &= A\Delta p - b_1 * An_x + b_1 * An_x - b_1 * b_2 * A\Delta p + b_1 * b_2 * \Delta p = \\ &= A\Delta p - b_1 * b_2 * A\Delta p + b_1 * b_2 * \Delta p = A\Delta p + b_1 * b_2 * (\Delta p - A\Delta p) \end{aligned} \quad [5]$$

Therefore,

$$\Delta p - A\Delta p = b_1 * b_2 * (\Delta p - A\Delta p) \quad [5a]$$

and

$$b_1 * b_2 = 1 \quad [5b]$$

The orthogonal regression observes this condition [Malinvaud, Dissanaïke and Wang, Saman]. In its classical form, the coefficients b_1 and b_2 are determined as follows:

$$b_1 = \{(\sigma_p^2 - \sigma_n^2) + [(\sigma_p^2 - \sigma_n^2)^2 + 4 * \sigma_{pn}^2]^{1/2}\} / (2 * \sigma_{pn}) \quad [6a]$$

$$b_2 = \{(\sigma_n^2 - \sigma_p^2) + [(\sigma_n^2 - \sigma_p^2)^2 + 4 * \sigma_{pn}^2]^{1/2}\} / (2 * \sigma_{pn}) \quad [6b]$$

where σ_p^2 is the variance of Δp , σ_n^2 – the variance of n_x , and σ_{pn} represents their covariance.

Substituting

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$A=(\sigma_p^2-\sigma_n^2)$ and $B=[(\sigma_p^2-\sigma_n^2)^2+4*\sigma_{pn}^2]^{1/2}$ which is equivalent also to $[(\sigma_n^2-\sigma_p^2)^2+4*\sigma_{pn}^2]^{1/2}$, we have

$$b_1*b_2=[(A+B)/(2*\sigma_{pn})]*[(-A+B)/(2*\sigma_{pn})]= \\ [(B+A)*(B-A)]/(2*\sigma_{pn})^2=(B^2-A^2)/(2*\sigma_{pn})^2 \quad [7a]$$

which means

$$b_1*b_2=[(\sigma_p^2-\sigma_n^2)^2+4*\sigma_{pn}^2-(\sigma_p^2-\sigma_n^2)^2]/(2*\sigma_{pn})^2=(4*\sigma_{pn}^2)/(4*\sigma_{pn}^2)=1 \quad [7b]$$

I do not consider here the problems associated to the classical form of orthogonal regressions and the possibilities to improve it (Dissanaike and Wang). At this point, only its property to generate reversible econometric coefficients is of interest to us.

4. We go back now to the initial parameters a , β and γ . Summing [3a] and [3b], and maintaining the assumption about their equality ($y_{pp}=y_{pn}=y_p$), we get the following formula for y_p :

$$2*y_p=2*y-\Delta p/\beta+a/\gamma-n_x/\gamma+(\varepsilon_p/\beta+\varepsilon_m/\gamma)=2*y-\Delta p/\beta+(a-n_x)/\gamma+(\varepsilon_p/\beta+\varepsilon_m/\gamma) \quad [8]$$

Including $\beta=b_1*\gamma$, potential output is approximated by

$$y_p=y+(a-\Delta p/b_1-n_x)/(2*\gamma)+\varepsilon \quad [8a]$$

The first order difference Δy_p will be determined:

$$\Delta y_p=y_p-y_p(-1)=y+(a-\Delta p/b_1-n_x)/(2*\gamma)+\varepsilon-y(-1)-(a-\Delta p(-1)/b_1-n_x(-1))/(2*\gamma)-\varepsilon(-1)= \\ =y-y(-1)-[(\Delta p-\Delta p(-1))/b_1+n_x-n_x(-1)]/(2*\gamma)+(\varepsilon-\varepsilon(-1))= \\ =\Delta y-(\Delta^2 p/b_1+\Delta n_x)/(2*\gamma)+\Delta \varepsilon \quad [9]$$

where Δ^2 is the second order difference operator.

Theoretically, it would be difficult to reject the conjecture that the potential output should be less volatile than the actual one. According to the usual methodologies,

$$\Delta y_p=\Delta y-(\Delta^2 p/b_1+\Delta n_x)/(2*\gamma)=0 \quad [10]$$

the coefficient γ is derived from (10) as:

$$\gamma=(\Delta^2 p*b_1+\Delta n_x)/(2*\Delta y) \quad [10a]$$

and β is given by:

$$\beta=b_1*\gamma \text{ or } \beta=\gamma/b_2 \quad [10b]$$

Therefore, both γ and β are variable, reflecting changeable factors which influence the level of potential output. Unlike these, the parameters a and b correspond to its relatively stable determinants.

The series of potential output can thus be approximated using the relationship [8a]:

$$y_p \approx y + [(a - \Delta p / b_1 - n_x) / 2] / \gamma \quad [8b]$$

The main characteristic of this determination is its organic connection not only with inflation, but with foreign trade balance, too.



III. An Empirical Application (The Romanian Case)

Some of the standard procedures for the determination of potential output were already applied to the Romanian transition economy (Croitoru, Doltu, and Târhoacă; Buc^oa; Ghizdeanu and Neagu; Stănică; Albu 2004, with reference to the natural unemployment rate). The algorithm, described in the previous chapter, will be further exemplified.

1. We have used quarterly data for the gross domestic product (at current and constant prices), net export (at current prices), and the consumer price index (more relevant for the present application than the GDP deflator). All variables are seasonally adjusted.

2. The orthogonal regression generates the relationships:

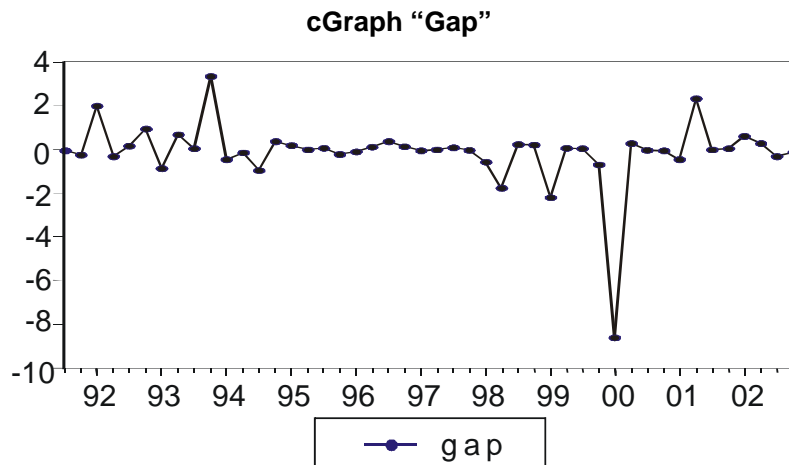
$$\Delta p = -0.59218 - 10.1032 * n_x$$

and

$$n_x = -0.05861 - 0.09898 * \Delta p$$

perfectly reversible [$-10.1032 * (-0.09898) = 1$].

Using the equations (10a) and (8b), the indices of potential output (Y_p) have been determined and, on this basis, the corresponding output gap. The results are presented in the Graph "Gap" below.



The sign of the gap clearly alternates, which is consistent with the rationale of the potential output.

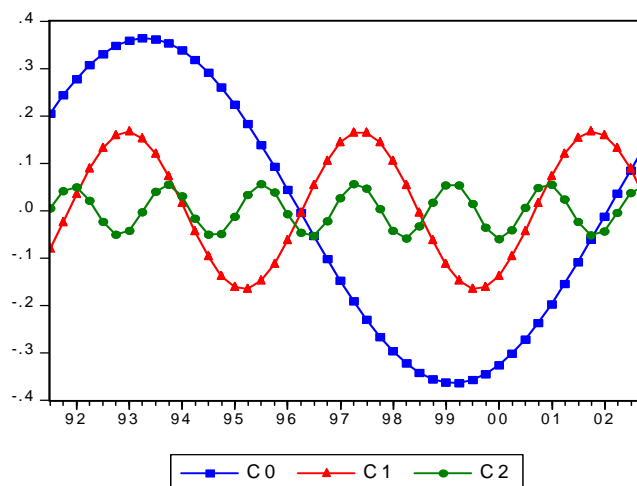
3. In order to identify the possible determinants of these fluctuations, a cycle analysis has been performed. The gap series was divided into cyclical part (C0) and residuals

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(ResC0). The last series (ResC0) was then submitted to the same procedure, obtaining C1 and ResC1. This decomposition has been successively applied until the amplitude of the cycle became zero (C11 in our case).

3.1. The series C0, C1, and C2 may be characterised as regular cycles.

Graph "C012"



a) We have no reasons to consider C0 – with a period of 11-11.5 years – as a classical long business cycle. In my opinion, it derives from specific transitional determinants. Its first segment (1991-1996) is characterised by positive output gaps, reflecting, probably, the “resistance” of the Romanian economy to the restructuring processes involved by the implementation of the functional market mechanisms. The incoherence of the macroeconomic and institutional policies promoted during the period 1997-1999 has pushed the output gap towards significant negative levels. A certain recovery is then observed, but a new demand pressure wave becomes visible. The causes of such an evolution are complex and their examination exceeds the intended framework of the present work.

b) I think C1– with a period of 4-4.5 years – represents a typical electoral cycle. After 1989 the Romanian data covers full election cycles - 1992-1996 and 1996-2000 – and one incomplete (2000-2003); they are characterised mainly by the variation of the nominal income policy. If this variation is expressed through the global indexation coefficient (ratio of annual index of current nominal GDP to previous annual CPI), we can identify, at least for this period (Dobrescu), the following pattern: for two consecutive years the coefficient value is above unit, after which, again for two consecutive years, it is below unit. From this point of view, we find that - apart from the elections year itself, one year before and one year after the elections - the second year after elections is the one that is least influenced by this major political event and, consequently, it can be conventionally named a “non-electoral” year. The arithmetic

averages (ELC) of the global indexation coefficient were computed for the corresponding years of electoral cycles. Their values were compared to the evolution of the output gap in C1.

Table 1

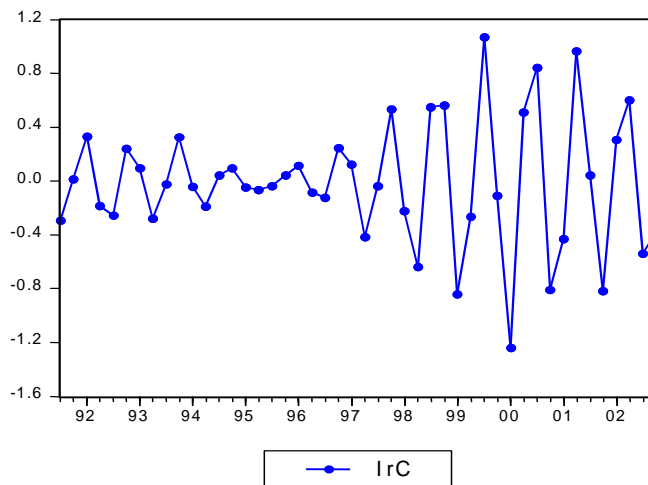
Position in electoral cycle	Years	ELC	Output gap in C1
Elections year	1992, 1996, and 2000	1.053196	Positive, increasing or passing from negative to positive
Post-electoral year	1993, 1997, and 2001	1.244457	Unambiguously positive
Non-electoral year	1994, 1998, and 2002	0.750399	Passing from positive to negative or positive but decreasing
Pre-election year	1995, 1999, and 2003	0.838702	Unambiguously negative

The output gap seems to be consistent with the demand pressure induced by nominal income policies.

c) As a regular cycle, C2 has a length of 1.8 years (approximately 7 quarters). Its amplitude is rather small. An attempt to explain such a cycle would be highly speculative at this point. This issue calls for additional research. The influence of this type of cycles is relatively weak.

3.2. The cycles C3-C10 can be considered irregular. Summing their effects, we have constructed an aggregate irregular (Graph "IrC").

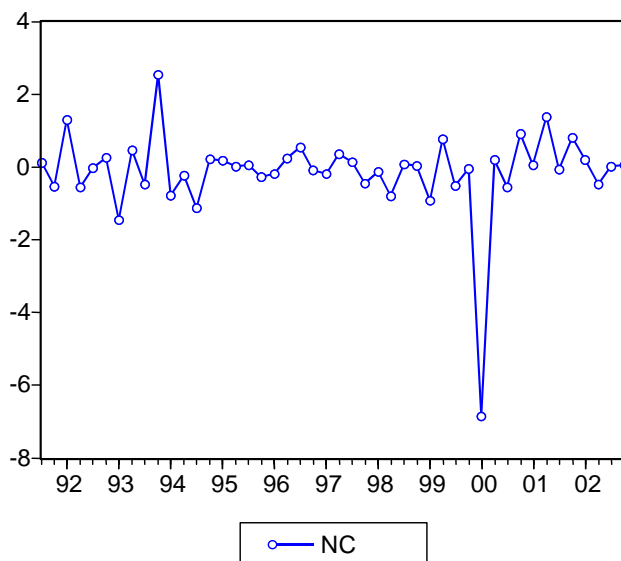
Graph "IrC"



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3.3. We have also identified an important non-cyclical component is present, too (Graph "NC").

Graph "NC"



4. The output gap and its main components have variable algebraic signs. We have, therefore, normalised the absolute values to compute the shares in the structure of the output gap. The computations have yielded the following shares: 0.22293 for C0, 0.117961 for C1, 0.038352 for C2, 0.273448 for IrC, and 0.34731 for NC.

Bucharest, April 2004

Appendix I

Inflationary Pressure of the Output Gap

Symbols:

Y – Output, constant prices

L – Employment, persons

K – Capital, constant prices

MLP – Marginal labour productivity, constant prices

W – Wage on employed person, current prices

P – Level of current prices

GOS – Gross operating surplus

swy – Share of wages in value added (output)



ex - Expectations

Relationships:

$$[A1] Y = A * L^{\alpha} * K^{1-\alpha}$$

$$0 < \alpha < 1$$

$$[A2] MLP = \partial Y / \partial L = \alpha * A * L^{\alpha-1} * K^{1-\alpha}$$

$$[A3] GOS = P^{ex} * Y - W^{ex} * L = P^{ex} * A * L^{\alpha} * K^{1-\alpha} - W^{ex} * L$$

$$[A4] \partial GOS / \partial L = \alpha * P^{ex} * A * L^{\alpha-1} * K^{1-\alpha} - W^{ex}$$

$$[A5] \partial^2 GOS / \partial L^2 = (\alpha - 1) * \alpha * P^{ex} * A * L^{\alpha-2} * K^{1-\alpha}$$

From $0 < \alpha < 1$ yields $\partial^2 GOS / \partial L^2 < 0$; consequently, GOS admits a maximum.

$$[A6] \text{MaxGOS results from } \partial GOS / \partial L = 0$$

$$\alpha * P^{ex} * A * L^{\alpha-1} * K^{1-\alpha} - W^{ex} = 0$$

$$\alpha * A * L^{\alpha-1} * K^{1-\alpha} = W^{ex} / P^{ex}$$

Therefore, the condition for profit maximisation is

$$W^{ex} / P^{ex} = MLP$$

[A7] At equilibrium (indicated by subscript p)

[A7.1] Share of wages in value added (output)

$$\begin{aligned} swy_p &= W^{ex} * L / (P^{ex} * Y) = L * (MLP / Y) = \\ &= L * \alpha * A * L^{\alpha-1} * K^{1-\alpha} / (A * L^{\alpha} * K^{1-\alpha}) = \\ &= \alpha * A * L^{\alpha} * K^{1-\alpha} / (A * L^{\alpha} * K^{1-\alpha}) = \alpha \end{aligned}$$

[A7.2] Employment

$$\alpha * A * K^{1-\alpha} * P^{ex} / W^{ex} = L_p^{(1-\alpha)}$$

$$L_p = [\alpha * A * K^{1-\alpha} * P^{ex} / W^{ex}]^{1/(1-\alpha)}$$

[A7.3] Output

$$\begin{aligned} Y_p &= A * L_p^{\alpha} * K^{1-\alpha} = A * [\alpha * A * K^{1-\alpha} * P^{ex} / W^{ex}]^{\alpha/(1-\alpha)} * K^{1-\alpha} = \\ &= A * [\alpha * A * K^{1-\alpha}]^{\alpha/(1-\alpha)} * K^{1-\alpha} * [P^{ex} / W^{ex}]^{\alpha/(1-\alpha)} = B * [P^{ex} / W^{ex}]^{\eta} \end{aligned}$$

where $B = A * [\alpha * A * K^{1-\alpha}]^{\alpha/(1-\alpha)} * K^{1-\alpha}$ and $\eta = \alpha / (1 - \alpha)$; both B and η are given.

Consequently, $Y > Y_p$ (with increasing wages) will accelerate inflation. The opposite is true for $Y < Y_p$. The coefficient β must, therefore, be positive.

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