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What Does Economics Assume About People's Knowledge? Who knows?

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Resumo/Abstract:

The purpose of the paper is to explore, from an assessment viewpoint, the ideas below. Economics, as a social science, has always considered sets of individuals with assumed characteristics, namely the level of knowledge, although in an implicit way in most of the cases. In this sense, an influential approach in Economics assumed that society, as a global set of individuals, was characterised by a certain level of knowledge that, indeed, could be associated with the one of its representative agent. In fact, an attentive recall of the evolution of these matters in Economics will immediately recognise that, since the very first economic models of the government, it was assumed that the level of knowledge of society, represented by a set of voters, was not the same as the one of the agent being elected, i.e. the government. The irrelevance of the difference in the level of knowledge of economic agents was soon abandoned after some seminal works of Hayek and Friedman. More recently, the viewpoint of Economics has changed by focusing on the characteristics (e.g. knowledge) of individuals, who may interact in sub-sets of society. From this point of view is clearly relevant, given the close connection with the assumed level of knowledge, to distinguish the adaptive behaviour from the rational one, as well as the full rational from the bounded rationality behaviour by people. Quite recent developments in the Economics of Knowledge, i.e. the so-called learning models, have been considered as more realistic approaches to model the process by which individuals acquire knowledge, for instance from other individuals that are, themselves, acquiring knowledge.

Palavras-chave/Keywords: Bounded Rationality, Economics of Knowledge, Knowledge, Learning, Rationality

Classificação JEL/JEL Classification: A12, B41, C91, D83

1. A structural introduction

Economics, as a social science, has always considered sets of individuals with assumed characteristics, namely the level of knowledge, although in an implicit way in most of the cases. In this sense, an influential approach in Economics assumed that society, as a global set of individuals, was characterised by a certain level of knowledge that, indeed, could be associated with the one of its *representative agent*. In fact, an attentive recall of the evolution of these matters in Economics will immediately recognise that, since the very first economic models of the government, it was assumed that the level of knowledge of society, represented by a set of voters, was *not* the same as the one of the agent being elected, i.e. the government, this fact being evident, for instance, at the time horizon being considered. All these questions are subject to a succinct analysis in section 2 of our paper.

The irrelevance of the difference in the level of knowledge of economic agents was soon abandoned after some seminal works of Hayek and Friedman. In fact, as it will be pointed out below, the importance of these two authors in the methodology of Economics goes well beyond their contribution to the analysis of knowledge in Economics. This will be made clear in section 3 of our paper.

More recently, the viewpoint of Economics has changed by focusing on the characteristics (e.g. knowledge) of individuals, who may interact in sub-sets of society. From this point of view is clearly relevant, given the close connection with the assumed level of knowledge, to distinguish the adaptive behaviour (i.e. the one where the knowledge, not even about the past, is fully exploited) from the rational one (i.e. the one where all the knowledge, even about the future, is optimally exploited). All these matters are to be analysed in section 4 of our paper.

In our opinion, quite recent developments in the Economics of Knowledge, i.e. the so-called learning models, have been considered as more

realistic approaches to model the *process* by which individuals acquire knowledge, for instance from other individuals that are, themselves, acquiring knowledge. In fact, these models also allow to make the distinction between the full rational behaviour (i.e. the one where all the available knowledge is subject to an optimal use), from the bounded rationality behaviour by people, who prefer to adopt a satisficing approach, even in what concerns the use of knowledge. These issues are subject to a concise analysis in section 5 of our paper, which, in conjunction to section 4, can be seen as the bulk part of our analysis.[1]

2. From the representative agent hypothesis to the non-representative agent solution based upon knowledge

In what concerns the level of knowledge by people, an influential approach in Economics started considering it as being represented by the one characterising a certain individual. The representative agent hypothesis is based upon a rational – in the sense of maximizing the (expected) utility – behaviour of the representative individual, from which are derived the aggregate counterparts. In doing so, it is assumed that the representative agent knows the microeconomic equations from which the aggregate counterparts are derived. Given that aggregation issues seem to be ignored, Kirman (1992) proposed that the heterogeneity of agents should not be reduced to that analytical convenience. In fact, given the preferences and constraints of an individual, it is quite simple to model the behaviour of this individual – under the usual, but not innocuous, hypotheses. To model the behaviour of a group of people is obviously more difficult, in particular when individuals interact and, notably, when they are not all alike.

Plainly, in the case of representative agent models, the aggregation of the level of knowledge, assumed to be a characteristic of the representative

[1] Trying to escape from the trap of *formalism* we leave for annexes the (mathematical) formalizations of the arguments presented in each section. These formalizations appear immediately after a brief conclusion.

individual, would not add to the level of knowledge that an agent, such as Government, assumed also to be a representative agent (of society's interests), should consider when taking decisions, that are supposed to be the best from the point of view of the set of individuals constituting the society.

In the particular case of government, as an agent taking decisions on behalf of society, there is, in fact, a matter of knowledge that makes it distinct from the rest of the people (even from the electorate that has elected it). As is well-known, elections can be seen as one of the – if not the – oldest ways of delegating decision power. Voters, through an electoral process, elect an agent who is supposed to take decisions, for instance implementing economic policies, which are the best for society. These decisions are supposed to be even better than those that would be taken by voters themselves. This traditional vision derives from the consideration that the government should essentially be an agent that can, and indeed should, have a more distant time horizon than voters or society do. Notably, this means that, when the electorate votes for a government which has implemented policies that have generated pleasurable outcomes and this is viewed as a bad phenomenon, it is because voters possess a shorter-sight view of the economy. In the limiting case, if voters are viewed as agents with the same time horizon as government, then a positive election result should be viewed as exactly what the society wants, if we consider the electorate as representative of society. In any case, the voters' objective should be to make government choose policies that are optimal from the society's point of view. Notwithstanding, this would require some knowledge by voters about the level of knowledge needed to force the incumbent not to behave as opportunistic, i.e. when creating an electoral cycle by exploiting the lack of knowledge by the electorate.

In reality, an electoral cycle created by governments is a phenomenon that seems to characterise, at least in some particular occasions and/or circumstances, the democratic economies. As it is generally accepted, the short-run electorally-induced fluctuations hinder the long-run welfare. Since

the very first studies on the matter, some authors offered suggestions as to what should be done against this electorally-induced instability. For some authors, ever since the seminal paper of Nordhaus (1975), a good alternative to the obvious proposal to increase the electoral period length is to consider that voters abandon a passive and naive behaviour and, instead, are willing to learn about government's intentions.

In the limit, the acquisition of knowledge through learning makes it possible to take strategic decisions. For instance, strategic voting, ever since studied by MacRae (1977), may, in fact, make the electorally-motivated government to choose socially-optimal economic policies. This can be done by strategically changing the relative importance of objectives *on the election day*.[2] For that to happen, it is enough that voting decisions *do not* reflect (in the correct way) the social importance of economic variables. In other words, from the society's point of view, a non-representative behaviour of voters may induce the government to behave as a representative agent of society's interests. This would then mean that the government, assumed to know as much as the electorate, whose interests are pursued by governmental decisions, would then make decisions that are those that society would make itself, in case of knowing everything needed to acknowledge that, in fact, those were the best decisions from its viewpoint.[3]

As said before, the existence of democratic elections may be associated with some short-run electorally-induced fluctuations that, indeed, prejudice the long-run welfare, this being the result of an intentionally created

[2] Note that as, for instance in Nordhaus (1975), the aggregate voting function is considered as the appropriate social welfare function. In fact, the assumption that the objective-function reflects both the government's and the society's preferences has been present in most of the relevant literature.

[3] This solution seems to suffer from an intrinsic incongruence as it requires a level of knowledge not available to the electorate. By the use of a principal-agent approach, Caleiro (2004) provides an alternative solution to this problem. As it is apparent that voters should have good reasons for motivating the government to act as a benevolent social-planner, it is analysed the circumstances under which an optimal contract can be established between the public and the government in order to guarantee enough motivation for the agent/government, to behave in accordance with the true interests of the principal/public. Barro (1973) already used a principal-agent approach to analyse how re-election motives can be used to *control politicians*, therefore avoiding over-spending. In fact, principal-agent models deal with an issue related to the level of knowledge, in the sense that the principal delegates the realization of a task to an agent and does not know how much is effort is put forward by the agent.

instability, which is possible to create due to some lack of knowledge of the electorate. Still, there are other sources of economic destabilization, not being created on purpose, are the result of a lack of knowledge by the economic authorities, such as the government. This is, in our opinion, the result that Friedman's introduced and that, from the issues related to knowledge, is one of the most influential in the methodology proposed by Friedman.

3. From Friedman's to Hayek's contributions on the role of knowledge in Economics

When assuming itself as an economic policy agent, the government can, effectively, have an important role in the economic stabilization. But, if it uses its powers in an imprudent or perverse way it will be able, by itself, to be a generating source of instability/cyclical uncertainty. In this sense, the stabilization function of the State can, in some way, be challenged. In general, two aspects have been pointed out that contribute to the possibility of the disturbances in the economic activity being caused by the agents responsible for the economic policies themselves:

1. As it happens with electoral cycles, the government, having perfect knowledge of the consequences, can take measures that destabilize the economy because it has objectives leading to that, namely, the desire of being re-elected;
2. However, even if the government intends only to achieve economic objectives of stabilizing the economy, that obviously does not mean that it will always be able to obtain that result. As a matter of fact, a condition for success of the stabilization policy is the existence of perfect control on the sign/value of the effect of economic policy measures, on the moment that the effects are in practice, as well as the knowledge of the economic situation that will be verified when those economic policies start to produce its effects. Thus, the elaboration of an economic policy and its implementation at the certain moment is a

difficult task. Therefore, it is entirely possible that this attempt of stabilization has results contrary to the ones desired. This is, in fact, the main argument that monetarists, such as Friedman, use to criticize the active (discretionary) actuation of the economic authorities (see Annex 1 for a formalization of these arguments).

The case illustrated in the Annex 1, even if only from an implicit point of view, indicates the methodology that Friedman has proposed in a seminal work (Friedman, 1953a) after some tentative introduction in Friedman (1946). In fact, following Friedman's ideas, the construction of a positive approach in Economics should involve the assessment of a theory based upon its predictive success while setting apart unrealistic assumptions, which are often present in the formalist strand of Economics.

For the matters under discussion, Friedman's own words (Friedman, 1946: 631), quoted in Hands (2003: 5), are the most striking:

> "A man […] who has a strong desire to learn how the economic system really works in order that *knowledge* may be used, is not likely to stay within the bounds of a method of analysis that denies him the *knowledge* he seeks. He will escape the shackles of formalism, […] A far better way is to try to derive theoretical generalizations to fit as full and comprehensive set of related facts about the real world as it is possible to get." (italics added)

The importance of Friedman in what concerns the methodological aspects in Economics has an evident (precedent) parallel in Hayek's contributions, from which we obviously point out the ones on the relationship between Economics and Knowledge.[4] In a major work (Hayek, 1945) Hayek

[4] Boulding (1966) is an interesting reference on the relationship between Economics and Knowledge where the possibility of assuming Knowledge to be a good is discussed. In fact, the recent views on the

explores the *limits of human knowledge* in order to attack the centrally-planned functioning of the economies. Given that the knowledge needed to solve the *economic calculation problem* is not available to central planners, Hayek advocates that only a free functioning economy could provide price signals allowing to share and synchronize personal knowledge, which is intrinsically disperse and incomplete. This, in turn, would coordinate individuals' actions, allowing society's members to achieve diverse, complicated goals through a principle of spontaneous self-organization. In his own words:

> "The peculiar character of the problem of a rational economic order is determined precisely by the fact that the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess. The economic problem of society […] it is a problem of the utilization of knowledge which is not given to anyone in its totality." (Hayek, 1945: 519)

Hayek's criticism on the possibility to solve the economic calculation problem through a central planner is also based upon what he called to be a *scientism*, often present in social sciences and, in particular, in Economics. This would correspond to an erroneous approach, so much in vogue, to reduce complex, dynamic, non-linear systems to caricatures of reality based upon some analytical convenient simplifications through assumptions. This point, in conjunction with the alleged limits to human knowledge, makes Hayek a precursor of some models of learning and memory, which are about to be

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importance of "knowledge-based economies" are, in some sense, related to the fact that knowledge is a good with an interesting economic value (see, also, Foray, 2006).

presented further below.[5]

4. From not willing to know how to learn to knowing (almost) everything

The importance of knowledge in Economics is most evident when taking into account the role of expectations. With some exceptions, it is possible to identify two clearly distinct phases in what concerns the level of knowledge assumed to be present when forming expectations. The first one, which took place in the 1970s, considered the existence of adaptive expectations by naïve agents. In accordance with the rational expectations revolution, in the 1980s the second phase of models considered fully rational expectations. Plainly, in the first case, agents are not willing to know why are they making systematic mistakes whereas in the last case agents know everything needed to prevent making systematic errors when forming expectations.

In simple terms, adaptive expectations are the ones where the expected value, computed at time *t*-1, for period *t* of a variable, *y*, is a weighted average of the value assumed by this variable at period *t*-1 and the value expected for that variable at period *t*-1, i.e. $y_t^e = \alpha y_{t-1}^e + (1-\alpha) y_{t-1}$. Plainly, this means that knowledge, not even the one about the past, is fully exploited. Rational expectations are those computed (optimally) using all the information, *I*, available at the period of computation, say *t*-1, i.e. $y_t^e = E[y_t \mid I_{t-1}]$. Plainly, this means that all knowledge, even the one about the future, is optimally exploited.

Undoubtedly, the level of knowledge is the key when distinguishing the two types of expectations – see Annex 2 for a formalisation – and its importance becomes clearer when taking into account the consequences of rational expectations, such as the irrelevance of policies or decisions – see Annex 3 for a formalisation – the time inconsistency of policies or decisions –

[5] Interestingly, a model of Hayek based upon some sort of Hebbian learning can be viewed as a precursor of neural networks as bounded rationality devices of learning (see section 5 below).

see Annex 4 for a formalisation – as well as the delegation of policies or decisions – see Annex 5 for a formalisation.

Given its relationship to the issues under consideration, it is interesting to point out that the time inconsistency of decisions, as illustrated in Annex 4, has some resemblance with the fact that, in a game with rational players, non-cooperative solutions are, in general, more plausible than cooperative ones despite all the players knowing that, by non-cooperating, a worse result will be obtained than that which could be obtained when cooperation is in place. The explanatory key to this result is the fact that cooperative decisions are not credible and therefore are not equilibria as, in fact, the non-cooperative solutions, in general, are. The most interesting fact is indeed to recognise that not even full knowledge by players prevent the worse result to be the most plausible one.

The existence of rational expectation also led to another result which is of particular importance in these fields (see Annex 5 for a formalization). In what concerns the so-called delegation problem, it was concluded that for society, in general, and for the economic authorities, in particular, it can be beneficial to delegate economic policy to agents with different characteristics from the ones of those authorities or of society, for example, a higher degree of aversion to inflation than that of society. In this sense, the question of the delegation of economic policies has also been associated to the question of the necessity (or not) of non-representative agents/entities but, in this case, not necessarily knowing more than those economic authorities.

5. On increasing the knowledge of bounded rationality people by learning

From those two approaches on expectations, it is our view that an intermediate approach is more appropriate, i.e. one that considers learning agents, which are boundedly rational. Generally speaking, learning models have been developed as a reasonable alternative to the unrealistic informational assumption of

rational expectations models. Moreover, through learning models it is possible to study the dynamics of adjustment between equilibria which, in most rational expectations models, is ignored. In fact, rational expectations hypotheses are, in some sense and with some exceptions, a limiting property of a dynamic system which evolves from one equilibrium to another, this being possible because it is assumed that agents know the true model of the economy and use it to form their expectations which, in turn, implies that agents are also able to solve the model.

Interestingly, learning models also deal with another difficulty of rational expectations models, namely the existence of multiple equilibria. It is well known that for linear models, where only expectations of current variables are considered, the rational expectations equilibrium is unique. Conversely, when expectations about the future endogenous variables are required, multiple rational expectations equilibria can occur. Moreover, this is also a common feature of stochastic control/decision problems. In this case, the lack of equilibrium uniqueness arises from an imperfectly specified intertemporal decision problem under uncertainty. The analysis of learning processes can, in fact, provide a way of selecting the 'reasonable' equilibrium or sub-set of equilibria. On the one hand, if the learning mechanism is chosen *optimally*, then a *desirable rational equilibrium* is selected from the set of the rational expectations equilibria (see Marcet & Sargent 1988;1989a;1989b). On the other hand, if the learning mechanism is viewed under an *adaptive* approach, in particular in *expectational stability models*, it can also act as a selection criterion in multiple equilibria models involving *bubbles* and *sunspots* (see Evans, 1986; Evans & Guesnerie, 1993; Evans & Honkapohja, 1994;1995). To sum up, learning mechanisms, whether optimally or adaptively chosen, 'select' the particular steady state as, in some sense, terminal conditions do.

Through this last point, one can already anticipate the usual distinction between learning mechanisms. Although a number of different studies modelling learning have been presented, two main classes of models can be

distinguished: rational learning and boundedly rational learning models.[6] In rational learning models, it is assumed that agents know the true *structural form* of the model generating the economy, but not some of the parameters of that model. In boundedly rational learning models, it is assumed that agents, while learning is taking place, use a 'reasonable' rule, for instance, by considering the *reduced form* of the model.

Rational learning, which some authors identify with Bayesian learning, thus assumes that the model structure is known by the agents while the learning process is taking place. Given the difficulties that arise in modelling this kind of learning, the bounded rationality approach has the appealing advantage of being (at least) more tractable. Moreover, the assumption that agents use a misspecified model during the learning process makes the bounded rationality approach less controversial.

In the bounded rationality approach, various notions of *expectational stability* and of *econometric learning* procedures have been the main formulations. Interestingly, the distinction between these two main procedures has to do with the 'notion' of time where learning takes place. While the *expectational stability principle* assumes that learning takes place in 'notional', 'virtual' or meta-time, *econometric learning procedures* assume real-time learning.

The *expectational stability* approach considers the influence of – and thus the distinction between – perceived laws on actual laws of motion of the economic system (see Annex 6 for a formalization). The actual law of motion results from the substitution of the perceived law of motion in the structural equations of the true model. It is then possible to obtain a mapping $L(\theta)$ from the perceived to the actual law of motion, where θ denotes the set of parameters. Rational expectations solutions $\bar{\theta}$ are then the fixed points of $L(\theta)$. Finally, a given rational expectations solution $\bar{\theta}$ is said to be

[6] Westaway (1992) prefers to distinguish closed-loop learning, where agents learn about the parameters of the decision rule, from open-loop learning, where agents form an expectation of the path for a particular variable which they sequentially update. As is pointed out, closed-loop learning will be virtually identical to the parameter updating scheme using Kalman filtering.

expectationally-stable if the differential equation $d\theta/d\tau = L(\theta) - \theta$ is locally asymptotically stable at $\bar{\theta}$, where τ denotes meta-time.

In adaptive real-time learning, agents are assumed to use an *econometric procedure* for estimating the perceived law of motion. Least-squares learning is widely used in this formulation in spite of its apparent drawbacks (see Salmon, 1995, for a criticism of this issue). A more sophisticated application of these econometric procedures is the consideration of the Kalman filter which, as is well known, nests least squares learning and recursive least squares.[7]

Notwithstanding those learning mechanisms, others have been proposed, which are in more coherence with the process of knowledge acquisition by agents that see their rationality bounded by some reason and, because of that, adopt a satisficing and adaptive behaviour *à la* Simon (see, among many others references, Simon, 1955). Salmon (1995) is, to the best of our knowledge, one of the very few references where an innovative bounded rationality approach such as *neural networks learning* has been applied in a policy-making problem. As it is well-known, (artificial) neural networks are simulations of how biological neurons are supposed to work, the structure of human brains, where processing units, the so-called *neurons*, are connected by *sinapses*, is approximated by these (artificial) neural networks.[8] In this sense, neural networks can be classified as 'non-structural' *procedural* models. Furthermore, they are in good agreement with a typical characteristic of bounded rationality: the *adaptive* behaviour. Indeed, the adaptation to the environment as a crucial characteristic of a neural network makes it distinct from many (standard) models of learning.[9]

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[7] If agents never discount past information, then Kalman filtering can be seen as a rolling least-squares regression with an increasing sample. On the contrary, if past information becomes less important, then a 'forgetting factor' can be included which gives a rolling window, or more precisely a form of weighted least squares.

[8] In Caleiro (2005) it is used this approach within a political business cycles context by considering that bounded rationality voters have to classify economic policies and outcomes as coming from opportunistic or from benevolent government behaviour.

[9] In particular, neural networks relax the constant linear reduced form assumption of *least squares learning* by considering a time varying possibly non-linear stochastic approximation of that reduced form.

6. A short conclusion and a long avenue for further studies on knowledge

We would like to conclude by acknowledging the limitations of the present paper, which, in fact, had a simple goal of pointing out some (of the many more) – hopefully the most interesting ones – of the situations that are usually considered in Economics where knowledge plays a crucial role, even if only in an implicit way. Undoubtedly, those other situations can be considered in subsequent studies, which we would like to share with other sources of knowledge, e.g. other non-economical perspectives. In doing so, we would like to be in coerence to Sargent's approach described as follows:

> "In the spirit of the bounded rationality research program, which is really to put the economist and the agents in his model on an equal behavioral footing, we expect that, in searching these literatures for ways to model our agents, we shall find ways to improve ourselves." (Sargent, 1993: 33)

Annex 1 – The formalization of Friedman's arguments

Following Friedman (1953b), the main goal of a stabilization policy is the reduction in the variation of national income or output, y, in real terms and measured from its natural level. In accordance to Friedman, y can be decomposed in two components, z and v, such that $y_t = z_t + v_t$, where z_t would be the value for output in case of absence of stabilization policy (in fact, the policy that *intends* to stabilize output) and v_t is the effect on output, at moment t, of that economic policy, independently of the date of its implementation. This means that v_t reflects the measures taken before t, at t, and even after t if the Government previously announces the decisions that will take after t.

Considering the variance as a measure of the magnitude of the variations, we have that

$$\sigma_y^2 = \sigma_z^2 + \sigma_v^2 + 2r\sigma_z\sigma_v ,$$

where σ_i, ($i = y, z, v$), represents the standard deviation of the variable i, and r is correlation coefficient between z and v. The higher σ_y^2 is the higher is the variation in output. The same type of interpretation can be made in relation to σ_z^2 and σ_v^2. But, in relation to σ_v^2, this variance can be seen as also a measure of the intensity of the stabilization policy. The more intense are the stabilizing measures the higher is the impact on the evolution of output, that is, the higher are the fluctuations in v. Thus, a large variance σ_v^2 means a strong actuation with intentions of stabilization. The correlation coefficient r takes, as it is known, values between -1 and +1. A negative value for r means that high (resp. low) values of z_t are associated with low (resp. high) values of v_t. Thus, r can be seen as a measure of opportunity/timing of the effect of the stabilization policy. In order that this policy effectively reduce the fluctuations in output it must have a positive impact if output was to be low in case of not being implemented that policy, and one negative impact if output was to be high, in case of not being implemented that policy. Thus, the correct

opportunity/timing corresponds to a negative correlation coefficient.

Notwithstanding the policy exerting its effect at the correct moment this does not guarantee the stabilization in output. One notices that the problem is not necessarily the signal of the effect, that can, indeed be known, but rather if when the policy will be exerting its effects these will be the desired ones. This is to say that, even if the policy has positive (resp. negative) effects when those would be necessary, those effects can be in magnitude such that it makes increase (resp. lower) too much output, consequently verifying a higher variation than that would be observed without being made use of any stabilization measures.

To sum up, only with r = -1 and $\sigma_z = \sigma_v$, we have $\sigma_y^2 = 0$, i.e. a full successful stabilization policy. In order to achieve some stabilization effect, $\sigma_y^2 < \sigma_z^2$, which means $\sigma_v < -2r\sigma_z$, and this will happen only if r < 0. Nevertheless, even if r < 0, the magnitude of the effects cannot be too strong. A counting of all the possible cases led Friedman to recommend a policy leading to constant effects $\sigma_v^2 = 0$ as the one that more plausibly would not be a source of instability.

Annex 2 – A formalization of the differences between adaptive and rational expectations

In order to verify the possible differences between rational and adaptive expectations let us assume a stylised model based upon an aggregate supply curve as follows:

$$y_t = \bar{y} + \alpha\left(\pi_t - \pi_t^e\right), \tag{1}$$

where y_t denotes output, whose natural level is $\bar{y}$, α is a positive parameter, and π_t denotes the inflation rate, whose expected level is π_t^e.

If the economic authorities consider targets for the output level and inflation such as, respectively, $\tilde{y} > \bar{y}$ and 0, their objective function can be:

$$L = (y_t - \tilde{y})^2 + \beta\pi_t^2, \tag{2}$$

where β is the relative degree of inflation aversion.

Given an expected rate of inflation, the minimization of society's loss (2) subject to the model (1) ruling the functioning of the economy leads to:

$$\pi_t = \frac{\alpha(\tilde{y} - \bar{y})}{\alpha^2 + \beta} + \frac{\alpha^2}{\alpha^2 + \beta}\pi_t^e. \tag{3}$$

In case of rational expectations, $\pi_t^e = E[\pi_t]$, which means that

$$E[\pi_t] = \frac{\alpha(\tilde{y} - \bar{y})}{\alpha^2 + \beta} + \frac{\alpha^2}{\alpha^2 + \beta}\pi_t^e = \pi_t^e,$$

leading to

$$\pi_t^e = \frac{\alpha(\tilde{y} - \bar{y})}{\beta}$$

and, obviously, to

$$\pi_t = \frac{\alpha(\tilde{y} - \bar{y})}{\beta}.$$ [10]

This discretionary solution can also be obtained as the limit of the solution corresponding to adaptive expectations. In case of adaptive expectations of the type $\pi_t^e = \pi_{t-1}$, expression (3) transforms into a first order difference equation

$$\pi_t = \frac{\alpha(\tilde{y} - \bar{y})}{\alpha^2 + \beta} + \frac{\alpha^2}{\alpha^2 + \beta}\pi_{t-1},$$

whose steady-state solution is:

$$\pi_t = \frac{\alpha(\tilde{y} - \bar{y})}{\beta}.$$

Annex 3 – A formalization of the irrelevance of economic policies

[10] Note that the equality between the actual level of inflation and the expected one is achieved *a posteriori*. If this equality was considered *a priori* – like it would be in the, so-called, rules solution – then, clearly, a better result could be obtained as inflation would be at a zero level whereas output would be (also) at the natural level.

In what concerns the irrelevance of economic policies, let us consider the following model. Let

$$Y_t^d = a + bP_t$$

be the equation of aggregate demand, where P_t represents the general level of prices. The introduction of an instrumental variable x_t, as well as some stochastic shock, u_t, affecting demand leads to

$$Y_t^d = a + bP_t + cx_t + u_t .$$

In relation to aggregate supply, let us consider that

$$Y_t^s = \overline{Y} + d\left(P_t - P_t^e\right) + v_t ,$$

where $\overline{Y}$ represents the potential or natural level of output, P_t^e represents the expected value of the level of prices, at moment t, and v_t represents a stochastic shock affecting supply.

Plainly, when considering only the demand side of the economy, the economic policy is (on average) efficient as, in general, will be possible to use x_t in order to (on average) achieve a target level for income, say $\widetilde{Y}$. Clearly, this result depends upon the knowledge (or not) of the realization of the demand shock u_t before the determination of the value to be assumed by x_t.

That result on the efficacy of economic policies is indeed challenged when introducing the supply side of the economy, by that also meaning the knowledge that is assumed to be present in the determination of expectations. Going over the mathematical details, it is possible to verify that when assuming a rational use of the information, i.e. the knowledge that is available when determining the level of prices that will clear the market, output will follow the expression:

$$Y_t - \overline{Y} = \frac{bv_t - du_t}{b - d} ,$$

which shows that output will only differ from its potential level in result of the existence of random factors, by that meaning the irrelevance, i.e. the complete inefficacy of the economic policies.

Annex 4 – A formalization of the time inconsistency of decisions

The time inconsistency of economic policies, in particular, or decisions, in general, is a phenomenon that can be, as well, related with the level of knowledge. To put it clearer, the decisions suffer from that problem when being determined for one (future) moment *t*, are no longer optimal as the result of time passage, which is a question that appears associated, normally, to the existence of rational expectations. In this particular case, economic policies are not considered credible when they are time-inconsistent. The model that follows illustrates this basic question.

Let us consider that the economic authorities consider the level of (real) output and the inflation rate, as objective variables, in such a way that the utility function is:

$$W = -\tfrac{1}{2}\pi_t^2 + \alpha y_t ,$$

where, in accordance with an aggregate supply curve,

$$y_t = \bar{y} + \beta\left(\pi_t - \pi_t^e\right).$$

In this in case it is easy to verify that, for any expected rate of inflation, the optimal inflation rate is $\pi_t = \alpha\beta$. This corresponds to the so called discretionary solution. Any another decision, namely $\pi_t = 0$, that would correspond to the rules solution, is not considered credible as it suffers from time inconsistency. This is so because the economic policy that would lead to the best result would be, indeed, to promise to choose $\pi_t = 0$, in order to influence the expectations in a favourable way, i.e. to make $\pi_t^e = 0$, but later choosing $\pi_t = \alpha\beta$. This would be the so-called cheating solution.

Annex 5 – A formalization of the delegation of policies solution

In order to formalize the argument on the delegation of policies let us follow,

for instance, Lippi & Swank (1999), and assume that the preferences of the economic authorities (*and also of the society*) can be represented by the following loss function:

$$L = \pi^2 + \beta u^2, \tag{4}$$

where π and u represent the inflation and unemployment rates, respectively. The parameter β indicates the relative cost, for the economic authorities being representative agents of society's objectives, of unemployment in relation to inflation. The smaller is β the higher is the degree of aversion to the inflation, i.e. $1/\beta$. One then says that the smaller is β the more conservative will be the agent responsible for the economic policy.

In what concerns the functioning of the economy, let us consider that the unemployment rate, u, deviates from its natural value, u_n for two kinds of reasons: (*i*) when the inflation rate, π, deviates from its expected value π^e; and (*ii*) when there are shocks (in the productivity), ε, which are considered of random nature, with null average and variance σ_ε^2. If this is so, the curve of Phillips that follows intends to be the representative model in the way of functioning of the economy:

$$u = u_n + \theta\left(\pi^e - \pi\right) + \varepsilon. \tag{5}$$

The minimization of the objective function (4) subject to the restriction (5), given an expected rate of inflation, leads to:

$$\pi = \frac{\beta\theta\left(u_n + \theta\pi^e + \varepsilon\right)}{1 + \beta\theta^2}.$$

As in equilibrium, $\pi^e = \mathrm{E}[\pi \mid I_{t-1}]$, then $\pi^e = \beta\theta u_n$, which means

$$\pi = \beta\theta u_n + \frac{\beta\theta}{1 + \beta\theta^2}\varepsilon.$$

This expression shows that, besides the use of inflation as form of reaction to the shocks, i.e. a correct use of the discretionary economic policy, the economic authorities generate an unnecessary inflating bias, $\beta\theta u_n$, which is an appalling component of the discretionary economic policy. To eliminate the inflating bias, the economic authorities would have to be the most conservative ones,

i.e. $\beta = 0$, but that also would mean no reaction to the shocks. The question in place is, then, to know if there exists another agent, *more conservative than society*, for which the resultant return on a diminished appalling component more than compensates the resultant loss from a worse reaction to the shocks. If this is the case then for the economic authorities themselves, as well as for society, is advantageous, given its objective function (4), to delegate the economic policy to an agent (central bank) more conservative, say a with a smaller parameter of aversion to unemployment - let us call β_i to it.

Avoiding the mathematical details, it is possible to show that, *for the economic authorities, i.e. for society itself*, the optimal agent to whom the economic policy should be delegated is characterized by a β_i satisfying the expression:

$$\beta_i u_n^2 \left(1 + \beta_i \theta^2\right)^3 + \sigma_\varepsilon^2 (\beta_i - \beta) = 0,$$

which shows that, indeed, the delegation of the monetary policy in an agent more conservative than society is, on average, advantageous for the society, whenever the natural unemployment rate is positive (i.e. higher than the ideal one).

Annex 6 – The formalization of learning

Following Evans & Guesnerie (1993) and Evans & Honkapohja (1995), let us suppose that some *state variable,* y_t, depends upon its own expectations, $E[y_t \mid \mathbf{I}_{t-1}]$, plus being influenced by some control variable, x_t, which, in turn, is generated by a first-order auto-regressive process, i.e.

$$y_t = a + bE[y_t \mid \mathbf{I}_{t-1}] + cx_t$$

and

$$x_t = \rho x_{t-1} + \varepsilon_t,$$

where $\rho > 0$ is a measure of *inertia* in the systematic utilisation of the instruments i.e. some kind of *policy rule* and ε_t is a *discretionary* policy shock assumed to be *i.i.d.* with finite variance.

Let us assume also that at time t agents believe that y_t follows the stochastic process:

$$y_t = \alpha_n + \beta_n x_{t-1} + \varphi_n \varepsilon_t \tag{6}$$

where n indexes the period over which expectations are revised.

If agents believe that (6) is the structure of the relation between the state and the control variables, their expectations of *y* for period t given the information available in $t-1$ will be given by

$$E[y_t \mid \mathbf{I}_{t-1}] = \alpha_n + \beta_n x_{t-1}. \tag{7}$$

But the way in which expectations are formed will affect the actual evolution of the state variable. This implies that y_t will be generated by

$$\begin{aligned} y_t &= a + b(\alpha_n + \beta_n x_{t-1}) + c\rho x_{t-1} + c\varepsilon_t \\ &= (a + b\alpha_n) + (b\beta_n + c\rho)x_{t-1} + \varepsilon_t. \end{aligned} \tag{8}$$

From there it is evident that the *learning process* of agents must be taken into account. Unless the economy has achieved a rational expectations equilibrium, i.e. when

$$E[y_t \mid I_{t-1}] = \frac{a}{1-b} + \frac{c\rho}{1-b} x_{t-1} \Rightarrow y_t = \frac{a}{1-b} + \frac{c\rho}{1-b} x_{t-1} + c\varepsilon_t,$$

then believed values of the state variable (6) will not be the same as the actual ones (8). We can assume that agents will realise that their rule (7) is leading them to forecast errors and so will revise it accordingly. One simple way to formalise this revision process is to admit that at time $n+1$ a new reduced form rule will be generated as follows:

$$y_t = \alpha_{n+1} + \beta_{n+1} x_{t-1} + \varphi_{n+1} \varepsilon_t. \tag{9}$$

Relating (8) with (9) we derive the learning process of agents to be characterised by

$$\alpha_{n+1} = (a + b\alpha_n), \quad \beta_{n+1} = (b\beta_n + c\rho), \quad \varphi_{n+1} = c.$$

If $|b| < 1$ the learning process for α_n and β_n will eventually converge to the rational expectations parameters $a(1-b)^{-1}$ and $c(1-b)^{-1}$, respectively.

However, if $|b|>1$ the learning process will diverge, leading to an obvious dynamic divergence of the economic system.

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