The paper deals with the effects of government policy promoting basic research as an incentive to economic growth. Government is included into a Schumpeterian endogenous growth model, in which, thanks to the income proceeding from proportional taxation of monopolistic enterprises profits, it is enabled to carry out basic research activities which match applied research carried out by private enterprises. The results obtained show how it is possible that government determine a taxation level able to optimize economic growth. The effectiveness will be determined by the market. In particular, high competition levels make government policy less effective. [JEL Classification: 031, 038, 040]

1. - Introduction

The object of the present paper is to assess the role and effectiveness of basic, government-promoted research aiming at stimulating economic growth and innovation, through the creation of an endogenous growth model, where the growth of the general level of knowledge is determined by both basic research and applied research.

Basic research has always been given little importance within
endogenous growth theory. As emerging from a review of current literature on public research, it can be seen that only a small number of authors has dealt with the subject in a macroeconomic context.

Among the economic scientists making a distinction between basic research and applied research are to be mentioned Aghion and Howitt (1996), who contribute a heterogeneity feature to a Schumpeterian growth model. These authors distinguish between innovative activities producing "fundamental knowledge", the kind of knowledge able to determine new opportunities but not to produce new processes and products; and the development productive of "secondary knowledge", which allows the new opportunities to be accomplished. A few years later, David (2000) discussed the issue of "open science" devoting his interests in particular on the distinction between the two types of research. His analysis focused on the market ability to provide basic research of a good level. The author, although interested in finding out which could be the correct policy for government research activities, dealt extensively with the externalities of basic research on industrial research. A similar diversification is also present in Morales (2004) who analyzed the effects of the different types of research on economic growth. On the subject of externalities between basic research and applied research are also to be mentioned Grossman and Helpmann (1991) who devoted to the subject a section of the introductory chapters of their work.

The second feature which is going to be dealt with in this paper concerns the role of the government in the field of research. Also with respect to this area, literature presents some gaps. The subject is generally dealt with in the perspective of the analysis of industrial organization and for this reason the existing works concentrate on the microeconomic effects of aids to research and patent policy. Nonetheless, for the aims of the present paper some

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1 The distinction between basic research and applied research is a necessary one in each economic policy choice concerning this subject. In order to understand, for example, the way in which growth can be enhanced by a subsidy policy, it will be necessary to assess, first of all, which between basic research and applied research is best favoured as regarding subsidies.
of these works are worth mentioning, such as Mamuneas and Nadiri (1996); Ham and Moverry (1998) and Mamuneas (1999) as they provide a microeconomic grounding to the hypothesis of public research implying positive externalities on private productivity.

Among the authors that consider instead public research from a macroeconomic point of view can be mentioned Glomm and Ravikumar (1994) who introduced a model where economic growth is determined by public research. The above mentioned work evidenced however distributional problems and, in such a context, the role of public research was limited to procure endogenous technological innovations, thus avoiding the need to resort to a private research and development sector. Pelloni (1997) analysed the hypothesis that government investments in basic research increase economy growth performance, excluding the same results for private research. Park (1998) included public research (both basic and applied) in the model of Romer (1990). He assumed that public research indirectly contributed to economic growth because of the positive externalities on the accumulation of knowledge in the private sector. Anyway, the work was less focused on public research policy than on the spillover of research.

Our work, whose aim is that of enlarging Aghion and Howitt model (1998) with the inclusion of government founded basic research, can be placed in the framework just outlined. Our paper features a model in which economic growth is provided by research activity, both basic and applied. Private enterprises invest in applied research projects which are likely to lead to new products or new production technologies. If the above said research projects are successful, the promoting enterprise appropriates all monopoly profits in the production of its own sector intermediate good. With every innovation, the general level of knowledge is also likely to expand, which is the basis of new research projects. Basic research, on the other hand, is carried out by government, which will devote to it the whole internal revenue obtained through proportional taxation of monopolistic enterprises profits. We posit complementarity between basic and applied research; for this reason there
will be sector-to-sector spillovers between government research and enterprise innovation. However, the spillovers are not of a direct kind. The knowledge introduced by basic research has no effects on the likeliness on new discoveries, but it has on the production parameter of innovations.

There are three relevant types of interaction between basic research and applied research. They are complementarity, replaceability and a third form which is a mix of the former two. Complementarity is treated extensively in the specific literature. Among the authors mentioned, such a view is present in the works of Aghion and Howitt (1996); Park (1998) and David (2000). According to this scheme, the two research types have positive effects on each other. High levels of basic research are likely to determine a growth in applied research productivity, as they allow the researchers operating in the latter sector an adaptation of the innovations achieved in the former sector. A highly innovating economy is also more stimulating for basic research.

Complementarity is not completely accepted in the literature, as some empirical studies have shown how there is a paradox in the interaction of basic research and applied research. Namely, although it is an opinion commonly held that in the long run basic knowledge is a critical element in turning applied research into a profitable investment for enterprises, in the short period length a form of replaceability can be noticed between the two types of research. Limitation in resources often results in promoting basic research to the detriment of applied research. In order to assess such a feature, Morales (2004) employs a model that includes both complementarity and replaceability between enterprises. Quite infrequent are instead the articles posing complete replaceability between the two types of research. Our paper posits complementarity between the two types. The results obtained are nonetheless similar to those obtained by Morales (2004), which shows a short-lived replaceability degree between the two research types.

The results achieved can be divided into effects on the growth rate and effects on applied research. As for the former, our model

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shows that the government can finance basic research by implementing a tax rate which maximize economy growth rate. With reference to applied research, it emerges that its productivity grows discontinuously as basic research increases. Namely, things being equal, tax increase by the government, resulting in an increase of basic research, determines a decrease in the number of researchers employed in the sector of applied research. This happens because taxation influences directly and proportionally monopoly profits of the innovated companies. In this way, taxes reduce the spur to applied research by companies.

The remaining part of the paper is structured as follows. In the second section is introduced the model and are illustrated its main features. In the third section are introduced analytic results and is explained their meaning from an economic point of view. In the fourth section a numeric simulation is carried out in order to analyze the performance of the growth rate of economy as the model parameters change. This procedure will also make possible to assess the optimal taxation level. The final section contains the conclusions.

2. - The Model

The model of Aghion and Howitt, in its very first version\(^3\), quite stylized under some respects, featured some interesting results that have largely influenced subsequent analysis. In the first place, it retrieved some Schumpeterian insights and placed them in a model in which growth is generated by a casual succession of vertical innovations (i.e. innovations determining a rise in the quality of products), due, in their turn, to a research activity characterized by doubtful results. Within the model was also retrieved the concept of creative destruction. Namely, the authors took into consideration a kind of vertical innovation characterized by the fact that innovations make old technologies or old products obsolete. Such obsolescence involves the existence of a single steady-state equilibrium and the opportunity of a cyclical growth. The latter is a consequence of the negative relationship between current and future

research. Innovation, in fact, beyond implying positive externalities on future research and development, grants negative externalities for current producers (business-stealing effect).

In Aghion and Howitt (1998) the authors introduced two important new features concerning both the possibility to produce the final good by employing a large variety of intermediate goods and the introduction of accumulation of physical capital. The resulting model is a hybrid one that can be interpreted either as a Schumpeterian model with physical capital or as a Solow model with endogenous technological progress.

The model we are going to introduce is characterized by features similar to those of Aghion and Howitt's one (1998) in its multisectoral version. Economy is populated by a mass of individuals $L$ with linear intertemporal preferences following the specification: $u(y) = \int_0^\infty ye^{-rt}dt$, where $r$ is both the rate of time preference and the interest rate. Each individual is also a worker so that the labour supply is equal to $L$.

Economy produces a consumer good, $y$, and a continuum of intermediate goods indexed in the unit interval, $x_{it}$. There are $n$ sectors of applied research, one for each intermediate good present in the economy, and a government funded sector of basic research.

The amount of final good that can be produced through the intermediate good $i$ in the time $t$ depends exclusively on the amount of the intermediate good $x_{it}$ employed, according to the production function:

\[ Y_{it} = A_{it}F(x_{it}) = A_{it}x_{it}^\alpha \]

where the $A_{it}$ stands for the productivity of the last generation of the intermediate good $i$. Aggregate output of the final good is equal to the sum of the products obtained through each intermediate good, that is:

\[ Y_t = \int_0^1 Y_{it}di \]

The price enforced by each monopolist\(^4\) is $p_{it} = A_{it} F(x_{it}) = \ldots$

\(^4\) Each intermediate sector is monopolized by the firm that obtained the latest innovation in the sector though a patent or innovation process.
$A_{it}\alpha x_{it}^{\alpha-1}$, and therefore the monopolists labour demand (and his production) is equal to:

$$x_{it} = \tilde{x}\left(\frac{w_t}{A_{it}}\right) = \left(\frac{w_t}{\alpha^2 A_{it}}\right)^{\frac{1}{\alpha-1}}$$

where $w_t$ is the wage measured through consumer goods. The profit is a fraction $1 - \alpha$ of the incomes:

$$\pi_{it} = A_{it}\tilde{\pi}\left(\frac{w_t}{A_{it}}\right) = A_{it} \left(1 - \alpha \frac{w_t}{A_{it}} \tilde{x}\left(\frac{w_t}{A_{it}}\right)\right)$$

It is assumed that there is a research sector for each intermediate good, in which companies compete in order to establish the next generation for that intermediate good. The innovation rate for each sector is equal to $\lambda n_{it}$, where $\lambda$ is the probability per unit of time that the event will occur now (according to a Poisson process) and $n_{it}$, is the number of researchers involved in the sector. Although each sector success rate is independent, all innovations stem from the same common knowledge basin. The level of such a knowledge is represented by the “leading-edge” technology, whose productivity parameter in the time $t$ is $A_{t\max}$.

Any innovation in the time $t$, in any sector $i$, allows the person

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5 The intermediate good production function follows a production function where to a given labour unit corresponds a given product unit.

6 In equation (2),

$$\tilde{x}\left(\frac{w_t}{A_{it}}\right)$$

shows that $x$ depends on

$$\left(\frac{w_t}{A_{it}}\right)$$

according to the formula specified in third term.
who obtained the innovation to start producing in that sector employing the *leading-edge technology*. The previous monopolist in the sector, whose technology has been superseded, is then replaced by a new one. When this happens, the technology parameter for that sector $A_t$, shifts to parameter $A_t^{\text{max}}$.

It is this latter parameter that basic research influences. Such an assumption reflects the common belief that in a long interval of time common knowledge cannot be enlarged if basic knowledge does not undergo a further development.

For this reason, it is assumed that the growth rate of $A_t^{\text{max}}$ is given by the expression:

$$\frac{\dot{A}_t^{\text{max}}}{A_t^{\text{max}}} = \lambda \psi b_t \ln \gamma$$

where $\psi$ is the intensity of discovery probability of basic research, $b_t$ is the number of people employed in basic research and $\ln \gamma$ is a proportionality factor.

The form of the above expression has a definite meaning. It establishes that basic research and applied research are complementary rather than interchangeable. Such an assumption is clear in a sense at least. As already mentioned, it is a commonly held opinion that a higher level of basic knowledge has a positive influence on innovation possibilities by companies. A better knowledge of natural laws, a greater number of starting point ideas and better trained researchers are some of the reasons on which such an assumption is grounded.

Less easy to understand can be why higher levels of applied research have positive effects on basic research. However, considering that an economy with a strong tendency to innovate is undoubtedly a dynamic economy, it is understandable that basic research has greater opportunities to develop.

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7 It is taken for granted that the present phenomenon can be also modelled like a Poisson model.

8 Complementarity between basic research and applied research is well documented in the specific literature. Among the others, it is discussed in the works by Aghion P. - Howitt P. (1996); Park W.G. (1998) and David P.A. (2000).
In each given time there is a distribution of the technological parameters of the various sectors, $A_{it}$, that can have values between zero and $A_{i}^{\text{max}}$. That distribution is not constant, as the most innovating sectors shift towards $A_{i}^{\text{max}}$, the level reached by the last innovated sector. In spite of this, the form of distribution must not change, although the sectors occupying the various positions of the distribution change with every innovation. In practical terms, in the long run the distribution through the various sectors of the parameters of the consistent productivity, 

$$a_{it} = \frac{A_{it}}{A_{i}^{\text{max}}}$$

is given by the distribution function:

$$H(a) \equiv a^{\ln \gamma}$$

with $a \in [0,1]$, whatever the performance of the aggregate rate of innovation over time.

Thanks to this property, technological progress produces a uniform and proportional shift of the distribution of absolute productivities, according to the law of motion governing the evolution of social knowledge (equation (4)). This also represents the growth rate of aggregate product.

As for the analysis of aggregate product and intersectoral allocation, it must be considered that, within the model, resources are continuously reallocated among the various sectors. Namely, as economy is influenced by innovations at any time, wages are always rising. This involves a gradual decrease in the profits and the number of workers employed in the less innovating sectors. Such a phenomenon represents a different, more gradual version of creative destruction that can be called crowding-out effect.

Because the distribution of relative productivities is unchanging, the different sectors can be grouped according to their relative productivity $a$ rather than their index $i$. Now, after the introduction of the concept of salary adjusted to productivity, equal
to the ratio between salary and productivity of the leading-edge sector

\[ \omega_t \equiv \frac{w_t}{A_t^{\max}} \]

it is possible to specify the labour demand function for a sector with relative productivity \(a\) in the time \(t\). That will be equal to:

\[ \tilde{x}(\omega_t/a) = \left( \frac{\omega_t/a}{\alpha^2} \right)^{1/\alpha-1} \]

The aggregate demand of labour can be then obtained by multiplying such a function for the density of the sector, \(h(a) \equiv H'(a)\), and summing over \(a\).

In order to assess instead the number of basic researchers, it is necessary to take into consideration government financing in such activity. Taxes are drawn from monopolists profits, according to a proportional rate equal to \(\tau\). The monopolist enterprises profits in the sector \(i\) in the time \(t\) are equal to

\[ \pi_{it} = A_{it} \left( 1 - \alpha \right) \frac{w_t}{\alpha} A_{it}^{\max} \left( \frac{w_t}{\alpha^2 A_{it}} \right)^{1/\alpha-1} \]

To obtain total profits in the time \(t\), profits themselves have to be classified according to salary adjusted to productivity, as resulting from the following expression:

\[ \pi_{it} = A_{it} \tilde{\pi}(\omega_t/a) = A_{it} \frac{1-\alpha}{\alpha} \frac{\omega_t}{a} \tilde{x}(\omega)a^{1-\alpha} = A_{it}^{\max} \frac{1-\alpha}{\alpha} \frac{\omega_t}{a} \tilde{x}(\omega)a^{1/\alpha-1} \]

It is possible to sum up the profits of the single monopolist
enterprises in order to obtain the total tax revenue. This is what comes out:

\[
\pi_t = A_t^{\max} \int_0^1 \left\{ \frac{1 - \alpha}{\alpha} \frac{\omega}{a} \frac{1}{\bar{x}(\omega) a^{1-\alpha}} \right\} h(a) da
\]

whose final result is as follows:

\[
\pi_t = A_t^{\max} \frac{1 - \alpha}{\alpha} \omega \bar{x}(\omega) \frac{(1 - \alpha)}{\ln \gamma + (1 - \alpha)}
\]

Taxes area percentage \( \tau \) of total profits and will be equal to:

\[
T_t = \tau A_t^{\max} \frac{1 - \alpha}{\alpha} \omega \bar{x}(\omega) \frac{(1 - \alpha)}{\ln \gamma + (1 - \alpha)}
\]

As for the features according to which the model is built, the revenue coming from monopoly taxes are entirely employed in the research activity by the government. Research is carried out by researchers who are paid the same wage as the researchers employed in the private sector. Therefore, the number of workers employed in basic research is equal to:

\[
b_t = \frac{T_t}{\omega} = \tau A_t^{\max} \frac{1 - \alpha}{\alpha} \bar{x}(\omega) \frac{(1 - \alpha)}{\ln \gamma + (1 - \alpha)}
\]

Having an idea of the flow of researchers involved in basic research in the time \( t \), it is possible to obtain the labour market equation. The following expression shows how workers are divided into the various sectors:

\[
(6) \quad L = n + \tau A_t^{\max} \frac{1 - \alpha}{\alpha} \bar{x}(\omega) \frac{(1 - \alpha)}{\ln \gamma + (1 - \alpha)} + \int_0^1 \bar{x}(\omega/a) h(a) da
\]

It can be seen that exists a positive relationship between the
workers employed in research and wages. Namely, the higher the number of researchers, the higher the scarcity of workers in the production sector and therefore the higher the wages. Wages increase not only as \( n \) grows, but also as the resources used in basic research grow, and so as \( \tau \) grows.

For equilibrium to be possible, it is necessary to take into consideration the non arbitrage equation. Analysing steady-state equilibrium, the level of research is constant, so it is: \( n_t \equiv n, \ \omega_t \equiv \omega, \ \text{e} b_t \equiv b \). Given such conditions, and considering an enterprise which innovates in the time \( t \), the latter will be characterized by a technology parameter \( A^\text{max}_t \), until an innovation is introduced in that sector. If the enterprise keeps its monopoly power in the time \( t + s \), given that wages grow at a constant rate \( g \), the flow of profits in the period will be \( A^\text{max}_t \pi(\omega e^{gs}) \). The likelihood that the enterprise is still in activity in the time \( t + s \), corresponds to the likelihood that no innovation has taken place, that is to say \( e^{-\lambda ns} \). Given such premises, the value of the enterprise innovating in the time \( t \) is given by the current expected value of the profits net of taxes by \( t \) until infinity, discounted by interest rate \( r \):

\[
(7) \quad V_t = A^\text{max}_t \int_0^\infty e^{-(r+\lambda n)s} \pi(\omega e^{gs})(1-\tau)ds
\]

The non arbitrage condition of research, which determines the level of research in the steady-state, implies that the salary is equal to the marginal expected value of research \((\lambda V_t)\). Dividing both terms of equation (7) by \( A^\text{max}_t \) the non arbitrage equation is obtained:

\[
(8) \quad \omega = \lambda \int_0^\infty e^{-(r+\lambda n)s} \pi(\omega e^{\lambda n s \ln g})(1-\tau)ds
\]

The non arbitrage equation shows a negative relationship between \( n \) and \( \omega \): as the wages of those occupied in the production increase, the number of researchers decreases. The positive and negative trends respectively of the labour market equation and the non arbitrage equation grant the existence and uniqueness of a steady-state equilibrium.
3. - Main Results

In order to proceed to a deeper analysis of the results, the two equations can be written as follows:

\[
1 = \lambda \left[ \frac{1 - \alpha \bar{x}(\omega)(1 - \tau)}{r + \lambda n + \frac{\alpha}{1 - \alpha} \lambda n \psi b \ln \gamma} \right]
\]

(9)

\[
\bar{x}(\omega) = (L - n) \left( \frac{\ln \gamma + 1}{1 - \alpha} \right) \left( \frac{\alpha}{A_t^{\max} \tau (1 - \alpha) + \alpha} \right)
\]

(10)

On the basis of the two formulas it is possible to assess the main results of the model. Concerning the number of applied researchers, the effects of government policy seem to be totally negative. Namely, the taxation of monopoly profits influences the main inducement to innovate by companies. Furthermore, as basic research influences the level of technology \( A_t^{\max} \), it increases the crowding-out effect, shown by the third term in the denominator of the non arbitrage equation. Lastly, one more effect of taxation is the decrease in the level of \( \bar{x} (\omega) \), that is the number of workers employed in the sector with the leading-edge technology, which implies, in its turn, a further reduction of monopoly profits.

For the reasons mentioned, taxation is likely to have negative effects on the level of applied research \( n^9 \). Anyway, this is not to

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\(^9\) Following a referee comment we tried to insert a different source of revenue (instead of tax on monopolist profits) and we studied its effects on investment in applied research. In our model, we don't include agents' choices, so we can't obtain significant results from this attempt. We make a numerical simulation including a proportional tax on wages in our model, and we obtain that the optimal rate of taxes was 100%. We think that after introducing workers' choices in the model, it could be very interesting to study the effects of different kinds of taxation. We can expect that taxation on all wages will produce a reduction in total labour force. This reduction in total labour force could induce a drop in research amount and a fall in production. Otherwise, taxation on skilled workers could bring to a shift of labour force from research to production.
say that government policy has a negative influence on the ability of economy to innovate. Namely, as a consequence of such a formulation of the model, if the government decided not to carry out basic research for a given period of time, reducing the tax rate to zero, there would be no technological progress. Such a conclusion stems from the hypothesis of the law of knowledge motion, according to which, in the long run, no conspicuous increase in the common knowledge can be had if there is no increase in the basic knowledge.

A further formulation of results is therefore necessary to assess all the effects on the growth of economy. The whole growth process should be studied in order to evaluate the effects on growth rate, that is \( g = \lambda n \psi b \ln \gamma \), but it could be enough to analyze the performance of \( n \cdot b \), as the other factors do not depend on government policy. The performance of \( n \) and \( b \) can be obtained by the following equations:

\[
\begin{align*}
    n &= \frac{\lambda(L-n) \left( \ln \gamma + 1 - \alpha \right)}{A_t^\max \left( \frac{\alpha}{\tau(1-\alpha) + \alpha} \right)} (1-\tau) - r \\
    b &= A_t^\max \tau(L-n) \left( 1 - \frac{1-\alpha}{\frac{\alpha}{\tau(1-\alpha) + \alpha}} \right)
\end{align*}
\]

Considering all the parameters as constants excepted \( \tau \), the multiplication between the two factors will result in a continuous function of \( \tau \). The function has, according to the Weierstrass theorem, a maximum. It has been seen that such a maximum cannot be on extremes, as the function with \( \tau \to 0 \), from the right, and \( \tau \to 1 \), from the left, is a decreasing one. This implies the maximum must be in the middle. This outcome will be confirmed in the next paragraph though a numeric simulation of results, as \( \tau \) changes.
The presence of a maximum shows that it exists a tax rate value that maximises economic growth. This implies that government policy influencing basic research can be adjusted so as to maximize the positive effects on economic growth rate. Such a result is a particularly relevant one as, among other things, it is obtained through a proportional taxation of income acting directly on private incentives to innovating. The previous works on the same subjects had namely taken for granted that government policy was financed through “lump-sum taxes” so as to focus on the general effects of research on growth only. Within the present model, where it is assumed that public research, which is not on a competitive basis with the private one, has always positive effects on economic growth, it has been decided to assess how the financing of these policies, which necessarily influences enterprises' income, has consequences on total results.

Obviously, the above said effects depend in large measure on the conditions of the country where such a policy is carried out. Namely, as it can be seen from the model results, economic conditions, shown by the different parameters, can make government policy more or less effective. The analysis of what occurs as parameters change will be carried out through a numeric simulation in the next paragraph.

The model's analytic difficulties do not allow to assess the effects of government policy on social welfare. In spite of this, it is possible to demonstrate, in any case, that the growth level achieved through the market is other than what is considered the optimal level for society. This is a typical consequence with this class of models. Aghion & Howitt (1998), and Barro & Sala-i-Martin (2002) show how in new-Schumpeterian endogenous growth models, the outcomes achieved by the market are usually less significant than those obtainable by making the most of collective welfare. Such a consequence is probably due to two sets of reasons. The first set is connected to some peculiar features of the model, such as appropriability effect and business-stealing effect, not related to the role of government in stimulating basic research. The impact of the monopolistic structure of the intermediate sector determines social welfare of
a minor entity, because, unlike the social planner, to whom innovation is always positive, a monopolist discounts his own profits at his own expected innovation rate. Such a feature reduces the amount of the research in case of *laissez-faire*. The second reason is instead closely connected to the hypothesis about the aims of government policy. It has been posited that the government carries on basic research projects with the aim of maximizing the growth of economy. It has to be considered, however, that maximizing the growth do not necessarily leads to the highest social welfare level. Namely, social utility is given not only by economy's innovation capacity, but also by consumption levels. In this model, innovation takes place to the detriment of final goods production (and therefore of consumption), so in the short period there can be a phase of intense growth characterized by low consumption levels. In the long run these achievements will obviously be balanced, as growth will also act as a factor multiplying consumption.

4. - Numeric Simulation of Results

The analytic expressions introduced show how the functions of $n$ and $b$ are respectively decreasing and increasing with respect to $\tau$. Their product does not have, instead, a single relationship with respect to the tax rate. The latter will increase in an initial stage and decrease later on. Such a feature confirms the existence of a value of $\tau$ which maximizes the product $n \cdot b$. Obviously both the function-maximizing value of $\tau$ and the absolute level of the product depend on the values of the parameters.

The object of the present paragraph is to assess the assumptions just carried out on the analytic function through a numeric simulation of the function $h = f(\tau) = n \cdot b$. The aim is therefore to carry out not a quantitative analysis but rather the assessment of the performance of the function as some parameters change. A qualitative study is then attempted through the theoretical simulation of the model. As it is known, in order to carry out a simulation some values must be provided to the
different parameters involved. It is therefore of great importance to reconsider the meaning of each one of the parameters present in the two formulas.

Parameter $\alpha$, whose variation can be between zero and one, shows the elasticity of the demand curve that the monopolists in the intermediate sector are to satisfy, and it also shows the level of market competition. From the analysis of the general model it is known that in such a context competition is without a doubt negative for growth, as it determines a decrease both in the value of $n$ and $b$, all other conditions being the same.

The probability of an innovation occurrence in the time unit is expressed by $\lambda$, which is therefore the probability flow of a new discovery. This parameters can take on all values higher than zero. The same behaviour is shown by $\psi$, which means the same as $\lambda$, but referring to basic research. Parameter $A_{i}^{\text{max}}$ shows, in the time $t$, the productivity of the sector where the last innovation has taken place, so it reveals frontier technology. The level of population, taken as a constant one in the model, is equal to $L$. The last one, $r$, shows the economy interest rate, which is the same as the rate of time preference by the agents.

Some of the parameters which simply indicate the scale of economy have been left constant in the carrying out of the simulation, that is $\gamma$, which has been established as equal to 1,2 and $L$, which has been established as equal to 100 so as to index the results of $n$ and $b$ on this scale. One more parameter which has been considered constant and which has been set equal to 0,04 is $r$, whose influence on the result of the model is very small. The analysis then focused on the change showed by the remaining four parameters.

Before considering the relationship of dependence of the function we are analyzing and the parameters values, the form of the function can be taken into consideration. As it comes out from each simulation, the function shows a Laffer curve trend, which grants an internal maximum, an essential feature for the significance of the results obtained from an economic point of view.

The data that will be used in the graphs of the function have been obtained by simultaneously solving the two functions of $n$ and
Once the parameters' values have been set and the unknown element \( \tau \) is allowed a variance between 0 and 0.7\(^{10} \). In this way have also been obtained the values that maximize the target function.

Setting out to analyze the consequences of the change of parameter \( \alpha \) on the product \( n \cdot b \), theory suggests that as the elasticity of the demand the monopolist has to satisfy grows, the propensity to research decreases. It is therefore possible to forecast in theory that as \( \alpha \) increases, the product total value decreases. More difficult to forecast analytically is instead whether the value maximizing the product is higher or lower in the case of a higher value. Our analysis has been carried out on the basis of three values, one simulating a situation of low competition (0.1), one an intermediate level (0.5), and one referring to high competition levels (0.9).

In the Appendix are to be found the graphs (Graphs 1, 2, 3) resulting from the three different competition levels. They show how, as \( \alpha \) increases, product \( n \cdot b \) strongly decreases. It can also be seen as the level of taxation maximizing the target function decreases with the increase of competition, but in a different way. Namely, it is equal to 0.36 in the case of the lowest competition level, goes down to 0.25 in the intermediate situation and is equal to 0.24 with the stiffest competition. Such a performance shows that as \( \alpha \) increases, government policy is less and less effective, given that the profit levels of innovating enterprises are very low. For this reason, private companies will not be much interested in investing on applied research and the government, in its turn, will have less inducement, as well as lower resources, to carry out basic research.

Another parameter influencing the function at hand is \( A_t^{\text{max}} \). It is possible to see what happens when employing a lower parameter than the one used in the previous analysis. The graph in the addendum (Graph 4) shows the results of the function\(^{11} \) with a parameter equal to 0.7. It can be seen that, as the starting

\(^{10}\) The possible values for \( \tau \) are those ranging from 0 to 1, but the values higher than 0.7 have been ignored because they are meaningless in real terms.  
\(^{11}\) The comparison is with the results in Graph 1, where \( A_t^{\text{max}} = 1.6 \).
level of knowledge decreases, there is also a decrease of the effectiveness of basic research on growth, which requires a higher tax rate. In this way, an economic system starting from lower technological levels must undergo higher costs in order to improve its situation.

To conclude, we can take into consideration the parameters that show the productivities of the two types of research. To make the analysis easier, it is possible to assume a relation between $\lambda$ and $\psi$, perhaps considering the one as being twice as much as the other. In this way, it will be possible to assess the consequences on the product of the combined change of the two parameters. Supposing the doubling of the parameters at hand with respect to the starting point, the efficacy of the policy is similar to the one obtained before, but the same results require now a lower tax rate. It comes out that, in the case of greater productivity by both basic and applied research, the government can apply a lower amount of taxes in order to carry out its policy. The outcome is in Graph 5 in the Appendix.

To sum up, the results coming out from the simulation show that the effectiveness of government public policy depends on market conditions. The higher the competition among businesses, the lower the efficacy of public policy. As for leading-edge technology, it has just a scarce influence on government policy. However, it has to be considered that the lower the level of the leading-edge technology, the higher the taxation costs for enterprises. Finally, the possibility of success of research, both basic and applied, influences not so much government policy as the need of resources to invest. For this reason, if research has more opportunities to be successful, a lower tax rate will suffice to obtain similar results. In this way, the government can obtain excellent results with no need to draw too many resources from businesses.

5. - Conclusions

In this work we have analysed the possible consequences of the promotion of basic research by the government. In particular,
public research has been introduced into an endogenous growth model financed through the taxation of monopoly profits of innovating enterprises.

The main results obtained can be summarized as follows. First of all, it is possible to notice some Barro effects. Namely, using as a proxy of economy growth rate the product of the number of researchers in private research and those employed in public research, growth effects depend on the tax rate\textsuperscript{12}. If the tax rate is equal to zero, there is no innovation. Likewise, tax rate levels around one can greatly reduce the resources employed in private research, leading to no innovation in the economy. Such extremity of the two effects grants the ideal level of the tax rate which maximizes economic growth.

Secondly, through the numerical simulation of the model results, we have been able to analyze the performance of the target function as market features change.

The most interesting outcome is the effect of competition on economic growth. Our model shows that a high level of competition between the various enterprises implies a low level of efficaciousness by government policy. This is in line with a commonly held position in the specific literature, starting with Schumpeter (1942), who underlines the dynamic efficiency of monopoly in stimulating innovation. This emphasizes how it is important to lead a valid patent policy, which generates monopoly rights with the aim of stimulating innovation itself. It is important to notice that the model, in line with Schumpeter view of creative destruction, does not mean the association of technological innovation with the persistence of monopolies. Monopoly profits granted by patents are a sort of prize, which is by the way obtained by always new enterprises. The field must be open to possible new competitors that challenge existing monopolies. Possible competition in the field of research and development must therefore be promoted. To make opportunities fair and equal for

\textsuperscript{12} This is obviously for given levels of the other parameters of economy, such as, for instance, the elasticity of the demand curve for monopolists, success rates of basic and applied research or the total number of the population in the economy.
new competitors, would be advisable to remove any obstacle to their entrance, such as, for example, possible problems in the credit market.

Thirdly, concerning leading-edge technology, it has been shown that it has little influence on government policy. Finally, the possibility, both of basic and applied research, of being successful, has more influence on the amount of resources to be employed than on the effectiveness of government policy. Specifically, the greater the possibility for research of being successful, the smaller the tax rate needed to achieve positive results.

Considering the effects of basic research on applied research, a distinction is necessary between the effects on productivity and the effects on levels. As for the first effect, it turns out that the finding of an innovation in a given sector makes its productivity develop discontinuously in the direction of the technological frontier. It moves upward as basic research grows, so it can be said that government policy effect on basic research productivity is a positive one.

The level of applied research deserves to be treated separately. Basic research has a negative effect on the level of applied research. This can be explained by considering the peculiar kind of financing of basic research by the government. Considering basic research directly linked to a tax policy proportionally influencing monopoly profits of enterprises, determines negative effects on the inducement to innovate, and therefore on the expenses on research, in the private sector.

To conclude, it has to be considered that the maximization of growth does not necessarily lead to the higher level of social welfare. Namely, social usefulness is given not only by the capacity of economy to innovate, but also by the levels of consumption. In models of this type, innovation occurs on the detriment of consumption, so that in the short run it is possible to have a stage of intense growth characterized by low consumption. With the passing of time, the results are balanced, as growth behaves as a multiplying factor for consumption.

Such results are plausible from an economic point of view.
Also in real life situations occur in which, within a given economy, in order to take over a technological gap, the decision is made to focus on the capacity to innovate, even to the detriment of social welfare in the short run.
GRAPH. 1

\( \alpha = 0.1; \ A_t^{max} = 1.6; \ \lambda = 0.8; \ \psi = 0.4; \ \gamma = 1.2; \ L = 100; \ r = 0.04 \)

GRAPH. 2

\( \alpha = 0.5; \ A_t^{max} = 1.6; \ \lambda = 0.8; \ \psi = 0.4; \ \gamma = 1.2; \ L = 100; \ r = 0.04 \)
GRAPH 3

\( (\alpha = 0.9; A_t^{\text{max}} = 1.6; \lambda = 0.8; \psi = 0.4; \gamma = 1.2; L = 100; r = 0.04) \)

\[
\begin{array}{c}
\begin{array}{ccccccccc}
\hline
\text{Tau} & 0 & 0.10 & 0.20 & 0.30 & 0.40 & 0.50 & 0.60 & 0.70 \\
\hline
\text{Growth rate} & & & & & & & & \\
\hline
\end{array}
\end{array}
\]

GRAPH 4

\( (\alpha = 0.1; A_t^{\text{max}} = 0.7; \lambda = 0.8; \psi = 0.4; \gamma = 1.2; L = 100; r = 0.04) \)

\[
\begin{array}{c}
\begin{array}{ccccccccc}
\hline
\text{Tau} & 0 & 0.10 & 0.20 & 0.30 & 0.40 & 0.50 & 0.60 & 0.70 \\
\hline
\text{Growth rate} & & & & & & & & \\
\hline
\end{array}
\end{array}
\]
(α = 0.1; \( A_{\text{max}}^i = 1.6 \); λ = 1.6; ψ = 0.8; γ = 1.2; L = 100; r = 0.04)
BIBLIOGRAPHY