The influence of subsidies on economic development: a system dynamics model

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Abstract

Many governments across the world put into practice different policies of subsidies to achieve goals of economic progress in spite of economic theory's arguments, which claims that subsidies hamper the efficient allocation of resources. But if a government decides to implement such policy, what type of subsidy has a higher impact on the economic growth? This paper examines the issue constructing a system dynamics model in which the effects of two types of direct subsidies are analysed: production and research and development subsidies. The model is based on feedback processes, non-linear relationships and delays that explain the decisions taken by different economic agents in a generic economy regarding physical capital accumulation, technological development and size of an intermediate sector. Using a system dynamics simulation the conditions under what either the use of each subsidy separately or a certain combination between them have a higher impact on the development of the economy are characterized.

Key words: Subsidies, Research and development, Economic growth, System dynamics, Computer simulation.

Introduction

It seems undoubted that the activities of innovation and their successful implementation in market will be crucial elements of the competitiveness of the nations over the coming decades. Different policymakers agree that innovation is the main driver of economic progress as well as an important factor for the solution of different current challenges in a wide variety of fields such as the health care, social services to ageing population, climate change, sustainable development or even on-line security and privacy.

As consequence of these facts, many countries have adopted national strategies in the last years to foster those elements that influence its innovation performances and to enhance its economic impact in order to achieve goals of economic progress. A report published by the Organization for economic cooperation and development (OECD) in 2007 indicates that the increases in research and development (R&D) intensity are led by a wide range of factors, such as reduction of anti-competitive product market regulations, low level of restriction on direct foreign investment, stable macroeconomic conditions (including low real interest rates), availability of internal and external finance, efforts to raise the supply of human resources, expansion of public research, fiscal incentives to stimulate private R&D or openness to foreign R&D.

In this instance, several countries have increased their investments in education as claimed by Education at a glance (2005) published by OECD. This report shows that across OECD countries, governments are seeking policies to make education more effective while searching for additional resources to meet the increasing demand for education. All countries belonging to OECD area have increased both their investments in education as a percentage of GDP and their enrolment rates in tertiary education. However, this fact is not extended to other regions. The education budget of a single country like France, Germany, Italy or the United Kingdom outweighs education spending across the entire sub-Saharan African region, according to Global Education Digest 2006 published by the United Nations Educational, Scientific and Cultural Organization (UNESCO). East Asia and the Pacific have the second-highest share of global public spending on education at 18% (after the North American and Western European region). Yet, governments in these regions are investing considerably less than their share of global wealth at 28% of GDP and their school-age population (29%). The opposite scenario is found in South and West Asia, where 7% of the world's public education resources are spent on 28% of children and young people. A more balanced situation emerges in Latin America and the Caribbean, a region that accounts for 8% to 9% of global education spending, the school-age population and global wealth.

Regarding the efforts to stimulate the intensity on R&D, the report published by OECD (2007) also showed that the intensity has grown significantly over the past decade in some countries belonging to the OECD area, such as Finland, Sweden or Japan. Nevertheless, the intensity has grown only lightly in the OECD area since 1995 and the cross-country differentials remain.

The report also indicates that the intensity on R&D activities has increase in some economies outside OECD area. It mentions specifically the progress carried out by countries such as Brazil, Russia, India and China. In fact, these economies have become the most active in industrial technology over the past decade. From 1996 to 2004 the share of high technology goods has doubled to reach about 30 per cent of the total trade in manufactured goods in those countries, thought it should be noted that most of this rise is due to China. On the other side, it is clear that, to date, only a small number of developing countries and economies in transition are participating in the process of R&D internationalization. In a report published by United Nations (UN) in 2005 is claimed that to eliminate the technology gap between countries is necessary to foster sustainable economic development, which require, among other aspects, a strong institutional support.

In this aspect, public subsidies are an internal tool frequently used to promote R&D activities in many industrial countries. All OECD countries provide public support to encourage innovative activities in their private sectors. Moreover, the use of this factor tends to increase in different ways: direct subsidies to innovative projects, R&D credits, R&D tax incentives or direct and indirect production subsidies for specify industries or firms in order to encourage the development of particular goods or services.

Although policies of direct and indirect subsidies have detractors because they hamper the efficient allocation of public resources there are economic arguments that justify governmental intervention involving in R&D activities: the R&D process has risks, it is costly and, moreover, it has associated external effects. As Arrow (1962) affirmed, the outcome of R&D activities is mainly knowledge, which can be used by different agents and therefore, there are difficulties in obtaining benefits from innovations. In other words, there are too little incentives to engage in costly innovations without governmental intervention since the innovators of new goods do not internalise the gains from their innovations.

Different authors such as Barro and Sala-i-Martin (2004), Davidson and Segerstrom (1998) agree that R&D subsidies promote R&D investment and economic growth. Nevertheless, taking into account that outcome a question arises: are public subsidies an instrument capable to promote R&D activities in all countries regardless of its level of development? Peretto (1999) argues that the expensive in-house R&D cannot de supported in countries that are in the early stage of industrialization because such economies grow accumulating physical and human capital. He concludes that only at sufficient high levels of development there are incentives for systematic R&D efforts. Then a new question can be posed in developing countries: if the private sectors have an effective public support, could R&D activities begin earlier? Barro and Sala-i-Martin and Zeng and Zhang (2007) indicate that linked to this matter there are other questions: first, are the subsidies to production better than R&D subsidies? Second, can different subsidies be combined to generate a better outcome than using a single subsidy?

In order to analyse these questions, this paper constructs a system dynamics model based on ideas and outcomes attained by Peretto, Barro and Sala-i-Martin, Soto and Fernandez (2006) and Zeng and Zhang in different studies of economic growth in which R&D activities are a key factor of growth. The construction of the model is carried out using system dynamics methodology that contributes efficiently to analysis of macroeconomic problems. In fact, the methodology makes possible to express in a clear and simple way how the actions of the different agents involved in an economy are interrelated. In addition, it enables the use of delays that capture realistic aspects of the problems in spite of the fact that they are often forgotten in economic literature. The importance of the methodology to help to solve complex problems is claimed by Sterman (2002, pp-501), who affirmed, *Thoughtful leaders increasingly recognize that we are not only failing to solve the persistent problems we face, but are in fact causing them. System dynamics are designed to help avoid such policy resistance and identify* *high-leverage policies for sustained improvement*. Recently, the use of the methodology in the study of macroeconomic models is proved by Wheat (2007), who creates a method for improving undergraduate instruction in macroeconomic called the feedback method, indicating that the dynamic behaviour in a market can be better understand by using feedback loop diagrams and interactive computer simulation models instead of static graphs or differential equations, which are often used in the traditional teaching.

The rest of this paper is organized as follows. The next section deals with the environment in which the different economic agents take decisions. The following subsections study separately the feedback processes explaining the accumulation of the stocks: physical capital, technology and size of an intermediate sector. Subsequently, a simulation exercise characterizes the evolution of different economies when their governments adopt different policies of subsidies and, finally, the paper closes with a summary of the analysis and some remarks about potential future research.

The set up

As Pareto, the issue is articulated within a generic economy in which a final producer, consumers and a set of intermediate firms take part. Due to the purpose of the model, it is also considered a government whose activities are in accordance with Soto and Fernandez. Every agent in the economy is involved in different economic activities that require taking decisions. This section focuses in the frame in which the activities are developed and the scope of the decisions taken by the agents.

- At any point in time, the intermediate sector is constituted by a set of firms, though the size of the sector could vary over time depending on their profits, as it will be explained later. The intermediate firms produce different goods using the same production technology that combines labour, capital and technology. The firms set both the price of their products and the prices of each effective unit of labour and capital used in their productive processes. Furthermore, they are owners of the technological factor used in their productions, which increases with efforts in the form of R&D. In addition, the firms of the intermediate sector have to decide the distribution of their profits between dividends and R&D investments.

- The final sector is represented by a firm that produces and sells a final good using the goods produced by the whole intermediate sector. It is assumed that the final good is sold at unit price and, furthermore, it is used as unit of measure of all the economic exchanges arising in the model.

- The economy is populated by an identical number of workers that grow endogenously over time at a specific rate. The households supply labour to the intermediate sector and are owners, at the same proportion, of both the capital used in the intermediate production and the intermediate sector. As a consequence of these contributions, in each productive period, households receive labour and capital income and, in addition, they might receive dividends. The labour income is obtained by the time devoted to labour market, the capital income is received from the capital lend to the intermediate firms, whereas the dividends are obtained as consequence of being shareholders. In each productive period, the households have to decide the fraction of their income dedicated to consumption. The part of wealth that is not consumed is saved provoking a variation in the available capital in the economy.

- The government sets and collects taxes to finance public spending. The taxes are levied on the labour and capital income as well as the households' consumption. The intermediate firms do not pay taxes. The tax revenue is used to finance the public consumption and to carry out transfers to the households. In addition, regardless of its fiscal policy, the government may implement policies of direct subsidies, both the production of intermediate goods and the R&D activities undertaken by the firms of the intermediate sector.

Figure 1 summarizes the contributions of each agent in the development of the economy and the interrelations among their actions.

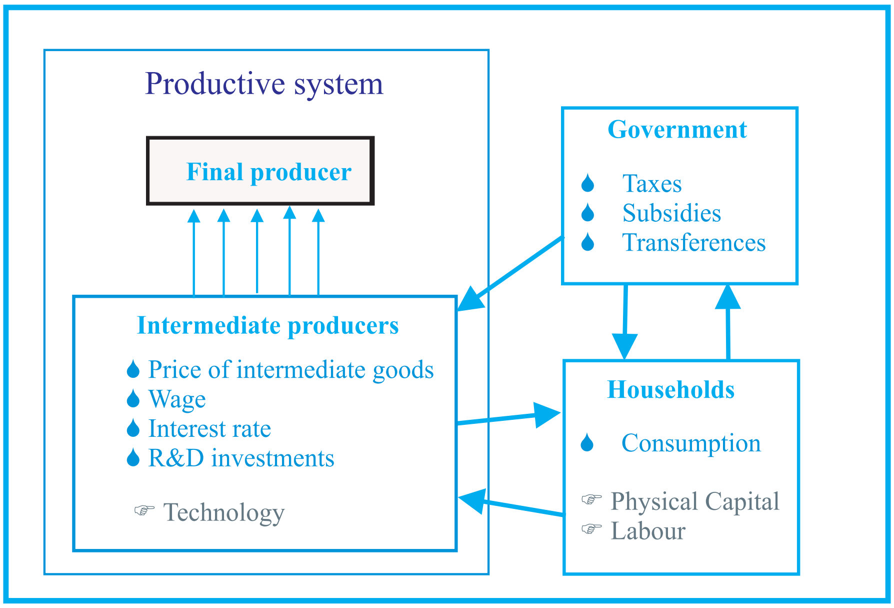

Figure 1: Interrelations among the actions of the economic agents

Accumulation of capital

The decisions adopted by the different economic agents influence the actions of the rest generating feedback processes that explain the evolution of the economy. In this section is analysed the capital accumulation caused mainly by household's decisions. Firstly, certain aspects related to the productive sectors are analysed and next, is studied how the saving affects to the evolution of the stock of physical capital.

The final sector, which produces final output from the intermediate goods, does not take decisions affecting the rest of agents since its role in the model is just to represent the economy. The importance of this sector in this study is consequence of two aspects. First, it is necessary to determine its production because all the exchanges in the economy are measured in terms of the final good. Moreover, its evolution over time determines the evolution of the economy. In particular, its rate of growth indicates the economic growth rate. The model assumes that the final good is produced using a specific technology: it increases if the intermediate production suffers an expansion as a result of either an increase of size or an increase of production. However, the evidence suggests that an increase of anyone of these two elements doesn't provoke an increase of the same magnitude in the final production. As Forrester (1968, pp. 404) affirmed *throughout our social systems, nonlinearity dominates behaviour*.

The intermediate sector uses a production technology that need the contribution of labour, capital and technology to produce the intermediate goods. If any factor does not take part, there is no production, whereas if a factor is employed more intensely, the intermediate production grows. As it happens with the final sector, the production technology used by the intermediate firms is a non-linear process and consequently, an increase of a factor does not provoke the same increase in the production of the intermediate firms.

As previously said, the intermediate sector has to take decisions about different aspects. In particular, the intermediate firms have to set the price of its products as well as the prices of each effective unit of labour and capital used in their productive processes. The price of the intermediate goods is set considering a mark-up of the productive costs of labour and capital. Regarding the prices of the factors, each unit effective of labour and capital is paid by its marginal contribution to the intermediate production. In that way, the intermediate firms determine the wage and the interest rate of the economy. The intermediate production can be measured in terms of the final production and, thereby the wage and the interest rate grow if the final production grows. Nevertheless, if the intermediate production intensifies the use of labour, the wage diminishes and as well, if the capital available in the economy grows, the interest rate decreases.

On the other hand, the households just decide the percentage of their wealth dedicated to consumption. Although there could be periods of time in which households do not save, the evidence suggests that households consume a percentage of their net income of labour and capital. Statistics show a strong variation of this variable across countries. According Serres et al. (2003), the gross private saving rates averaged in per cent of GDP in the U.S. is closed to 11%, the rate is estimated at about 19% in Euro area and 28% in Japan, in 2000. The model assumes that the households always save a part of their income after tax in each productive period to consider a generic economy. The part of net income no consumed is saved and accumulated in the capital. The percentage of income dedicated to consumption, this is, the marginal propensity to consume, is considered an exogenous variable of the model.

The causal influence the households' income in the physical capital accumulation can be explained taking into account different variables: the interest rate, the wage, the consumption of the households as well as the taxes. Figure 2 illustrates the feedback processes explaining the capital accumulation because of the contribution of the capital income. In that figure it is possible to observe four loops. The two loops with positive polarity foster the accumulation of capital considering the saving whereas the loops with negative polarity restrain the accumulation as a consequence of the consumption.

In a similar way, it is possible to examine how the saving is affected by the labour income in which the wage plays a main role. Figure 3 shows the feedback processes involved in the capital accumulation as consequence of the labour income. The loop R3 reinforces the capital accumulation considering how the net labour income and the saving are related, whereas loop B3 adds the consumption provoking a change of polarity. Both loops contain the wage, which grows if the final production grow and it diminishes if the number of workers in the economy increases.

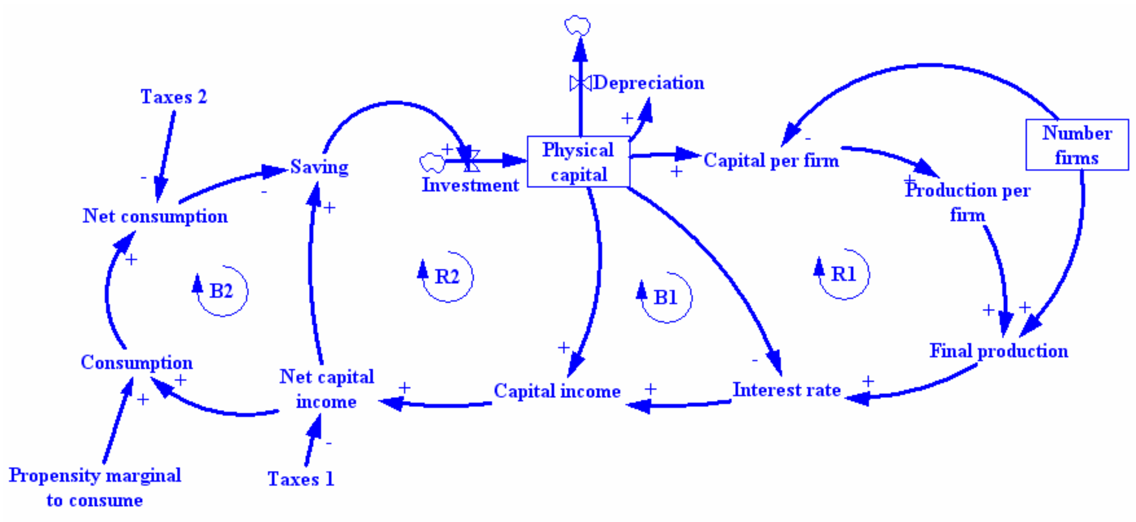

Figure 2: Capital accumulation from capital income

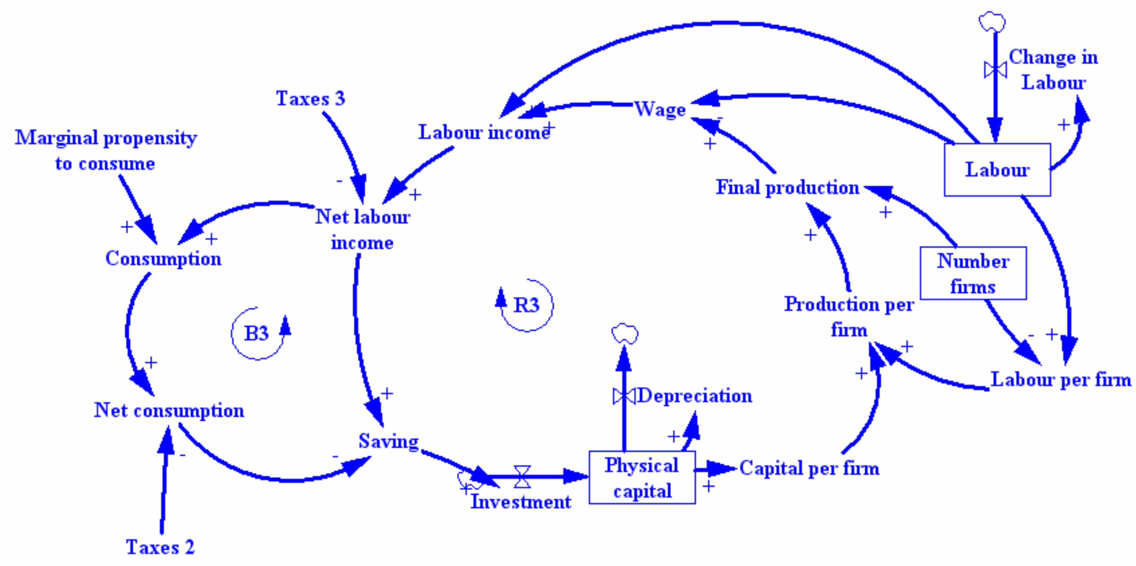

Figure 3: Capital accumulation from labour income

In figures 2 and 3, the level, *Number firms*, collects the number of intermediate firms. Observe that the intermediate firms receive the same share of capital and the same number of workers.

Implications of a balanced public budget

If the government maintains a balanced public budget over time, then the difference between the public revenues and the public spending must be zero in each productive period.

However, it is possible that the public revenues obtained levying taxes on consumption as well as capital and labour income are not enough to finance the public spending that include consumption, transfers to households and subsidies. Therefore, the public budget could present surplus or deficit in different productive periods. In order to eliminate these possibilities, it is assumed that the government can modify the available capital in the economy as follows. If the public budget has surplus, that amount will be transferred to the capital, which means an increase of transfers to the households. On the contrary, if the public budget presents deficit, then the capital will be diminished by that amount, which implies an increase of indirect taxes.

The governmental policy of maintaining a balanced public budget generates new feedback processes that affect the accumulation of capital. Figure 4 shows how loop R4 fosters the accumulation of capital from the public revenues though its effect is thwarted by the action of loop B6, which includes the public spending affected by the public consumption and the subsidies to the intermediate sector.

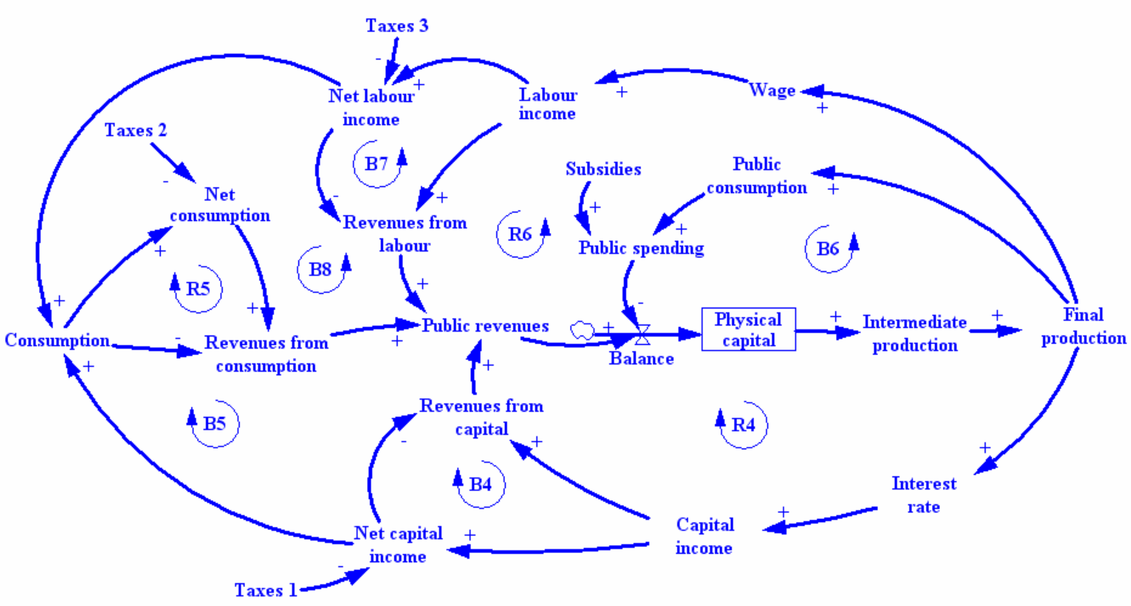

Figure 4: Balanced public budget

The public consumption is assumed proportional to the final production whereas the amount of public revenue dedicated to subsidies is considered an exogenous variable. The influence of labour income and net labour income, respectively, on the public revenues is considered by loops R6 and B7. Similarly, loops R5 and B8 have an opposite effect on the public revenues. Both loops contain the consumption, but loop B8 also includes the net consumption, which does not belong to loop R5. Finally, loop B5 collects the influence of consumption in the public revenues, but considering the capital income.

Investments in R&D

All the intermediate firms are owners of the technological factor used in their productive processes. Nevertheless, as a result of the interrelations among firms, it is possible to consider two types of knowledge: private and public knowledge. Each intermediate firm generates the first and it is only used by it. However, the knowledge is only partially appropriable by each firm and, in addition, has spillovers across firms; as a consequence, one firm will produce depending on its own knowledge but also it could take advantage of the knowledge acquired by other firms. In other words, its production will also depend on the overall state of technology in the economy. Pareto and Cohen and Levinthal (1989) also consider this approach considering the firms´ capacity to apply ideas and methods developed elsewhere to its production processes.

Therefore, the production of the intermediate goods will depend on four factors: labour, capital, private and public knowledge. The last variable is formulated by means of the sum of the private knowledge of each firm, which varies as consequence of the investments in R&D carried out by each intermediate firm.

As mentioned above, the intermediate firms set the price of their products using a mark-up of the variable costs of labour and capital. However, besides the variable costs of labour and capital, it is logical to assume that the intermediate productions entail fixed costs, which are proportional to the state of technology in the economy. Pareto affirms that the fixed cost should be interpreted as overhead to take into account that managing industrial facilities is more expensive in a technologically advanced environment. Then, the prices of the intermediate goods allow the firms to cover the variable costs, but the firms' profits are not guaranteed because of the fixed costs.

On the other hand, if the prices of the intermediate goods allow the firms to obtain profits, then the firms have two possibilities of allocating them: to pay dividends to households or to invest in R&D activities. The first option implicitly means that the physical capital in the economy will grow, whereas the second option implies that the technological factor used in the intermediate production will increase. Actually, the investments in R&D provoke an increase of two factors: the technological factor used by each firm and the public knowledge due to the spillover of the knowledge across firms. As a consequence, the allocation of profits between dividends or R&D investments depends on whether the firms prefer to invest in capital or in technology. This issue is solved comparing the rate of return to investment and the rate of return to R&D. The investment in technology will require that the rate of return to R&D was equal to the interest rate of the economy; otherwise, if the interest rate in the economy is higher than the rate of return to R&D, the intermediate firms will distribute dividends.

Figure 5 collects feedback processes involved in the accumulation of technology per firm. This accumulation is modelled in two stages assuming that, in first place, the technology is conceived and next, the ideas are put into practice. Sterman (2000, pp. 411) considered that *a delay is a process whose output lags behind its input in some fashion*, which is a clearly justifiable characteristic for the formation of the knowledge in this model.

There are three flows associated with the technological accumulation: depreciation, technology in progress and designs. The first takes into account that a proportion of technology can become obsolete over time. Technology in progress transforms the technology under development into the technological factor used in the intermediate production. The inflow, designs, determines the increase of the technology under development. This flow depends on both the resources dedicated to the R&D activities per firm and the cost of these activities. According to Barro and Sala-i-Martin (pp. 303), the cost of the R&D activities is an increasing function of the level of technology in the firm, this is, depends on the ideas previously invented. Consequently, if at different time two intermediate firms have the same resources for investments but the level of technology is different, the firm with a lower level of technology increases more its stock.

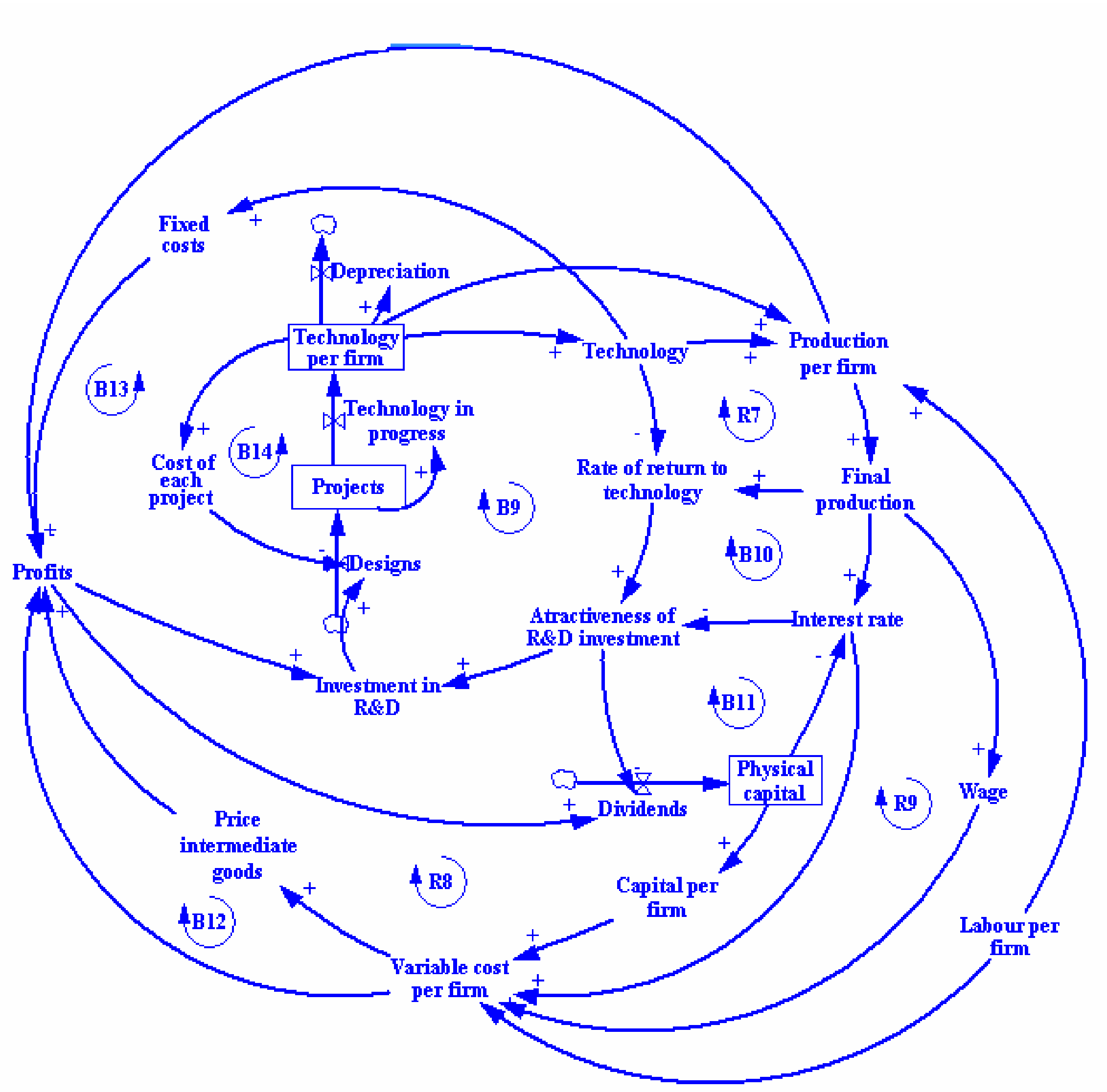

Figure 5: Feedback processes in the accumulation of technology

Figure 5 also contains the auxiliary variable, *Attractiveness of R&D investment*, which distributes the profits per firm between dividends and R&D investments comparing the rate of return to technology and the interest rate of the economy.

Observe in figure 5 that the positive loop R8 together with R2, R3 and R4, which are included in figures 2, 3 and 4, respectively, totally determine the accumulation of capital in the economy from dividends, capital income, labour income and transfers from government, respectively. Although most loops in figure 5 are negative, there are two loops with positive polarity: R7 and R9. The first fosters the accumulation of technology: if the production per firm grows, the final production increases. Consequently, the rate of return to technology increases. This fact provokes that the investment in technology becomes more attractive. The technological accumulation is also encouraged by loop R9, which considers the causal relationship between the final production and the wage. In fact, if the wage increases, then the variable costs per firm increases and, as a result, the price of the intermediate goods grows provoking an increase of the profits. Then, if the firms invest in R&D, the investments grow. Observe that the effect of loop R9 on the technology is thwarted by the negative loop B12 containing the same variables than loop R9 except for the price of the intermediate goods.

The growth of the technology per firm could be restrained by loops B9, B10 and B13. The first indicates that its growth would provoke a decrease of the investment in R&D due to the negative causal relationship between the technology in the economy and the rate of return to technology. The second loop states how the lack of capital in the economy would affect the investments in R&D: if the interest rate grows, the attractiveness of R&D investment diminishes. Finally, loop B13 takes into account the increase of the fixed costs as consequence of the increase of the technology.

The negative loops B11 and B14 collect different aspects. The former specifies how the physical capital could diminish due to the allocation of the intermediate firms' profits in R&D activities instead of being distributed among the shareholders. The latter captures the effects of new technologies' costs: if the resources dedicated to R&D do not increase, the growth of the technology per firm will go slower as the technology grows.

Subsidies

Regardless of the fiscal policy adopted by the government, it could put into operation two types of direct subsidies: production subsidies and R&D subsidy. It must be noted that, the second one will be just possible if the intermediate firms carry out R&D activities.

It is easy to realize of the direct influence of the two types subsidies in some variables of the model: the production subsidies will increase the profits of the intermediate firms whereas the second one allows the firms to have at one's disposal more resources to invest in R&D activities. However, the profits and the investments in R&D are involved in several feedback processes supporting the structure of the model; consequently it is possible to predict that the effects of the subsidies on the development of the economy are uncertain. The results attained by Barro et al. and Zeng et al. confirm it in spite of the fact that the latest base his developments on the approach carry out by the former. Barro and Sala-i-Martin proved that the production subsidy always dominates the R&D subsidy whereas Zeng and Zang justified that the R&D subsidy always leads to a higher growth rate than the production subsidy.

Nevertheless, it is important to understand how the subsidies affect the economy:

- Subsidizing in a direct way the intermediate production has implications because this subsidy will alter the economic results of the firms. The subsidy may provoke that the firms would achieve profits instead of losses since the subsidy could compensate the fixed costs. The amount accumulated, this is, profits and subsidy, could have two different uses. If the firms are investing in R&D, the amount accumulated will increase the investment in R&D and the production subsidies have a similar role than the R&D subsidy. If the firms are not investing in R&D, the amount accumulated will be dedicated to pay dividends. Consequently, the physical capital will increase and if the subsidy is maintained over time, the stock of physical capital will increase progressively, which would foster the growth of the final production. Moreover, this fact might provoke a progressive decrease of the interest rate allowing it to converge to the rate of return to technology.

- If the intermediate firms carry out R&D activities, the subsidy for R&D will provoke an increase of the available resources for those investments. Consequently, the technological stock of each firm will increase provoking an increase of the public knowledge as well. The increase of these two variables influences almost all the variables of the model. A direct consequence of this fact is an increase of the fixed costs and consequently, a decrease of the firms' profits. But also, some effects on other variables are clear. For example, the increase of both factors will stimulate the production of the intermediate sector and as a result, an increase of the final production, which, in turn, influences the economic growth. Nevertheless, the increase of the final production could cause a variation of both the interest rate and the rate of return to technology. Then, if a lack of convergence between these rates appears, the firms would have to alter their technological plans, at least, in the short term.

In addition, in terms of public spending, both subsidies could generate public deficit. In that case, an increase of the fiscal pressure over the households would arise.

The influence of the public subsidies in the decisions of the households, intermediate firms and government can be observed in Figure 6, which considers some variables of figure 5 adding the subsidies.

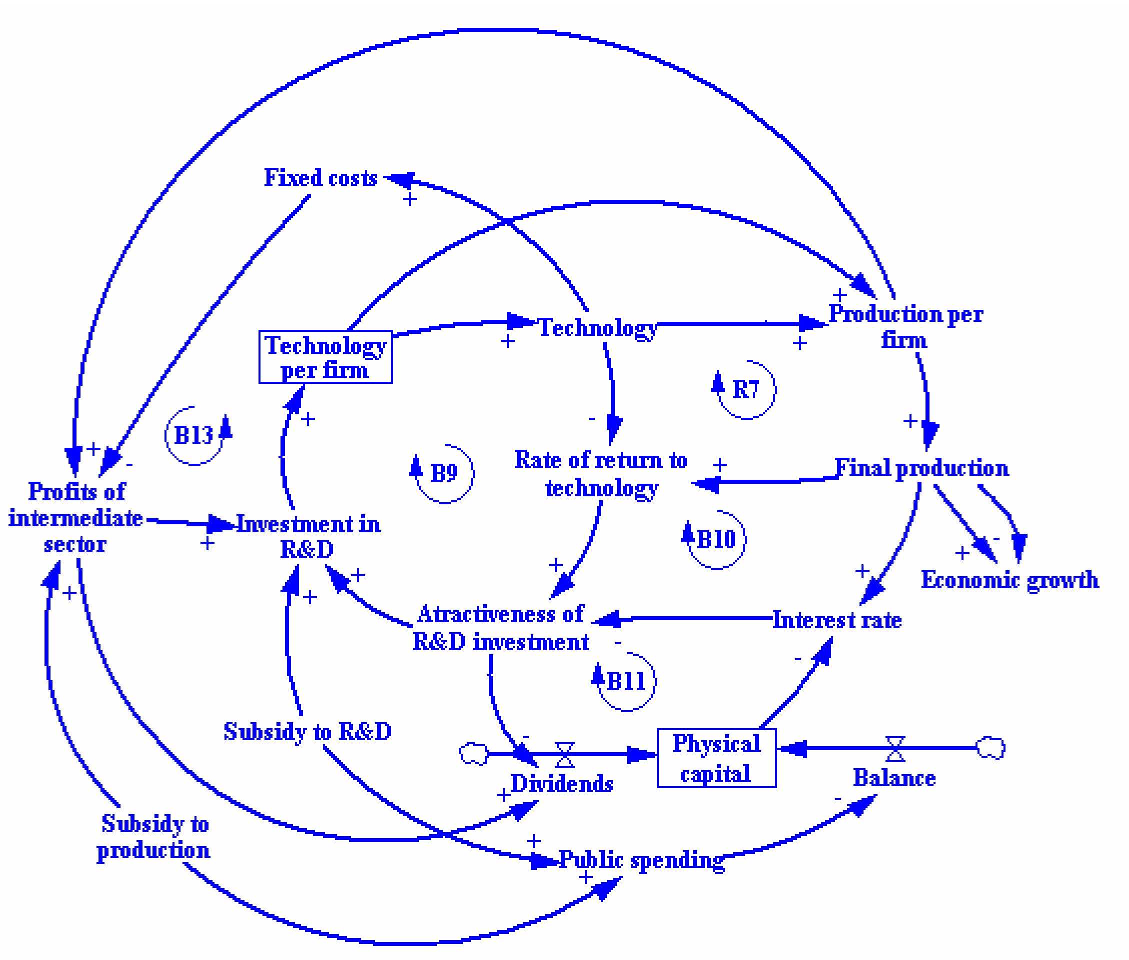

Figure 6: The influence of subsidies on the capital, technology and public spending

Size of the intermediate sector

Assuming certain conditions about the structure and the operation of the intermediate sector, this section examines why the size of the sector depends on the profits attained by its firms in each productive period.

It is assumed that the intermediate firms belong to a sector where there is free entry and exit, this is, the firms must not have legal or commercial barriers to entry or exit of the sector. On the other hand, it is also required that the firms produce similar, but not identical, products. These two conditions guarantee that the intermediate firms would rather not have excessive profits. In fact, if a firm is very profitable, it is possible to expect other firms to enter in the sector. If a new firm enters and it starts producing a product that is close substitute for the old one, then the demand for the old product would decline and it could imply that the firm would have to leave of the sector. Consequently, the firms prefer that their profits are not excessive to remain in the sector, which within economic literature means null profits.

The condition about null profits can be used to determine the size of the intermediate sector when the firms do not invest in R&D because of the interest rate is higher than the rate of return to technology. In fact, when the profits are null, then the difference between income for sales and the variable costs coincides with the fixed costs. This result makes possible to find the size of the sector that is directly proportional to the final production and inversely proportional to the fixed cost. Otherwise, when the firms carry out R&D activities, then the size of the sector will be determined considering that, in such situation, the interest rate is equal to rate of return to R&D. This last condition implies that the capital stock per firm must be proportional to its level of technology. In this situation, the condition about null profits determines the investment in R&D per firm.

Nevertheless, it is realistic to assume that the decision to enter or exit of the intermediate sector takes time. For this reason, the size of the intermediate sector will be modelled considering the difference between the number of desired firms, which is determined by the conditions analysed above, and the current number of intermediate firms. An adjustment time determines how quickly the size of the sector tends to its desired value.

Notice that the number of intermediate firms must not be considered literally, the variable could take fractional values due to the values reached by the variables affecting to its evolution. Barro and Sala-i-Martin (pp.287) suggest that the number of intermediate firms should be viewed as a tractable proxy for the technological complexity of the typical firm’s production process or alternatively, for the average degree of specialization of the factors employed by the typical firm.

However, the intermediates firms share the available factors in the economy. Consequently, when a new firm enters in the sector, it obtains the share of capital and labour assigned to each firm. Thereby, the new firm has the same resources than any other to undertake its new production. Similarly, when a new firm enter in the sector, it is necessary to redistribute the factors and each firm will have fewer resources to carry out its productive process. Though it could seem that this process will provoke strong instabilities on the system, the results do not show that characteristic because of the number of firms is not a natural number.

Two diagrams are used to show the feedback processes that determine the size of the intermediate sector depending on either the firms carry out R&D activities (Figure 7) or not (Figure 8). The variable, *Attractiveness of R&D investment*, will control the dominant diagram in each productive period.

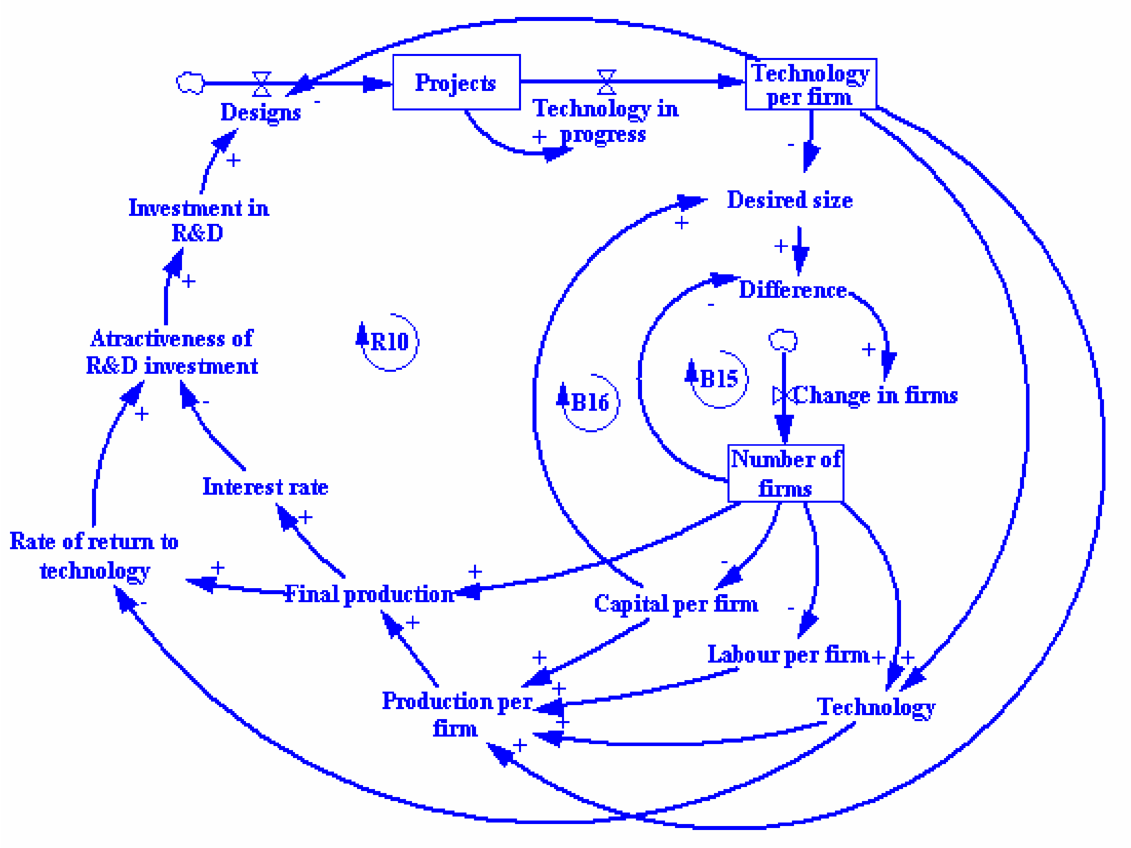

Figure 7: The size of the intermediate sector when the firms carry out R&D activities

It seems important to emphasize that the size of the intermediate sector is an important variable of the model because it has a direct influence on the final output, which determines the evolution of the economy. Also, the size of the sector influences the capital and the labour per firm as well as the public knowledge, which are productive factors of each intermediate firm.

Figure 7 shows the feedback processes that explain the size of the intermediate sector when the firms carry out R&D activities. In this case, the desired number of intermediate firms is determined by means of the technology per firm and the capital per firm. The figure indicates three loops: two with negative polarity and one loop with positive polarity. The delay governing the size of the intermediate sector is collected by loop B15. The influence of the capital per firm on the size of the intermediate sector is collect by loop B16 whereas loop R17 shows how the size fosters the development of the technology in the economy.

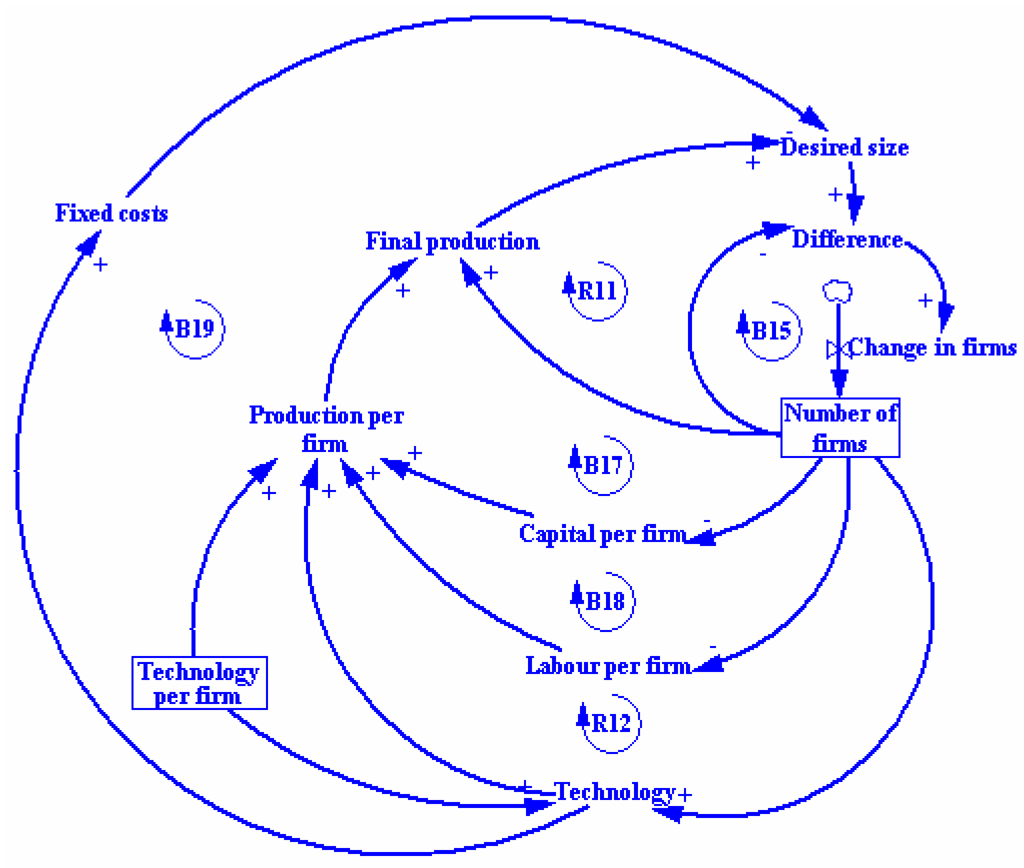

Figure 8: The size of the intermediate sector when the firms do not carry out R&D

The feedback processes determining the size of the intermediate sector when the firms do not carry R&D activities are collected by figure 8. Observe that in that situation the technology per firm stays constant. The figure illustrates how the size of the sector is reinforced by the public knowledge and the final production. However, the actions of these loops are thwarted by the actions of three negative loops including the capital and the labour per firm and the fixed costs, respectively.

Preparing the simulation

The simulation results are obtained considering a time step equal to 0.25 years and the unit of time is equal to one year. The simulations are run over a period of 30 years, a horizon sufficiently long to be aware of the effectiveness of the public policies of subsidies.

The parameters of the model are selected taking into account different considerations. By simplification, it is assumed that the physical capital and the technology do not suffer depreciation. By the same motive, the public consumption coincides with the public benefits except when it subsidizes to the intermediate sector in whose case the public consumption is diminished by the amounts subsidized. Both the elasticity of substitution between intermediate goods and the parameters associated to the factors in the production function of every intermediate firm are set considering economic literature. The parameter affecting to the physical capital is set equal to 0.35 and it is assumed that the proprietary and public knowledge affect the production function at the same proportion.

The growth rate of labour is selected in order to labour has not a strong importance on the final production because it is attempt that the economic growth was explained from all the factors not just by labour. The taxes are assumed identical, the percentage is 15%. The adjustment times selected are: six moths for the size of the intermediate sector, one year for capital accumulation and two years for the formation of technology distributed by half between technology per firm and projects. Finally, the cost of the designs is defined using a non-linear function depending on the stock of technology per firm. This function takes into account those suggested by the evidence: if the stock of technology per firm is low, the technology grows quickly whereas if the stock is high, the technology grows more slowly. The reasons are simple, if the stock of technology is low, the firms imitate technology created elsewhere, this is, the firms adapt technology more than create new technology, and then the technology grows quickly because the cost is low. On the contrary, if the technology per firm exceeds a critical threshold, the firms create new technology and the costs are higher.

The feedback processes analysed in the previous sections enable to suspect that the evolution of the economy over time could be different depending on the initial values of the levels, which would indicate its initial level of development. For this reason, it is possible to consider two situations: either the economy starts out the simulation with a rate of return to technology inferior to the interest rate or the rate of return to technology is equal to the interest rate. The first situation implies that the intermediate sector does not yet carry out R&D activities. The second one means that the intermediate firms invest in technology, which indicates that the economy has an initial level of development higher than the first situation.

Nevertheless, if at the beginning of simulation the interest rate is set with a value close to 5%, the required condition to verify between the interest rate and the return rate to technology for both types of economies permits to determine the initial values of the levels, except for capital per firm and projects. Moreover, for the economy in developing, the condition determines the value of the parameter influencing the fixed costs of the intermediate firms. That value will also be considered when the firms carry out those activities.

Under these initial conditions and parameters is just necessary to initialise the physical capital in the economy, the size of the intermediate sector and the projects to obtain the results of the simulations. The initial values of these stocks jointly with the propensity marginal to consume allows the simulation exercise to consider different economies with different phases of development and to observe the effectiveness of the public policies of subsidies on them.

Table 1 summarizes the initial values of capital, size of the intermediate sector and projects for four economies when the households maintain the same policy of consumption that is shown by table during the horizon of the simulation.

The simulation generates four paths for each economy. The paths 1 assume that the economies do not receive subsidies. In the paths 2, the economies only receive subsidies for production (30% of the public benefits). In the paths 3, the economies only receive subsidies to R&D if they carry out that activity (30% of the public benefits). Finally, the paths 4 assume that the intermediate firms receive both types of subsidies (20% of the public benefits for each subsidy).

	Economy 1	Economy 2	Economy 3	Economy 4
Initial physical capital	**Low**	**Low**	**Medium**	**High**
Initial size of the sector	**Low**	**Low**	**Medium**	**Medium**
Initial R&D investments	**No**	**No**	**No**	**Yes**
Initial projects	**Zero**	**Zero**	**Zero**	**Positive**
Marginal propensity to consume	**High**	**Medium**	**Medium**	**Medium**

Table 1: Distinctive features of the simulated economies

Results of the simulation

The evolution over time of the variables: interest rate, rate of return to technology, rate of innovation per firm and economic growth for the economy 1, are shown in figure 9.

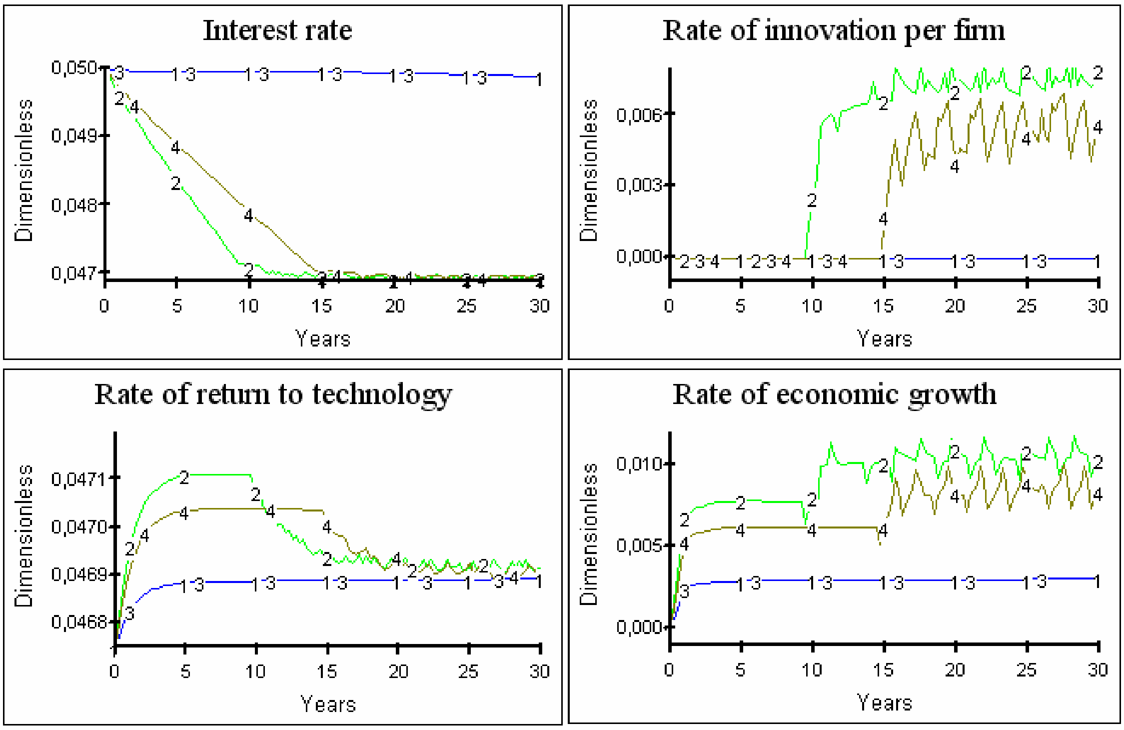

Figure 9: Evolution over time of the economy 1

At the beginning of simulation, the economy 1 presents characteristics of an underdevelopment economy due to the initial values of its levels. The paths show the importance of the subsidies to the production to foster its economic development. In fact, without subsidies for production, the interest rate always exceeds the rate of return to technology and the economy cannot undertake R&D activities. Moreover, the economic growth is blocked and stays close to zero. The economy has an obvious lack of capital and the behaviour of the consumers do not help to its accumulation.

The subsidy to the production increases the profits of the intermediate firms. Then while the firms do not carry out R&D activities, they distribute dividends and as a result, the capital in the economy increases progressively. Moreover, the capital accumulation is higher when the subsidy grows as the paths 2 and 4 (figure 9) illustrate. For this reason, the economic growth rate attains higher values when the economy only receives subsidies to the production (path 2). In addition, the influence of the subsidy in the capital accumulation provokes that the interest rate decreases progressively until to reach the rate of return to technology. At this moment, the firms begin the technological development. The increase of both the capital and the technology allows the economy to attain a rate of economic growth that is not possible without the subsidy to the production. Observe that, when the economy undertakes R&D activities, the new increases of technology affects the production per firm and consequently to the final production. But those increases, for each step of the simulation, have not the same magnitude and as a result, the rates shown by figure 9 start to oscillate.

Although the stocks of the economy 2 have the same initial values than the economy 1, the marginal propensity to consume is smaller and consequently the households in this economy accumulates more capital over time. As a result, the interest rate decreases progressively reaching to the rate of return to technology. This fact provokes that the intermediate firms undertake R&D activities without receiving public subsidies as the path 1 (figure 10) shows.

The paths, collected by figure 10, show that the amount subsidized for production determines the moment in which the firms begin to invest in R&D. But also, the subsidy to the production is important for the economic development since it provokes that the rates of innovation and economic growth attain values that they are not possible if only are subsidized the R&D activities.

Moreover, observe that if the firms receive subsidies to the production (paths 2) the rates associated to the economy 2 maintains an evolution over time rather stable whereas they suffer cyclical oscillations when the economy either receives only subsidies to R&D (paths 3) or does not receive subsidies (paths 1). These facts can be explained to a large extent by the capital accumulation. In fact, the subsidy to the production always guarantees certain level capital accumulation and as a result, the interest rate maintains its convergence to the rate of return to technology. Nevertheless, if the economy does not receive a subsidy to the production, the saving is not sufficient to achieve the convergence between the interest rate and the rate of return to technology. The loss of convergence stimulates the capital accumulation though it interrupts the technological development. Once again, the capital accumulation provokes the decrease of the interest rate and its convergence to the rate of return to technology beginning a new oscillation. Observe that the cycles also arise when the economy receives both types of subsidies though the oscillations are smoother due to the influence of the subsidy to the production.

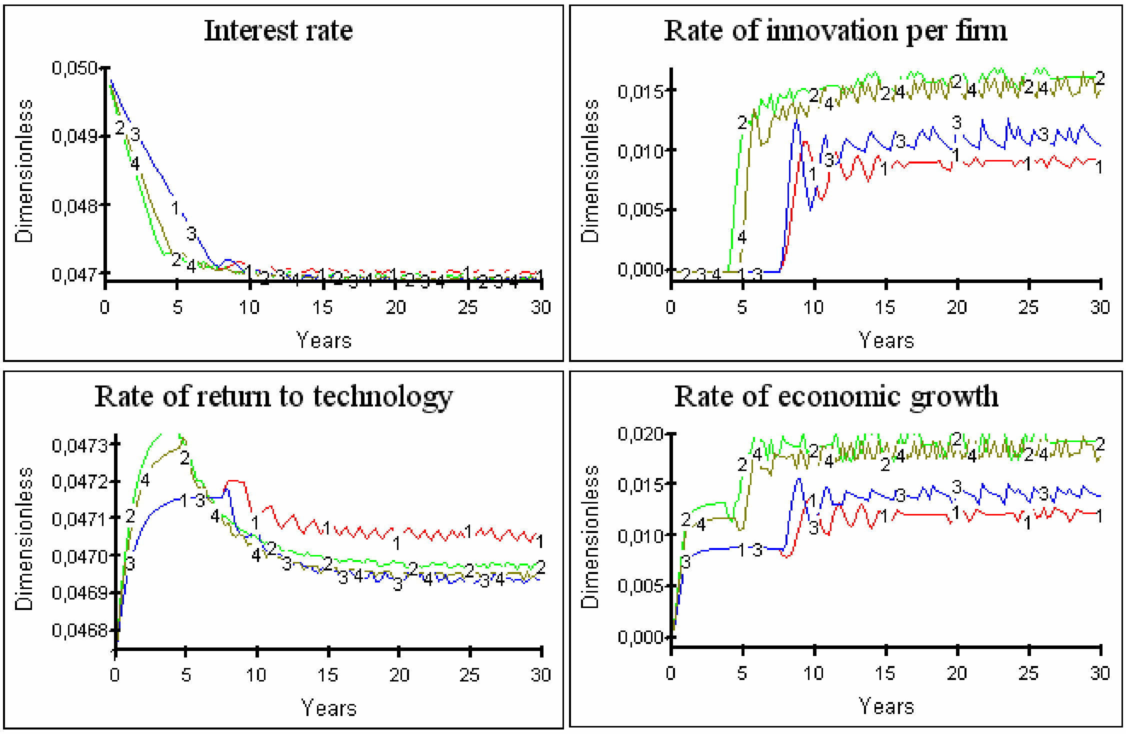

Figure 10: Evolution over time of the economy 2

If both the initial size of the intermediate sector and the initial value of the physical capital grow regarding the initial values in the economy 2, the interest rate and the rate of return to technology follow similar singularities that those shown by figure 10. Nevertheless, as figure 11 shows, the technological accumulation begins early and the economy 3 has annual rates of economic growth higher than the economy 2.

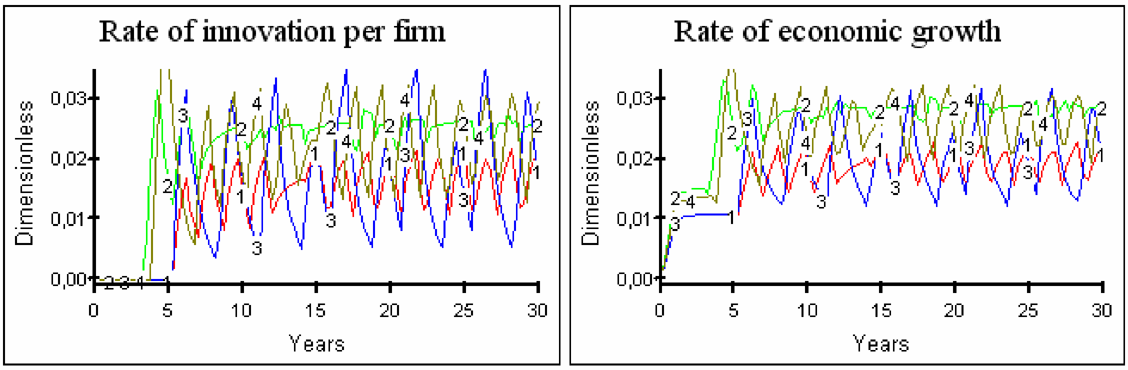

Figure 11: Evolution over time of the economy 3

At the beginning of simulation, the economy 3 does not carry out R&D investment, because the interest rate and the rate of return to technology have not yet converged. The subsidies for production moreover the saving provoke an increase of the physical capital that encourages the decrease of the interest rate. Then, the economy begins to invest in technology. Consequently, the profits of the intermediate sector are turned aside to R&D investments and the accumulation of capital diminishes. As consequence, the interest rate grows and the firms stop their R&D investments. Once again, the shift of allocation of the profits provokes a new decrease of the interest rate and a new cycle starts. The oscillations shown by the paths of the economy 3, after beginning the technological accumulation, indicate that the economy is making adjustments, but it is stable in spite of the shifts. The subsidies provoke an increase of the rates but do not affect the number of shifts but the oscillations are stronger.

The economy 3 has not yet the sufficient capital to maintain a stationary situation. In that regard, Peretto (pp. 407) affirmed that the economy will reach a situation where growth is led by knowledge accumulation, the intermediate sector settles in a stable industrial structure with a constant number of firms and the economy will achieve a stage of balanced growth.

If the economy 4 is initialised with the values attained by the stocks of the economy 3 in the long term, then the economy 4 starts out the simulation carrying out R&D activities. Figure 12 collects the behaviour over time of the interest rate and the rate of return to technology for that economy.

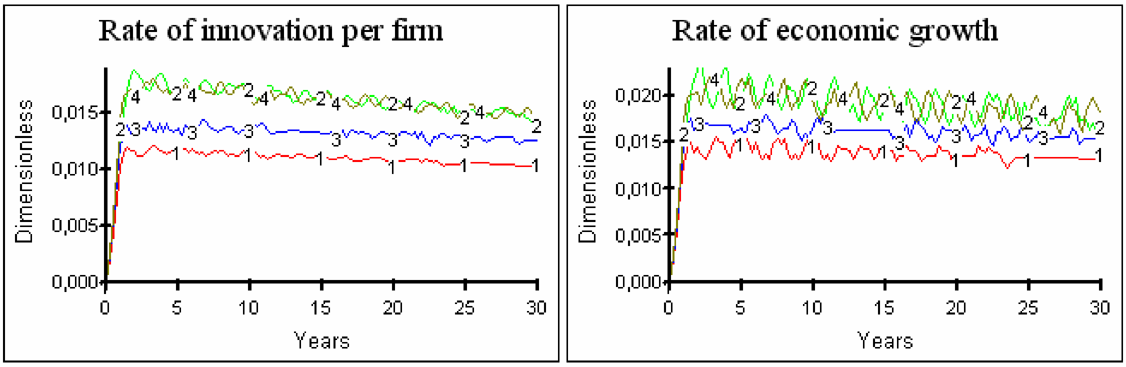

Figure 12: Evolution over time of the economy 4

Regardless of the policy adopted by the government about subsidies, the economy 4 has attained a stationary situation since the variations over time of the variables are insignificant. It is possible to observe that when the intermediate sector is subsidized, the annual rates of innovation and economic growth are low. They are always exceeded by the rates when the economy receives subsidies. The influence of the subsidies on the rates is now very clear since it is possible to observe that the economy attains practically the same results both if the government subsidizes the production and if subsidizes both the production and the R&D activities in spite of the fact that this last type is more expensive. Anyway, figure 12 illustrates that the subsidy to R&D (paths 3) does not generate a good result for the economy in spite of the fact that it consumes the same public resources than the subsidy to the production.

Conclusions

It is well known that the implementation of certain public policies has effects on the general development of the economy. Sometimes the effects are unsatisfactory, other times are successful, often it is not well known its direct or indirect effects on the economy and, at times, the policy is not to put into practice because the results are not sure and possibly it is too expensive. Even the same policy could not provoke the same results if it is put into practise in different countries or even more, the results might be different in the same country at different dates. At this point, it is essential to carry out a simulation exercises to confront the ideas with the reality.

One policy requiring such analysis is to proportionate public subsidies to a specific productive sector. It is possible that if a sector is benefited, other economic agents will see their aspirations unsuccessful. However, if the policy is going to be put in practice, the issue enlarges if the policy offers alternatives. Is it better to dedicate public resources to that activity or to other one? Once again a simulation exercise is essential to know the degree of adaptation of the policy to the aim pursued.

This paper considering feedback processes that explain the interrelations among the decisions of different economic agents, taking into account non-linear features of the economic process as well as delays involved in the activities of an economy, constructed a system dynamics model to analyse the impact of two types of public subsidies on economic growth. An exercise of simulation characterized the evolution over time of the rate of economic growth and the rate of return to technology for four economies, which at the beginning of simulation have a different level of development. The evolution of the rates was obtained under four different public policies of subsidies: no subsidies, only subsidy for production, only subsidy for R&D activities and finally, a policy that combines subsidies to the production and to R&D activities.

The results showed that the subsidies improve the economic growth rate and the rate of innovation. This result is general and it is not depend on the type of subsidy received or on the level of development shown by the economy at the beginning of simulation. If the firms do not carry out R&D activities, the subsidy for production achieves that the process of technological innovation starts. Moreover, the process starts earlier if the firms receive more resources. If firms carry out R&D activities, subsidy for production generates better results than subsidy for R&D as regards the economic growth rate and the innovation rate. Even the values attained by these rates are better in economies when they receive subsidies to production instead of a mix of subsidies to the production and R&D activities. This result is due to the fact that the subsidy to the production shows more flexibility than the subsidy to R&D, because whereas the subsidy to R&D only promotes that activity, the subsidy to the production promotes R&D when there is sufficient capital in the economy.

Undoubtedly the structure of the model conditions the results. In this regard, Schaffernicht (2006) argues that system dynamics proposes to construct a useful understanding of a situation via the elaboration, validation, exploitation and interpretation of a simulation model, based heavily on mental models. He continues, during a modelling endeavour, saying that, the modellers will go through a series of tentative models that finally stabilize-temporarily-in the form of the validated model. In the longer run, experience from acting in the real world will lead to remodelling, bringing about new validated versions.

There are several possible extensions to the model, which are worth mentioning. First, it could be possible to consider that the intermediate sectors of different economies have different production functions. Then some modification with respect to the production function used by the intermediate firms could be considered. Somehow the importance of the capital in the model might be partially replaced in favour of the technology to check if the same results are obtained. Another promising extension would be an analysis of confrontation between the subsidies for production and the fiscal policy. What amount of public resources might be dedicated to subsidies supporting certain aims of social well-being? Few modifications in the model would allow to undertake the study.

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