An Applied Endogenous Growth Model with Human and Knowledge Capital Accumulation for the Turkish Economy[1]

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Abstract

The main objective of this research is to analytically investigate and assess the interactions between knowledge driven growth, acquisition of human capital, and the role of strategic public policy for the Turkish economy within the context of a general equilibrium model. The model aims to investigate the public policies towards fostering the development of human capital (such as investments in education and learning) and those at enhancing total factor productivity through investments in physical capital and innovation (such as subsidies to R&D); and study the impact of various public policies on patterns of growth, along with their likely consequences from the points of view of capital accumulation, income distribution, social welfare and economic efficiency for the Turkish economy. With the aid of the model, we seek for analytical answers to the following question: *for a government constrained with its budgetary requirements, which type of public subsidiziation policies are more conducive for enhancing growth and social welfare: promotion of human capital formation through subsidies to education expenditures, or promotion of new R&D formation through subsidies to R&D investment expenditures?*

According to the model findings, a single-handed strategy of only subsidizing education expenditures to promote human capital formation falls short of achieving desirable growth performance in the medium to long run. Under the policy of human capital formation promotion, expected growth and welfare results are weak in the medium-to-long run unless increased human capital can upgrade the number of research personnel employed in the R&D development sector. Under these observations, it can be argued that the public policy should be directed to R&D promotion in the medium-to-long run, to complement an education promotion programme to sustain human capital formation.

Key words: endogenous growth; human capital; R&D, general equilibrium, Turkish economy; public policy for education and R&D

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1 Introduction

The main objective of this research is to analytically investigate and assess the interactions between knowledge driven growth, acquisition of human capital, and the role of strategic public policy for the Turkish economy within the context of a general equilibrium model. The model aims to investigate the public policies towards fostering the development of human capital (such as investments in education and learning) and those at enhancing total factor productivity through investments in physical capital and innovation (such as subsidies to R&D); and study the impact of various public policies on patterns of growth, along with their likely consequences from the points of view of capital accumulation, income distribution, social welfare and economic efficiency for the Turkish economy. The main analytical rationale of the model rests on the complementary relationships between government expenditures on education and other knowledge capital investment; and private expenditures on R&D and knowledge capital investment with a direct intent to provide a decomposition of growth dynamics for the Turkish economy.

It is a well known fact that, a growth model which solely depends on accumulation of physical capital is unsustainable. This fact, which was first put through by Solow (1956), asserts that the most important obstacle against capital accumulation is diminishing returns. As a matter of fact, the new economic growth literature indicates that there exist strong linkages between growth of national income and expenditures on education, knowledge (R&D) and other social infrastructures. Expenditures on education (investing in human capital) directly elevate the efficiency of the labor force, and provide significant externalities for growth. Additionally, R&D activities conducted by both private and public sector raise the available knowledge level and elicit capital accumulation. Thus, economic growth is fed by two sources which nourish each other: Education and R&D capital accumulation. Both practices have cross spillover effects onto each other.

As a result of the research activities at available knowledge level, stock of differentiated capital expands; in other words, with technological improvement, varieties of differentiated capital goods raise. Each "*intermediate capital input*" is obtained as a result of R&D activity or associated with a patent or blueprint. Technological spillover effects can be generated by human capital acquisition and R&D activities through "*learning via varieties*", rather than physical capital investment. Finally, knowledge accumulation resulting from both of these activities are sensitive to public policies. Determination of the optimal public policy tools that enable internalization of these externalities and their relative efficiency lie at the main focus of this study.

Developments in the new growth theory literature underline the crucial roles of research and development activities and accumulation of human capital in explaining the disparities between productivity, per capita income, and growth rates of countries. These observations led to construction of economic models which allow for limitless growth of per capita income, and in which long run performance depends on structural parameters and domestic and foreign fiscal policies. Some theories consider capital accumulation, which became a broader concept with the inclusion of human capital, as the engine of growth. (Jones and Manuelli, 1990, King and Rebelo, 1993, and Rebelo, 1991). Another approach attributes a leading role to externalities in growth process. Each firm's physical (Arrow, 1962) and human (Lucas, 1988) capital investment unintentedly contributes to the productivity of other firms' capitals. Pioneered by Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992), a third approach focuses on the effect of human capital on economic growth by triggering technological development and adoption of new technologies. The new growth literature that follows the paths of the above mentioned literature, developed models in which private industrial development, capital variety production, and technical skill dispersion lead to growth, depending on the importance of representation of knowledge-led economic conditions.

Romer (1989) and Barro (1991) are among the studies that examined the importance of human capital in the context of conditional convergence and economic growth. Additionally, Barro and Sala-i Martin (1995) and Benhabib and Spiegel (1994) stated that both human capital stock and additions to human capital stock are major factors of economic growth. More recent studies such as Temple (1999, 2001a), Easterly and Levine (2001), Vandenbussche, Aghion and Meghir (2006) and Cohen and Soto (2007), indicate the productivity enhancing impact of human capital accumulation and education on macroeconomic findings. Recent models, following the theoretical contributions of Uzawa (1965) and Lucas (1988), presented more evidence to the claim that human capital is one of the most fundamental determinants of economic growth. Influenced by public and private funds and public policies, as well as education, learning by doing and health care services; process of human capital accumulation become a crucially important subject for researchers dealing with empirical growth and growth theories. More comprehensive evaluation can be reached from Aghion and Howitt (1998, chapter 10).

In the seminal Lucas (1988) model, production activity, that is formed as a complementary process within, is a function of the human capital stock. Externalities that originate from educated labor force (human capital) serves as the engine of growth. Likewise, according to the primer work of Nelson and Phelps (1966), in many endogenous growth models human capital stock sustain long term growth by elevating the ability of producing technological innovation and catching up with the other countries.

In fact, the significance of educational funding to generate human capital and the provision of such funds to education investments in a large number of countries, has led to an increased awareness of education as the ultimate engine of growth, inviting many researchers to analyze the associated welfare effects. For instance, educational spending is regarded as one of the largest expenditure categories in the developed economies. Public and private expenditures on educational institutions account for over 6%, or roughly $1550 billion of the collective GDP of the OECD member countries each year (Temple 2001). The Lisbon Strategy (2005) of the European Union strongly emphasizes the need to invest more in human capital and R&D.

From such a perspective, educational attainment is also regarded as one of the key factors influencing the distribution of income both across households and labor categories. On the one hand, educational attainment and an individual's stock of human capital formation enable its owner to obtain better-paying jobs, more bargaining power and flexibility in the job market. On the other hand, initial distribution of wealth and household income have a direct impact on the agent's capacity to invest in human capital formation. Under these conditions, provision of public funds to education and the government's ability to invest in education and human capital formation play a crucial role in both attaining greater equality and in promoting growth. In US, 55% of the education expenditures is provided by government, enrolling 89% of all school children. Similar data from the OECD suggests not only relatively large contributions of public spending on education and training, but also suggests that government is typically the provider of the majority of public education and training services (OECD, 2000).

Finally, in most developing countries, education is considered as a priority to reduce poverty and to achieve sustained growth. Barro (1991), Tanzi and Chu (1998) and Jung and Thorbecke are among the studies that emphasize the importance of education and both the size and efficiency of public education expenditures in improving economic growth. Following a similar path, Kim (1998), in an endogenous growth model with financial, physical and human capital that is calibrated both to the US and the East Asian NIC economies, evaluates the contribution of different taxation schemes on growth rate differences. Sener (2008), in an R&D driven endogenous growth model investigates the effectiveness of R&D subsidy vs. taxation policies to promote growth. Such observations bring issues of human capital formation and optimal design of public policies in terms of investments in education, fiscal debt management, and the inter-household and inter-generational burden of taxation to the fore.

The main purpose of this study is to analytically investigate and assess the interactions between knowledge driven growth, acquisition of human capital, and the role of strategic public policy for the Turkish economy within the context of a general equilibrium model. We investigate two alternative public policies that aimed at fostering the development of human capital (such as investments in education and learning) and those at enhancing total factor productivity through investments in innovation (such as subsidies to R&D); and study the impact of various public policies on patterns of growth, along with their likely consequences from the points of view of per capita income growth, social welfare, burden to government budget and economic efficiency.

Clearly, the potential determinants of long run growth are numerous and a single model, based on the experience of a selected number of countries cannot capture all of the long run dynamics of the history of real world economies. For example, in his review of the growth experience of the East Asian countries, Stiglitz (1996) suggests that the determinants of growth are generally caused by a host of market failures that vary by country and by the level of development. This view implies that models focusing on a single or narrowly based determinant of growth are unlikely to explain the experience of a large number of countries. Keeping in mind the gulf that still appears to exist between the various theories of growth and the lack of empirical evidence to support one category of theory over another, it is nevertheless possible to empirically explore the effects of human capital formation, technological spillovers and the production of capital varieties on growth. In this context, attention can also be focused on the extent to which a decentralized market economy provides adequate incentives for the accumulation of production technology, and how variations in economic structures, institutions and public policies might translate into different rates of productivity gains.

In a nutshell then, within the economic literature context mentioned above, this study is organized around three main objectives:

1. Design of a small open economy dynamic general equilibrium model that can be used

to analyze the fiscal and education/R&D stimulating policies for the Turkish economy.

2. Taking advantage of this modeling frame, examination of taxation, expenditure policies and education and R&D stimulation policies under budget and social welfare constraints.

3. Analysis of market economy balances and regulation between private sector and state; taxation and investment relations under optimizing behavior, in the context of Turkish economy's medium to long-term growth targets.

In line with these objectives, underlying model of the study is based on the analytical setup of two main approaches of Lucas (1988) and Romer (1990). Both analytical approaches link growth to different individual elements and beyond that, set up economic activities using representative consumer/household. The model used here aims to examine Turkey as a developing country by preserving all distinctive characteristics and heterogeneous structure, using real data.

The analytical model simulates the "production - creation of income- and demand generation" components of the national economy under market constraints in applied general equilibrium context. In the model, four production industries, labor markets that consist of formal (human capital) and informal labor force, and public sector balances are decomposed by means of algebraic equations. Production process is portrayed as an augmented Cobb-Douglas type of production function that utilizes both skilled (human capital) and unskilled labor and physical capital varieties. Industrial production increases with accumulation of physical capital. Physical capital becomes available through knowledge capital (R&D). Knowledge capital investments are performed by oligopolistic (Shumpeterian) entities and oligopolistic profits are used to finance R&D investments. In the meantime, fixed costs enable increasing returns to scale in physical capital accumulation and allow growth process to be sustained endogenously.

Furthermore, accumulation of knowledge capital depends on the production of human capital. Human capital is solved endogenously by inter-household dynamic inter-temporal consumption optimization behavior; and nourished by externality effects of public capital. Thus, three main forces that provide economic growth emerge: Knowledge capital accumulation, human capital accumulation, and public capital accumulation. While first two depend on rational optimization behavior of private investors under market constraints, the last one is determined by the medium/long run expenditures of a rational government to provide stimulus to R&D and education (human capital) investments. Thus, the macroeconomic general equilibrium model used in this study has a unique approach that combines the optimization elements of the private sector and strategic growth objectives of the state.

Static general equilibrium models were built previously to study different kinds of topics in Turkish economy literature. Dervis, et al (1982), Celasun (1986), Lewis (1992), Yeldan (1997, 1998), Diao, Roe and Yeldan (1998, 1999), Karadag and Westaway (1999), De Santis (2000), Voyvoda and Yeldan (2005), and Agénor et. Al. (2005) are some examples. Lewis (1992), Yeldan (1998), and Agénor et al. (2005) are composite models which also contain financial sectors besides real sectors and focus more on taxation and trade. But, Cass-Kopmans-Ramsey type dynamic general equilibrium models based on consumption smoothing for Turkish economy are very few. Diao, Roe and Yeldan (1998) studied monetary policy alternatives for Turkish economy where Voyvoda and Yeldan (2005a, 2005b) analyzed policy alternatives for sustainability of public debt in the inter-generational wealth effects and endogenous and exogenous growth models context.

Remaining pages of the study are designed in five sections. In the second section, we present R&D and human capital data, and discuss characteristics of the growth path for Turkey. Analytical and algebraic set up of the model is presented in the third section, while policy analyses are conducted in the fourth section. In the fifth section, we summarize the main findings of the study and conclude. Data set and calibration strategy of the algebraic model are introduced in a separate Appendix section in deeper detail.

2 Main Characteristics of R&D and Human Capital Accumulation in Turkish Economy

Turkey displays typical developing country characteristics from the perspective of R&D investment activity. According to the *2011 Annual Economic Program* published by the State Planning Organization (Ministry of Development), by 2008 the proportion of R&D expenditures to the GDP was 0.73%. In contrast the EU-27 average was 1.9%. Proportion of R&D expenditures performed by the private sector to total R&D expenditures was 33.8% in 2005, and reached up to 44.2% in 2008. Considering the EU-27 average, this ratio was reportedly 63.7% in that year.

According to the same data source, by 2007, total labor engaged in R&D activities constituted 0.56% of the total civilian employment, while the same ratio was 1.57% in EU-27. In full-time equivalent values, in 2005, 30.4% of the R&D labor employment was generated by private sector, and it reached up to 40.8% in 2008. When we take a look at the EU-27, we observe that 52% of the R&D employment was created by the private sector. Main indicators of science and technology production in Turkey are summarized in Table 1.

Results of the Innovation Survey (2006-2008) as conducted by the Turkish Statistical Institute (TurkStat) indicate that 37.1% of the enterprises that employ more than 10 workers were engaged in innovation activities. The same data source reveals that innovation activities tend to grow in direct proportion to the scale of the enterprises. Accordingly, 33.8% of the enterprises that employ workers between 10-49; 43.7% of the enterprises that have workers between 50-249; and 54.4% of the enterprises that have more than 250 workers stated that they were engaged in innovation activities.

Additional information about decomposition of R&D expenditures of selected countries can be found in Table 2. Data in Table 2 indicate that in 2006 OECD countries as a group spent more than $ 817.6 billion for research and development. This amount constitutes 2.26% of that year's national income. The leading countries in terms of R&D spenditures are Sweden (3.73%) and Finland (3.41%). They are followed by Japan (3.39%) and South Korea (2.23%). Lowest shares for R&D can be observed around Southern Europe: Turkey, Greece and Portugal. We can also observe that Mexico, and the transition countries of Europe especially Poland, Romania, Slovakia also have lower R&D shares compared to their respective national income.

Data disclosed by OECD (2011) convey more detailed information for a broader set of countries. Data presented in Table 3 indicate that Israel, Finland and Sweden are in the forefront at R&D expenditures. As a share of national income, R&D expenditures are calculated to be 4.86% in Israel, 3.76% in Finland, and 3.75% in Sweden.

From this data set we can further observe that, in Turkey the level of R&D expenditures as a share of national income was 0.52% in 2004, and rose to 0.59% in 2005. Parallel to this process, we can conclude that although full-time equivalent R&D labor force is steadily increasing in Turkey, it is still behind from the desirable levels (Figure 1).

Even though education expenditures display significant disparities across countries, it is still a concentrated expenditure item. For instance, it can be observed that OECD countries devote 6.1% of their national income to the education sector as a whole (including both private and public funds) (OECD, 2011). From this data set, a comparable data for Turkey exists only for 2004. In that year, the share of public expenditures to national income was reported as 3.12%. This ratio is significantly below the OECD country averages.

On the other hand, development level of human capital can be followed from publications of UNCTAD. According to the calculations conducted by UNCTAD using data from 119 countries at 2005, along with India, China and Indonesia, Turkey is among the countries that possess a high level of human capital stock.[2]

Despite this positive observation, there exist considerable concerns about the general outlook and quality of Turkish education performance. For instance, in its *2011 Annual Program* document, the SPO (Ministry of Development) drew attention to the most important structural defects in the Turkish education system with the assessment that "*access to education and education quality are the most fundamental problems of the education system*" (SPO, 2011, pg 198). According to the same document, "*schooling ratio and disparities between regions and genders are among the most acute areas within the scope of accessibility, where inadequacy of physical infrastructure, updating of curriculum, development of teacher qualifications and harmonization of the curriculum and education costs are the main concerns as far as the quality of education services is concerned*" (ibid, pg. 198). A recent TUSIAD project report further asserts that the average schooling duration for the Turkish students is estimated to be 6.5 years. Turkey ranks 97th in the ratio of literates to the population 15 years and older. In the age bracket 25-34, the share of high school diplomas reach only to 41%, and that of university degree holders reach to 16.6%. Under both categories, Turkey ranks 33rd among 34 OECD countries.

Hence, according to these assessments, despite the positive developments of the schooling ratios at early levels of education, higher degrees that are not protected under legal compulsory education coverage fall short of the mark in comparison to OECD and EU averages. Table 5 introduces these data closely.

According to the Ministry of National Education data, in Turkey government expenditures on students in higher education reach fourfold of the government expenditures on student in basic education. Government expenditures on all levels of education are below OECD and EU countries; consequently, correction of the imbalances between higher education and other education levels is essential. Especially, if concentration of population in this age group is taken into account, it can be better understood that government expenditure on these levels are insufficient in reference to international standards.

3 The Model Structure

The model is a direct application of the recent advances in the literature of the new growth theory, and is built on the complementarities between R&D-driven technological change and human capital acquisition. The algebraic structure of the model is presented in five

[2]The calculations of UNCTAD depend on literacy ratios (population percentage), ratio of individuals at secondary school (age group percentage) and ratio of individuals who have occupational technical education (age group percentage).

sub-sections, starting with the final output production, concluding with the conditions for equilibrium and discussion of the macroeconomic identities.

3.1 Production Activities

The economy is presumed to be open, and is *small* in the world markets. It accommodates four activities in the aggregate, three of which are *production* activities: (i) production of a final good, Y; (ii) production of capital input varieties, $k(i)$ to be used as inputs in the production of Y; and (iii) production of R&D (blueprints, ideas, etc..). A final activity further entails education services (human capital formation).

Final output is produced using plain labor, L^Y , human capital (skilled labor), H^Y, and differentiated capital varieties as inputs:

$$Y_t = A_Y L_t^{Y\alpha_L} H_t^Y \sum_{i=0}^{A_t} k_t(i)^{\alpha_k} di \tag{1}$$

with $\alpha_L + \alpha_H + \alpha_k = 1.0$. All differentiated capital varieties are of equal quantity and are valued equally. They are produced by symmetric firms (each capital variety is produced by a single oligopolist firm). That is, $k(i) = k$ for all $i = 1, ..., A_t$. Therefore, we have at any moment, $\int_0^A k_t(i)^{\alpha_k} = A_t k_t^{\alpha_k}$.

Note that the Y -sector uses L_Y, H_Y, and a series of inputs $\{k_1 ... k_A\}$; where $\{A\}$ is the index of varieties of capital inputs available to this economy. As new research is conducted, the index set $\{A\}$ expands. Following the idea in Funke and Strulik (2000) and Sequiera (2008) this is achieved in the R&D sector as follows:

$$A_{t+1} - A_t = \varphi H_t^A \tag{2}$$

New research is generated solely by human capital allocated to the production of new ideas (research personnel), H_A and excludes decreasing returns as well as the scale effects of A[3]. The research productivity of each researcher is a factor $\varphi > 0$. In what follows, an additional driving source of this economy is the rate of human capital formulation:

$$H_{t+1} - H_t \;\; = \;\; \xi H_t^H + \gamma H_t^{\epsilon} A_t^{1-\epsilon} \tag{3}$$

In (3) human capital is a *non-market activity* and is thought to be "produced" via human capital allocated to education, H_H, and existing stock of ideas A. Past accumulation of human capital is also necessary to generate further human capital (students cannot be trained without teachers).

Generation of H is the end-result of schooling (ξH^H) where the parameter ξ acts as the productivity of schooling and sets the incentive to spend time in education. Sequeira (2008) refers the second term on the right hand side as "learning with varieties" since it is a composite of the stock of human capital and the existing knowledge (ideas) in the economy. This effect is driven by a productivity parameter, γ, which measures the relative importance

[3]Such a specification rather than the more general form $A_{t+1} - A_t = \varphi H_t^A A_t$ as in Romer (1990), where the R&D production function admits positive externalities through past research, helps to ensure the steady state.

of "learning with existing knowledge". The elasticity parameter ϵ measures the intensity of human capital to capture the existing knowledge.

As human capital expands, research workers keep on producing new ideas at a constant speed. The growth rate of knowledge production, g^A becomes

$$g_t^A = \frac{A_{t+1} - A_t}{A_t} = \varphi \frac{H_t^A}{A_t} \tag{4}$$

and remains constant under steady state when the share of human capital allocated to research, $u_t^A = \frac{H_t^A}{H_t}$, stabilizes. So, defining $H_{t+1}/H_t = (1 + g_t^H)$, growth rate of human capital becomes:

$$g_t^H = \xi \frac{H_t^H}{H_t} + \gamma \left(\frac{A_t}{H_t} \right)^{1-\epsilon} \tag{5}$$

At the balanced growth path, g_t^H is constant as long as the ratio of total available number of ideas to the stock human capital remain fixed. These formulations further necessitate that a steady state solution with a constant rate of growth requires a constant allocation of H_t along its components. This means that, under long run equilibrium, infinitely-lived people will dedicate in each period a constant amount of time-share between working and schooling.

The final good sector works under perfectly competitive conditions. The producer hires both types of labor and the capital varieties up to the point where the value of the marginal product of each factor is equated to its wage and rental costs, respectively. Therefore, labor is demanded according to

$$w_t^L = P_t^Y \frac{\partial Y_t}{\partial L_t^Y} \tag{6}$$

Human capital demand is similar

$$w_t^H = P_t^Y \frac{\partial Y_t}{\partial H_t^Y} \tag{7}$$

Capital varieties are demanded along the functions,

$$p_t^k(i) = P_t^Y \alpha_k {L_t^Y}^{\alpha_L} {H_t^Y}^{\alpha_H} k_t(i)^{\alpha_k - 1} \qquad i = 1, ..., A_t \tag{8}$$

In the R&D sector, given public subsidies on R&D costs, human capital is demanded so as to satisfy its marginal productivity condition:

$$w_t^H = \frac{P_t^A \varphi}{(1 - s^R)} \tag{9}$$

Here, s^R represents the subsidy rate to accumulate human capital in the R&D sector. Note that, competitive conditions in factor markets necessitate that wage costs of human capital are equated across its uses in the R&D sector and in the final goods production sector. Thus, $w_t^H = \frac{P_t^A}{(1-s^R)} \varphi = P_t^Y \alpha_H \frac{Y_t}{H_t^Y}$

3.2 The differentiated capital and investment decision

"Capital" is modeled here as a heterogenous input which accumulates by the varieties, $k(i)$. The intermediate firm purchases '*blueprints*' (the technological knowledge generated in the R&D sector) and according to the instructions therein, produces a new capital variety. The number of new capital varieties produced at period t is equal to the number of new blueprints produced in the same period, A_t. Ignoring depreciation, the number of accumulated capital varieties in the economy at time period t is equal to the number of blueprints available in the economy. Each new capital input $k(i)$ is produced by using real resources and other inputs at a constant ratio, η, where η acts as the '*input-output coefficient*' to produce one unit of $k(i)$. Costs of η is the rental price, r –the interest rate in this economy.

Now, observe that as the intermediate producer has purchased the R&D blueprints she had incurred the upfront fixed costs of research. These research costs totaling P_t^A, have to be borne up front by the intermediate capital variety firm. Thus, the expression $P_t^A \Delta A_t$ becomes the fixed costs of production of $k_t(i)$, and leads to increasing returns in its production. Since the i-th firm has monopoly rights in the production of $k_t(i)$, it acts monopolistically in the capital goods market. Taking the demand function for $k_t(i)$ from the final good producer (8) as given, each monopolist seeks to maximize the monopoly profits,

$$\underset{k_t(i)}{max} \quad \pi_t(i) = p_t^k(i) \cdot k_t(i) - \eta r_t k_t(i) - P_t^A \Delta A_t \tag{10}$$

In (10) the term $\eta r_t k_t(i)$ is the variable costs of production. For each unit of k_i produced η units of other inputs are rented out at the interest rate r_t. The solution of (10) reveals that the profit maximizing price $p_t^k(i)$ is given by a '*mark-up*' over the marginal costs, ηr_t. Using the demand for $k_t(i)$ from the final good producer's decision we have the following optimal pricing rule for the monopolist:

$$P_t^Y \alpha_k^2 L_t^{Y^{\alpha_L}} H_t^{Y^{\alpha_H}} k_t(i)^{\alpha_k - 1} = \eta r_t$$

Therefore, optimal quantity of the capital variety is set via:

$$k_t(i) = \left[\frac{P_t^Y \alpha_k^2 L_t^{Y^{\alpha_L}} H_t^{Y^{\alpha_H}}}{\eta r_t} \right]^{\frac{1}{1-\alpha_k}} \tag{11}$$

The size of the monopolistic mark-up is $1/\alpha_k$.

$$p_t^k(i) = \frac{P_t^Y \eta r_t}{\alpha_k} \tag{12}$$

Since all firms are symmetric and they all set the same price (12) to sell their respective capital varieties, we will take $p_t^k(i) = p_t^k$ and $k_t(i) = k_t$, $\forall\ i$. Under these conditions the maximal profits are given by

$$\pi_t^{\max}(k_t) = p_t^k \cdot k_t - \eta r_t \cdot k_t = (p_k - \eta r_t) k_t \tag{13}$$

Since $r_t = \frac{\alpha_k p_t^k}{\eta}$ from above, we can express maximal profits of the monopolists as,

$$\pi_t^{\max}(k_t) = (1 - \alpha_k) p_t^k k_t \tag{14}$$

The monopoly firms have a forward-looking behavior. That is, they make investment decisions on developing new blueprints and producing new capital varieties so as to maximize the long-run expected returns from an infinite stream of monopoly profits. In particular, the expected returns from investment must be comparable with those from holding a "safe" asset such as bonds or bank deposits. Thus, asset market equilibrium requires, for any point in time, that the following non-arbitrage condition holds:

$$\pi_t + \left(P_t^A - P_{t-1}^A\right) = r_t P_{t-1}^A$$

where the term $\left(P_t^A - P_{t-1}^A\right)$ denotes changes in the valorization of the $i-th$ firm over time. In equilibrium, the value of the firm is equal to aggregate investment expenditures of this firm, which includes the cost of developing a new blueprint (P_t^A), plus the material costs of investment goods. Imposition of the transversality condition to rule out speculative bubbles gives:

$$P_t^A = \sum_{t=0}^{\infty} R(t)\pi_t$$

that is, the value of the monopoly firm is equal to the discounted value of the stream of monopoly profits, where $R(t)$ is a discount factor defined according to

$$R(t) = \prod_{s=0}^{t} (1 + r_t)^{-1}$$

Note that, the above *no-arbitrage* condition can also be expressed more succinctly as,

$$(1 + r_t)P_{t-1}^A = \pi_t + P_t^A \tag{15}$$

Investment expenditures in this model, are used in generating new research and producing new capital varieties:

$$I_t^D = \eta \left[(A_{t+1} - A_t)k_t + (k_{t+1} - k_t)A_t\right] \tag{16}$$

3.3 Consumption and savings decisions

Households are endowed with human capital, H_t each period, and decide to allocate it among three uses, final good production, knowledge production and further human capital formation:

$$H_t = H_t^Y + H_t^H + H_t^A \tag{17}$$

where $(H_t - H_t^H)$ is associated with a wage rate w_t^H and H_t^H is subsidized through $s^H w_t^H$. The representative household maximizes a utility function of the form:

$$max \quad U_0 = \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\theta} - 1}{1 - \theta} \tag{18}$$

subject to

$$\begin{aligned} \sum_{t=0}^{\infty} R(t) P_t^C c_t &= TW_0 \\ H_{t+1} - H_t &= \xi H_t^H + \gamma H_t^{\epsilon} A_t^{1-\epsilon} \end{aligned}$$

with control variables $c_t > 0$ and $H_t^H \geq 0$. Here, TW_0 is the total wealth, which includes the present value of period-wise income. $Y_t^H = (1 - t^Y)[w_t^H(H_t - H_t^H) + s^H w_t^H H_t^H + w_t^L L_t^Y + p_t^k k_t A_t]$ is the private household disposable income composed of returns to primary factors of production and the value of monopoly firms of capital variety.

The F.O.C.'s associated with the maximization problem above are twofold:

$$\beta(1 + r_{t+1}) \left(\frac{c_{t+1}}{c_t}\right)^{\theta} = \frac{P_{t+1}^C}{P_t^C} \tag{19}$$

$$\frac{w_t^H}{w_{t+1}^H} = \frac{1}{1 + r_{t+1}} \left(\frac{\xi}{(1 - s^H)} + 1 + \gamma\epsilon \left(\frac{H_{t+1}}{A_{t+1}}\right)^{1-\epsilon}\right) \quad \textit{with} \;\; H^H > 0 \tag{20}$$

The first condition above is the discrete version of the standard Ramsey rule. The second equation implies that the growth rate of wages must be sufficiently high enough compared to the interest rate to ensure positive investment in human capital.

Using $\frac{(1-s^R)w_t^H}{\varphi} = P_t^A$ from (9), we get,

$$\frac{w_{t+1}^H}{w_t^H} = \frac{P_{t+1}^A}{P_t^A}$$

The rate of growth of P_t^A above is narrated in the *no-arbitrage condition* (15). Inserting in the equations for π_t and P_t^A and equating the two expressions for $\frac{w_{t+1}^H}{w_t^H}$, gives us:

$$1 + \frac{1 - \alpha_k}{\alpha_H} \varphi \alpha_k \frac{u_{t+1}^Y H_{t+1}}{A_{t+1}} \;\; = \;\; \frac{\xi}{(1 - s^H)} + \left(1 + \gamma\epsilon \left(\frac{H_{t+1}}{A_{t+1}}\right)^{(1-\epsilon)}\right)$$

Now assume that we denote the share of H_t allocated to final goods production, H_t^Y as u_t^Y. The equation above should provide the value of u_{t+1}^Y, given H_{t+1}/A_{t+1} which is critical in terms of the allocation of human capital to different sectors of the economy. It also implies $u_{t+1}^Y = u^Y$ at the steady state.

3.4 Export and import functions and balance of payments

The representative final good producer has the following production possibility boundary between exports, E_t and domestic sales, DC_t (the constant elasticity of transformation - CET frontier):

$$X_t = \bar{Z}_X \left(\nu E_t^{(1+\sigma)/\sigma} + (1 - \nu) DC_t^{(1+\sigma)/\sigma}\right)^{\sigma/(1+\sigma)} \tag{21}$$

In equilibrium, the ratio of exports to domestic good becomes:

$$\frac{E_t}{DC_t} = \left(\frac{P_t^E}{P_t^D}\right)^{\sigma} \left(\frac{1 - \nu}{\nu}\right)^{\sigma} \tag{22}$$

Import decisions are derived from the *Armingtonian composite commodity* specification, where imports M_t, and domestic good, DC_t, are regarded as imperfect substitutes in trade.

$$CC_t = \bar{Z}_{CC} \left(\kappa M_t^{(\psi-1)/\psi} + (1 - \kappa) DC_t^{(\psi-1)/\psi}\right)^{\psi/(\psi-1)} \tag{23}$$

In equilibrium the ratio of imports to the domestic good becomes

$$\frac{M_t}{DC_t} = \left(\frac{P_t^D}{P_t^M}\right)^{\psi} \left(\frac{1-\kappa}{\kappa}\right)^{\psi} \tag{24}$$

where $P_t^M = (1+t^m)P_t^{WM} and P_t^E = P_t^{WE}$ with t^m representing tariff rate at period t. The economy has balanced trade in each time period.

3.5 National Income Identities and Equilibrium Growth

Intra-temporal equilibrium requires that at each time period, (1) demand for primary factors (L_Y, H_A, H_Y) equal their respective supplies; (2) Human capital allocation among Final Good Production, Y, R&D Production, ΔA, and Education, ΔH exhausts its total supply; (3) domestic demand plus export demand for the output of each sector equal its supply; (4) the output of R&D, that is the number of new blueprints, equal the number of new capital varieties invested; (5) household savings equal investment –costs of new blueprints plus costs of investment goods in capital variety production; (6) the value of total exports equal the value of total imports; and (7) the government budget is satisfied. These conditions imply that the commodity market is in equilibrium with

$$CC_t = C_t + G_t + I_t^D \tag{25}$$

Saving investment balance is maintained through:

$$S_t = P_t^C I_t^D + P_t^A \Delta A_t \tag{26}$$

Government's budget is in balance:

$$P_t^C G_t + s^H w_t^H H_t^H + s^R w_t^H H_t^A = GREV_t \tag{27}$$

with government revenues equal to total tax revenues[4].

Gross domestic product (GDP) at factor cost (exclusive of production taxes) is the sum of value added of the final good, human capital expenditures, and the R&D sectors:

$$GDP_t = P_t^Y Y_t + P_t^A \Delta A_t \tag{28}$$

$$= w_t^L L_t^Y + w_t^H (H_t^Y + H_t^A) + \sum_{i=1}^{A_t} p_t^k(i) k_t(i) \tag{29}$$

Using $\sum_{i=1}^{A_t} p_t^k(i) k_t(i) = p_t^k A_t k_t$, which in turn will be equal to $\alpha_k P_t^Y Y_t$, the identity in (29) can also be written as

$$p_t^k A_t \cdot k_t = \alpha_k \left(GDP_t - P_t^A \Delta A_t\right)$$

or, using (29),

$$\begin{aligned} \left[GDP_t - w_t^L L_t^Y - w_t^H (H_t^Y + H_t^A)\right] &= p_t^k A_t k_t \\ &= \alpha_k P_t^Y Y_t \end{aligned} \tag{30}$$

[4]Total government tax revenues compose of income tax, consumption tax, production tax and tariff revenues.

Furthermore, using the definition of profits from (14), the GDP identity can also be written as:

$$P_t^Y Y_t + P_t^A \Delta A_t = w_t^L L_t^Y + w_t^H (H_t^Y + H_t^A) + A_t \frac{\pi}{(1-\alpha_k)} \tag{31}$$

In the steady state equilibrium all quantity variables grow at a constant rate which is proportional to the growth rate of human capital formation. All prices, including prices for final goods produced and consumed domestically, the unit cost of the R&D output, differential capital varieties, and the interest rate grow at a constant rate in the steady state. Also, the allocation of H_t among its uses will be constant; hence, given $H_t^Y = u^Y H_t$, $H_t^A = u^A H_t$ and $H_t^H = u^H H_t$, with $u^A + u^H + u^Y = 1$.

Based on these specifications, and the growth rates of H, g_t^H and A, g_t^A implies that at steady state H_t/A_t is constant. Combining the definitions of g_t^H and g_t^A, we have $g^H = g^A$ at the steady state.

We know that w_t^H in R&D sector is the same as the w_t^H in the final goods sector. Equating the two, we have:

$$\begin{aligned} \frac{P_t^A \varphi}{1-s^R} &= \alpha_H L_t^{Y\alpha_L} H_t^{Y\alpha_H - 1} A_t k_i^{\alpha} \\ P_t^A &= \frac{\alpha_H L_t^{Y\alpha_L} H_t^{Y\alpha_H - 1} A_t k_i^{\alpha}(1-s^R)}{\varphi} \end{aligned}$$

Similarly,

$$\pi_t(i) = (1-\alpha_k)\alpha_k L_t^{Y\alpha_L} H_t^{Y\alpha_H} k_i^{\alpha_k}$$

Therefore:

$$(1 + g^{P_A}) = r_t - \frac{(1-\alpha_k)}{\alpha_H} \alpha_k \frac{H_t^Y}{A_t} \varphi \tag{32}$$

Since we now have the solution for P_t^A above, we can also derive the growth rate P_t^A at the steady state as:

$$(1 + g^{PA}) = (1 + g^H)^{\frac{\alpha_H}{1-\alpha_k}} \tag{33}$$

Finally, since $Y_t = A_Y L_t^{Y\alpha_L} H_t^{Y\alpha_H} \sum_{i=0}^{A_t} k_t(i)^{\alpha_k}$, we have

$$\frac{Y_{t+1}}{Y_t} = \left(\frac{L_{t+1}^Y}{L_t^Y}\right)^{\alpha_L} \left(\frac{H_{t+1}^Y}{H_t^Y}\right)^{\alpha_H} \frac{A_{t+1}}{A_t} \left(\frac{k_{t+1}}{k_t}\right)^{\alpha_k}$$

So, under the steady state:

$$(1 + g^Y) = (1 + g^H)^{\frac{1+\alpha_H-\alpha_k}{1-\alpha_k}}$$

4 Policy Analysis: Dynamic Effects of the Selected Public Policies

4.1 Base Path Equilibrium

Now we will turn to the investigation of alternative public subsidization programs to promote growth and welfare with the context of our analytical model. In this exercise our first step will be construction of a business-as-usual *base-path* against which alternative policy scenarios are to be contrastsed. To this end we will follow the long run growth trajectory of the Turkish economy under the historically realized parametric values starting from its 2005 equilibrium onwards.

As a starting reference point, the base path assumes an annual rate of growth of 1.5 percent over a time span of 90 periods. Note that this rate narrates growth of only the *total factor productivity (TFP)* content of the growth of the GDP. To this value, addition of the growth in population and of other factors of production will bring us the *aggregate* rate of growth of the national economy. It is further assumed that the ratio of R&D investment expenditures to the GDP is 0.75%. The equilibrium rate of interest is taken as 5%. Under these specifications, the share of differentiated capital income in gross value added (α_k) is calculated to be 0.65. The ratio of monopolist profits to the national income, on the other hand, is calculated to be 20%.

Model simulations of the *base-path* under these specifications reveal that the value of the gross domestic product will reach to 3,500 billions TL in fixed 2005 prices after 90 periods starting from the 2005 value of 648 billions TL. The path of the equilibrium level of GDP is portrayed in Figure 2.

Similarly, amounts of the stock of human capital and the index of R&D can be enivsaged over the time span of 90 periods under the *base-path* specification. Figures 3 and 4 display this information.

Values of the various other parameters and macroeconomic variables are displayed in Table 1 of the Appendix. Now we turn to the analysis of alternative public subsidization regimes utilizing the *base-path* as a point of reference..

4.2 Analysis of Alternative Subsidization Programs

In this sub-section we turn to the analysis of the basic mechanisms of growth-generating dynamics of the model, incorporating both accumulation of R&D and accumulation of human capital. Since the framework employed here takes into account the complementarity between human capital and the R&D activities, and the externalities associated with the accumulation of both, we first explore the basic mechanisms of "correcting" the "market failures" toward superior outcomes. To this end, we investigate two policy instruments, each of which promotes the accumulation of factors that are most needed in the production of the final good in the economy. Specifically, we first study *subsidization of education expenditures* (subsidy on the buildup of human capital through skill-accumulation function via s^H) and contrast it with *subsidization of the R&D activities* (subsidy on the input costs to R&D via s^R). The first policy experiment is designed to analyze the households' response to allocate human capital among different sectors and activities in the economy under the conditions of increased reward to education activities. Since the instrument, s^H, enters into representative household's intertemporal maximization problem, we shall observe the effects on the derivation of the future wages both in the final goods and the R&D sectors of the economy and the trade-offs embedded. The other policy instrument analyzed at this stage is designed to promote R&D activities through a demand stimuli. It is implemented through the addition of an *ad valorem* subsidy to the input cost of the production of new R&D. More formally, our policy question can be stated sucinctly as the following: *for a government constrained with its budgetary requirements, which type of public subsidiziation policies* *are more conducive for enhancing growth and social welfare: promotion of human capital formation through subsidies to education expenditures, or promotion of new R&D formation through subsidies to R&D investment expenditures?*

We will utilize the endogenous growth model, whose algebraic structure is presented above, to make a comparison between these two policy alternatives. First and foremost, we note we ought to ensure that the incentive levels of both policies remain equal (as a ratio to the GDP) in order to compare alternative policy interventions quantitatively. For this reason, stimulation of the cost of fiscal intervention is designed to be 1% of national income, and the corresponding subsidy ratio is solved by the model endogenously. Solutions of the model indicate that an equivalent subsidy of 1% of national income corresponds to 4.0% for the human capital subsidy program, and 4.3% for the R&D subsidy program. The fiscal authority which is bounded with a public budget constraint is modeled to find necessary funds for subsidies by decreasing government consumption expenditures. Hence, the subsidy system does not lay extra burden to the public budget, as such a burden is avoided by directly restructuring other government expenditures.

Our results indicate that under both policy regimes growth in output is above the long run base path. Since the growth rate depends on a variety of factors encompassing the distribution of human capital across production of the final good, R&D activities and the education sector, as well as the path of R&D accumulation, the announced government subsidy creates complicated general equilibrium dynamics. Subsidizing R&D costs aspire to improve R&D activities by stimulating the differentiated capital production sector. Government subsidy to investment cost of each new blueprint (R&D) stimulates the differentiated capital good production and raises the production of further R&D activity. This, in turn, encourages resources to move away from other sectors and activities. Under the alternative policy scenario where we analyze the impact of dedication of human capital across different sectors by subsidizing education we run into different trade-offs in human capital formation versus R&D investments. One should note that, government subsidy to human capital accumulation appears within the inter-temporal optimization problem of the private individuals. This decision involves recognition of the signals emanating from the wage rate differences from the production of the final good versus the R&D activity.

It can be observed that, the government subsidy on human capital devoted to education activities leads to reallocation of resources away from the R&D sector and channel them to human capital accumulation. This kind of a restructuring enables a higher level of human capital available to the economy, yet it initially results in lower R&D activity.

In the case of the subsidy to R&D investment (through the s_R parameter), production of R&D is elevated to a higher equilibrium level compared to the base path. On the other hand, since both human capital devoted to R&D and human capital employed for education are both effective for human capital production, we do not experience any significant reduction of human capital production as a whole. Figure 5 presents the disparate paths of the gross domestic product under alternative policy regimes relative to the base path over a time span of 30 periods.

Our results indicate that government's subsidization of the private education expenditures generates very strong growth effects initially, and yet, after this initial positive impact, the growth stimulating effects of the policy turn negative and weaken out. Under this policy, initiation of the education subsidy leads to a higher level of human capital devoted to education activities. Remaining resources will be shared between R&D and final good production sectors. Employment of more human capital by education activities through income transfer, leads lower levels of human capital at R&D and final good production sectors. As a result of this, once the initial stimulus wanes out, production falls abruptly below the base path as the economy faces a severe re-adjustment of balancing out the returns to human capital across its three uses (final good production, R&D activities, and further human capital production). According to the model solutions, the initial gain in GDP is around 8 percent. After this initial gain, as human capital had been re-allocated away from the R&D and final good production, we witness the rapid scaling down of the production activity. Over the medium to long run, more human capital formation eventually re-invigorates the R&D activities. As the number of researchers expand in the R&D sector, the economy starts to pick up through expansion of capital varieties, and hence, of the level of final output –the GDP. Over the long run, the equilibrium level of GDP lies about 1% above that of the base-path.

In contrast, the government subsidy on R&D investments have a relatively mode modest initial impact on the GDP. The GDP jumps by 4.5% upon impact, and then stabilizes around at a plateau that is 2% higher than the base-path.

Overall, we observe that the growth paths display a fluctuating structure toward equilibrium. Revelation of such fluctuating structures toward equilibrium is recognized also by Sequeira (2008). In general, human capital employed by R&D activities displays a more fluctuated structure than human capital employed by final good production. This result is an indicator of the trade off impact of the most needed human capital in the economy.

Various relevant macro variables are portrayed in Figures 6 to 9 below. In Figure 6 we follow the equilibrium stock of knowledge capital (stock of R&D, *i.e.A*).

Subsidization of the R&D investment activities lead to expansion of the R&D stpck 4% above the base path. The R&D subsidy ulitmately leads to expansion of the capital stock of the economy by increasing the number of differentiated capital varieties. (Figure 8). The education subsidy in the model is represented by a direct transfer of income from the government budget to the human capital accumulation activity. An announcement of subsidy to human capital accumulation activity basically drives resources away from the R&D activity, leaving the amount allocated to final goods sector only slightly lower. As a result, the accumulation of human capital in the economy continues at a higher pace than the accumulation of R&D (Figure 7). The output growth, which is dependent on both the accumulation of R&D and the human capital allocated to final goods sector is adversely affected due to this reason, as discussed above. Although the rate of growth of GDP quickly bounces back, the immediate negative effect of bidding resources away from the other sectors of the economy is felt during a longer transition period.

The announcement of an R&D subsidy as reflected in the reduction of cost of input (wage of human capital, w^H) employed by the producers of R&D, on the other hand, encourages them to pull primary resources away from other sectors. Under such an instrument, the demand for R&D activities is increased to a higher steady-state level, compared to the benchmark and the education subsidy scenario. On the other hand, total human capital built up is only slightly lower (2.2%) with respect to benchmark; and since both the R&D, and therefore, human capital employed in R&D activities and the human capital allocated to education are effective in the production of new human capital in the economy, the R&D subsidy leads to the reallocaton of human capital stock at a rate of 3.5% lower with respect to the education subsidy scenario. As more human capital is devoted to R&D activities through subsidization, less is devoted to education, leading to an adjustment toward education activities in the following period. Such effects on total R&D and total human capital stock of the economy are visible in Figure 7.

When the R&D production cost is reduced by the subsidy, the stream of monopoly rents, acquired from the property rights of the blueprint increases. Such an increase stimulates further incentives for the production of capital, as new firms are attracted by increased profits. So, the subsidy to the cost of R&D production encourages an upward shift in the demand for differentiated capital (new information technologies) production sector, leading to higher investment and higher capital accumulation in the economy, both during transition and at the steady state (See Figure 8). It is basically through the stimulation of the activity in the final goods sector that keeps both the wage rate of human capital and the price of R&D higher under this scenario.

Another interesting result obtained from these observations is related with the pricing of human capital. Rapid increase in human capital stock under government subsidy brings along a cheapening of the wage costs of human capital in the long run. As one can observe from Figure 9, as a result of the direct subsidy to education, wage costs of human capital rise initially. But after this momentary reaction, effect of the increased demand for human capital relative to supply leads to a n increase in the wage rate, and thus, the wage rate of human capital catches up its benchmark value by the sixteenth period.

At the R&D subsidy system, production process of human capital follows a different path. Subsidizing R&D affects human capital wages in a milder, but continuously positive manner. On the other hand, steady increase in knowledge stock derived from R&D implies a milder and more positive impact on economic activities. From the viewpoint of the algebraic structure of the model, as investment costs fall, a higher level of capital stock become available to the national economy. Such an augmentation directly influences quantity of final good production and accordingly acquired factor incomes. Since, both profits generated by differentiated capital good production and wages are part of individuals' income, a direct government subsidy which channels resources to final good production provides conducive conditions in terms of long run equilibrium dynamics. Lower levels of saving promote investment and also make room for rise of expenditures. In other words, despite the low saving ratios, higher levels of production and consumption levels can be reached by means of the government subsidization.

5 Overview of Results and Concluding Comments

In this paper we attempt to analytically investigate and assess the interactions between knowledge driven growth, acquisition of human capital, and the role of strategic public policy for the Turkish economy within the context of a general equilibrium model. The model aims to investigate the public policiestowards fostering the development of human capital (such as investments in education and learning) and those at enhancing total factor productivity through investments in physical capital and innovation (such as subsidies to R&D); and study the impact of alternative public policies on patterns of growth, along with their likely consequences from the points of view of capital accumulation, income distribution, social welfare, and economic efficiency for the Turkish economy. The main analytical rationale of the model rested on the complementary relationships between government expenditures on education and other knowledge capital investment; and private expenditures on R&D and knowledge capital investment with a direct intent to provide a decomposition of growth dynamics for the Turkish economy.

In line with this scope, the algebraic structure of the model relies on the analytical set up of two main approaches: human capital-driven growth due to Lucas (1988), and R&D-driven growth a la Romer (1990). Each analytical approach links growth to different elements individually and beyond that build economic activities through a representative consumer within the context of an abstract economy. The model used here, by contrast, aims to examine Turkey as a developing country by preserving all distinctive characteristics and heterogeneous structure, by using real data.

The analytical model simulates the "production - creation of income- and demand generation" components of the national economy under market constraints in applied general equilibrium context. In the model, four production industries, labor markets that consist of formal (human capital) and informal labor force, and public sector balances are decomposed by means of algebraic equations. Production process is portrayed as an augmented Cobb-Douglas type of production function that utilizes both skilled (human capital) and unskilled labor and physical capital varieties. Industrial production increases with accumulation of physical capital. Physical capital becomes available through knowledge capital (R&D). Knowledge capital investments are performed by oligopolistic (Shumpeterian) entities and oligopolistic profits are used to finance R&D investments. In the meantime, fixed costs enable increasing returns to scale in physical capital accumulation and allow growth process to be sustained endogenously.

Furthermore, accumulation of knowledge capital depends on the production of human capital. Human capital is solved endogenously by inter-household dynamic inter-temporal consumption optimization behavior; and nourished by externality effects of public capital. Thus, three main forces that provide economic growth emerge: Knowledge capital accumulation, human capital accumulation, and public capital accumulation. While first two depend on rational optimization behavior of private investors under market constraints, the last one is determined by the medium/long run expenditures of a rational government to provide stimulus to R&D and education (human capital) investments. Thus, the macroeconomic general equilibrium model used in this study has a unique approach that combines the optimization elements of the private sector and strategic growth objectives of the state.

Formally, our policy question has been the following: *for a government constrained with its budgetary requirements, which type of public subsidiziation policies are more conducive for enhancing growth and social welfare: promotion of human capital formation through subsidies to education expenditures, or promotion of new R&D formation through subsidies to R&D investment expenditures?* To seek for answers to this task, we first studied *subsidization of education expenditures* (subsidy on the buildup of human capital through skill-accumulation) and contrasted it with *subsidization of the R&D activities* (subsidy on the input costs to R&D). The first policy experiment was designed to analyze the households' response to allocate human capital among different sectors and activities in the economy under the conditions of increased reward to education activities. The other policy instrument analyzed was designed to promote R&D activities through a demand stimuli. This was implemented through the addition of an *ad valorem* subsidy to the input cost of the production of new R&D.

Using the solutions of the model, one can derive the following summary conclusions:

• Stimulation policies of government on human capital and R&D have permanent long run consequences. This result documents that, predictions of traditional neoclassical macroeconomic theories, which claim that government intervention can have only limited short run impacts on the national economy with almost zero net effects in the long run, are not valid. Knowledge and education externalities serve as powerful tools to eliminate bottlenecks and market imperfections, and providing a second best equilibrium solution.

• The strategy of stimulating education expenditures by government subsidies initially induce positive influences on national income; however, in the long run, this positive impact on national income fades away. As a result of stimulation of education expenditure by government subsidization, national resources move away from other sectors (including R&D sector) and are devoted to human capital accumulation. Relatively regressing R&D sources cancel out the expected positive acceleration from human capital formation and leads to deceleration in GDP. But, blueprints/knowledge/contributions to technology created by R&D directly benefits to incentivized capital variety. For this reason, relative deceleration in R&D, downgrade first capital accumulation and later speed of growth instantly (upon impact). Long run accumulation of human capital will ultimately accelerate R&D activity. As a result of such long run expectations, along with the sufficient raise in the number of R&D researchers, R&D production rises again and accelerates the economic growth.

•As a consequence, the most important finding of the model is the determination of weakening of the positive impacts of a public stimulation program that is based on the stimulation of only education investment in the medium-long run. A single-handed strategy of only subsidizing education expenditures to promote human capital formation falls short of achieving desirable growth performance in the medium to long run. Under these observations, targeting a hybrid program, which stimulate education in the short-medium run and incentivize R&D investment in the medium-long run seems to be more appropriate for a government, as a resource subsidization strategy.

As a final reminder for the reader, one should also be cautioned that, as in all quantitative modeling studies used in social sciences, the obtained policy implications are sensitive to algebraic properties of the model in use. The applied general equilibrium model, is a technical laboratory equipment which reflects a well-defined and harmonious general equilibrium system without any rigidities and/or structural imbalances on consumer and producer optimization basis. Thus, adjustments of model economy to various policy shocks, should not be seen as a criterion for real economies' global stability characteristics, but rather should be considered as a direct consequence of laboratory characteristics of a macroeconomic simulation apparatus. For these reasons, our results should be acknowledged as rough approximations of long run equilibrium impacts of public stimulation and investment policies on production, employment, and physical and human capital accumulation, and consumer welfare. It is essential to continuously improve these policy suggestions obtained from such a social laboratory environment at mathematical abstraction level with a more realistic and detailed analysis of national economies. We believe that, the general equilibrium approach used in this study that has the privilege of serving as a first attempt for the Turkish economy, is an important step toward this direction.

Appendix: The data and the calibration strategy

Calibration steps

The data related to the initial period's equilibrium are drawn primarily from the Turkish Statistics Association (TurkStat) input-output data set 2002 for Turkey. As the TurkStat data are originally in the form of annual flow values and primarily compiled for the purpose of static general equilibrium analyses, they need to be further augmented by information associated with the Turkish growth path, namely, capital stock, technological knowledge stock, R&D expenditures, growth rate(s), interest rate, and the discount rate in the intertemporal utility functional.

The intertemporal elasticity of substitution, $1/\sigma$, in the household utility function is chosen in the range estimated by Hall (1988). The rate of time preference, ρ , is taken from Lucas (1988). The average growth rate between 1990 and 2005 for Turkey is chosen as the growth rate of human capital formation, hence for R&D; thereby, as the initial *steady state* growth rate, $g_A(0)$, for the economy. The initial interest rate, r_0, then has to be calculated in a way consistent with the choices of σ, ρ, and $g_A(0)$ [5]. We further assume that the depreciation rate of capital varieties is zero.

The data on Turkish professional personnel occupation categories are used to adjust the original TurkStat data for the labor inputs. We distinguish the returns to the differentiated capital from the returns to the labor resource based on these data. This is accomplished using the calibration restrictions implied by the model. For purposes of calibration, we normalize the initial stock of the R&D output (A_0) to one. Then, the number of the new blueprints produced in the benchmark is equal to the growth rate, as $g^A(0) = \Delta A_0/A_0$.

To ensure the existence of a balanced growth path, we calibrate α_k and the total investment, including the value of R&D output $P^A \cdot \Delta A_0$, and the cost of new capital variety production R&D, simultaneously see Eqs. (26), (29) and (31).

Under the steady state we know that $r_{SS} = g^{PA} + \frac{\Pi_{SS}}{PA}$. Now, recall the GDP identity from (31):

$$P^Y Y + P^A \Delta A = w^L L^Y + w^H (H^Y + H^A) + \frac{\Pi}{(1-\alpha_k)}$$

Using the the no-arbitrage equation we have $(1 + g^{PA}(t)) = \frac{1+r_{t+1}}{1+\frac{\Pi_{t+1}}{PA_{t+1}}}$. Thus, under the steady state equilibrium the national income identity satisfies,

$$GDP = w^L L^Y + w^H (H^Y + H^A) + \frac{P^A}{(1-\alpha_k)} (\frac{1+r}{1+g^{PA}} - 1)$$

or equivalently,

$$(1-\alpha_k)\left[GDP - w^L L^Y - w^H (H^Y + H^A)\right] = P^A (\frac{1+r}{1+g^{PA}} - 1) \tag{34}$$

[5] As in static applied GE models, where calibration is based on the assumption that data reflect an economy in equilibrium, we assume that the benchmark data depict an initial steady state growth path. This steady-state assumption for the benchmark data is widely used in applied intertemporal general equilibrium models. For example, Goulder and Summers, 1989; Go, 1994; Mercenier and Yeldan, 1997; and Diao, Roe and Yeldan, 1999.

Using (30) and (34) together,

$$(1-\alpha_k)\alpha_k\left[GDP - P^A\Delta A\right] = P^A(\frac{1+r}{1+g^{PA}} - 1) \tag{35}$$

Using the fact that g_{PA} and g_A are related via equation (33) in discrete time as $(1+g_{PA}) = (1+g_A)^{\frac{\alpha_H}{1-\alpha_k}}$, and recalling that we had set $A_0 = 1$; using $\Delta A = g_A$, this information will allow us to utilize the following relationship for calibrating P_A and α_k:

$$(1-\alpha_k)\alpha_k\left[GDP - g^A P^A\right] = P^A(\frac{1+r}{1+g^{PA}} - 1) \tag{36}$$

The second simultaneous relationship between P_A and α_k is obtained from the savings - investment equilibrium condition (26). Using (26) and (29) together, and making note of the fact that $\Delta A/A = g_A$, we have

$$SAV = r\cdot\eta\cdot g^A\cdot k + r\cdot\eta\cdot\Delta k + P^A g^A$$

Since, from the optimal pricing rule of the monopolist (equation 12) $r = \frac{\alpha_k p_k}{\eta}$, the saving - investment equilibrium can be re-written as

$$SAV = \frac{\alpha_k(g^A + g^{PA})}{r(1-\alpha_k)}\cdot P^A\left(\frac{1+r}{1+g^{PA}} - 1\right) + P^A g^A \tag{37}$$

Now let's switch to calibration of the factor markets. We read the values of SAV, wages paid to human capital in the production of the final good, and the value added of Y from data. Normalizing w_H to unity, the share parameter α_H can be found as $\alpha_H = wagesH/Y$. And thus, $H_Y = wagesH$. We set the steady state growth rate of A, to 0.015. Then, using $(1+g_{PA}) = (1+g_A)^{\frac{\alpha_H}{1-\alpha_k}}$ we solve for P_A and α_k via simultaneous iterations of (36) and (37).

Using the F.O.C in the R&D production function with $w_H = 1$, we set $\varphi = 1/P_A$. Similarly, from the R&D production function, $\Delta A = \varphi H_A$ with $A(0) = 1$ and $g_A = 0.025$; level of human capital allocated to R&D is read as

$$H_A(0) = \frac{g_A}{\varphi} = g_A P_A \tag{38}$$

For calibration, we set the initial values of u_A, u_H and u_Y to accordingly. Using the definition of g_A this will allow us to solve for the level of aggregate human capital.

Using H_Y from SAM data, $H_A(0)$ from (38) and $H(0)$ we now calibrate for H_H as

$$H_H(0) = H(0) - H_Y(0) - H_A(0) \tag{39}$$

Next, given $H(0)$, denote the calibration variable $\overline{z} = \frac{H(0)}{A(0)} = H(0)$. From the rate of growth of H equation (20)

$$\frac{\Delta H}{H} = g_H = g_A = \xi u_H + (sg_E)\gamma\left(\frac{1}{\overline{z}}\right)^{1-\epsilon} \tag{40}$$

We also have from the optimal u_Y decision:

$$u_Y = \frac{\xi \alpha_H}{\varphi(1 - s^H)(1 - \alpha_k)\alpha_k} \left(\frac{1}{\overline{z}}\right) - \frac{\epsilon \gamma \alpha_H}{\varphi(1 - \alpha_k)\alpha_k} \overline{z} \tag{41}$$

Equations (40) and (41) are iterated to solve for the parametric values of γ and ξ.
Using discrete time, condition for equilibrium growth of consumption is

$$\left(\frac{1 + r_{SS}}{1 + \rho}\right)^{1/\sigma} = 1 + g_c \tag{42}$$

Thus growth in final good becomes $g_Y = g_C$. The rest of the system is calibrated using standard methods of applied general equilibrium.

Table A-1 presents the initial levels of selected variables and parameters obtained from sources other than the main data base or from this calibration process. The initial state of the macroeconomic equilibrium of the Turkish economy (2005).

Table A-1. Pre-assumed and Calibrated Values of Structural Parameters	
Share of human capital in final good value added, α_H	0.139
Share of plain labor in final good value added, α_L	0.214
Share of rental value of differentiated capital in final good value added, α_K	0.647
R&D Production productivity parameter, φ	0.00035
Productivity of schooling in human capital formation, ξ	0.012
Productivity of learning via knowledge and varieties, γ	0.020
Share of past human capital in human capital formation, ϵ	0.879
Value of input output coefficient to produce unit capital variety, η	12.983
Share of human capital allocated to final good production, $\frac{H_Y}{H}$	0.158
Share of human capital allocated to R&D production, $\frac{H_A}{H}$	0.421
Share of human capital allocated to human capital formation, $\frac{H_H}{H}$	0.421
Value of R&D expenditures as a ratio to GDP, $\frac{P_A \Delta A}{GDP}$	0.061
Ratio of aggregate savings to GDP, $\frac{SAV}{GDP}$	0.199
Share of oligopolistic profits in GDP, $\frac{\Pi}{GDP}$	0.202
Inverse of intertemporal elasticity of substitution for the consumer, σ	1.0001
Subjective discount rate, ρ	0.030
Income tax rate, t_y	0.032
Armingtonian elasticity of substitution between M and DC, ε_{CC}	3.000
CET elasticity of transformation between E and DC, ε_{CET}	3.000

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Table 1. Turkey's Basic Indicators on Science and Technology					
	2004	**2005**	**2006**	**2007**	**2008**
R&D Expenditures as a Ratio to GDP	0.67	0.79	0.76	0.71	0.73
Gross Expenditures on R&D (Millions TL) (In fixed 2003 prices)	2,564.6	3,143.4	3,283.6	4,200.7	4,447.1
Gross Expenditures on R&D (PPP* Millions US$)	3,653.0	4,373.0	4,883.0	6,578.0	7,034.0
Per capita R&D Expenditures (PPP* US$)	51.4	60.7	69.2	93.2	98.4
R&D Expenditures by Sector of Origin (%)					
High Education	67.9	54.6	51.3	48.2	43.8
Private Sector	24.2	33.8	37	41.3	44.2
Public Sector	16	17.9	17.8	15.1	14.7
R&D Personnel per 10,000 people	18.1	20.4	24.5	30.6	31.7
(*) PPP: Purchasing Power Parity					
Sources: SPO (Ministry of Development), 2011 Ekonomic Program, Tab IV.26; Tübitak, www.tubitak.gov.tr					

Table 2. International comparisons of gross domestic expenditures on R&D and R&D share of gross domestic product, 2006

Country/economy	GERD (millions PPP$)	GERD/GDP (%)	Country/economy	GERD (millions PPP$)	GERD/GDP (%)
United States (2006)	343,747.5	2.62	Denmark (2006)	4,651.6	2.43
			Norway (2006)	3,686.2	1.52
G-7 countries (2006)	667,911.1	2.50	Czech Republic (2006)	3,489.1	1.54
European Union-27 (2006)	242,815.6	1.76	Poland (2006)	3,110.0	0.56
			Ireland (2007)	2,490.4	1.33
OECD, All (2006)	817,768.9	2.26	Portugal (2006)	1,839.5	0.83
Japan (2006)	138,782.1	3.39	Hungary (2006)	1,831.3	1.00
Germany (2006)	66,688.6	2.53	Greece (2006)	1,734.6	0.57
France (2006)	41,436.2	2.11	New Zealand (2005)	1,189.3	1.16
South Korea (2006)	35,885.8	3.23	Luxembourg (2006)	542.1	1.47
United Kingdom (2006)	35,590.8	1.78	Slovak Republic (2006)	467.1	0.49
Canada (2007)	23,838.9	1.89	Iceland (2005)	293.0	2.78
Italy (2005)	17,827.0	1.09			
Spain (2006)	15,595.7	1.20	Selected other countries/economies:		
Sweden (2006)	11,815.3	3.73	China (2006)	86,758.2	1.43
Australia (2004)	11,698.1	1.78	Russian Federation (2006)	20,154.9	1.08
Netherlands (2006)	9,959.0	1.67	Taiwan (2006)	16,552.9	2.58
Austria (2007)	7,865.3	2.52	Israel (2006)	7,985.1	4.65
Switzerland (2004)	7,479.2	2.90	Singapore (2006)	4,782.5	2.31
Belgium (2006)	6,472.4	1.83	South Africa (2005)	3,654.3	0.92
Finland (2007)	6,283.3	3.41	Argentina (2006)	2,317.9	0.49
Mexico (2005)	5,919.0	0.50	Romania (2006)	1,066.8	0.45
Turkey (2006)	4,883.7	0.76	Slovenia (2006)	784.1	1.59

GDP = gross domestic product; GERD = gross domestic expenditure on R&D

NOTES: Date of latest available year in parentheses. Figure for Israel is civilian R&D only.

SOURCES: OECD, Main Science and Technology Indicators (2008/1); National Science Foundation, Division of Science Resources Statistics

Table 3. Research and development expenditure (% of GDP)					
Country Name	**2004**	**2005**	**2006**	**2007**	**2008**
Argentina	0.44	0.46	0.49	0.51	
Austria	2.26	2.44	2.46	2.54	2.66
Belgium	1.87	1.84	1.86	1.90	1.92
Brazil	0.90	0.97	1.00	1.10	
Canada	2.07	2.05	1.97	1.90	1.84
China	1.23	1.34	1.42	1.44	
Colombia	0.16	0.16	0.16	0.16	
Croatia	1.05	0.87	0.76	0.81	0.90
Cuba	0.56	0.51	0.41	0.44	0.49
Cyprus	0.37	0.40	0.43	0.45	0.47
Czech Republic	1.25	1.41	1.55	1.54	1.47
Denmark	2.48	2.46	2.48	2.56	2.72
Finland	3.45	3.48	3.45	3.47	3.46
France	2.15	2.10	2.10	2.04	2.02
Germany	2.49	2.48	2.53	2.54	
Greece	0.55	0.58	0.57	0.57	
India	0.77	0.80	0.80	0.80	
Ireland	1.24	1.25	1.25	1.28	1.42
Israel	4.26	4.37	4.41	4.76	4.86
Italy	1.10	1.09	1.13	1.18	1.18
Japan	3.17	3.32	3.40	3.44	
Kazakhstan	0.25	0.28	0.24	0.21	0.22
Korea, Rep.	2.68	2.79	3.01	3.21	
Malaysia	0.60		0.64		
Mexico	0.40	0.41	0.39	0.37	
Netherlands	1.81	1.79	1.78	1.72	1.63
Norway	1.59	1.52	1.52	1.64	1.62
Poland	0.56	0.57	0.56	0.57	0.61
Portugal	0.77	0.81	1.02	1.21	1.51
Romania	0.39	0.41	0.45	0.53	0.59
Russian Federation	1.15	1.07	1.07	1.12	1.03
South Africa	0.86	0.92	0.95	0.93	
Spain	1.06	1.12	1.20	1.27	1.34
Sweden	3.62	3.60	3.74	3.61	3.75
Switzerland	2.90				
Turkey	0.52	0.59	0.58	0.72	
United Kingdom	1.69	1.73	1.76	1.82	1.88
United States	2.58	2.61	2.65	2.72	2.82
East Asia & Pacific (all income levels)	2.42	2.44	2.50	2.61	
East Asia & Pacific (developing only)	1.12	1.09	1.30	1.44	
Euro area	1.84	1.83	1.86	1.87	1.68
European Union	1.82	1.82	1.85	1.85	1.75
Latin America & Caribbean (all income levels)	0.56	0.62	0.63	0.68	
Latin America & Caribbean (developing only)	0.56	0.62	0.63	0.68	
OECD members	2.27	2.30	2.32	2.33	2.29
World	2.05	2.03	2.06	2.07	

Source: OECD (2011) Education At A Glance, Paris.

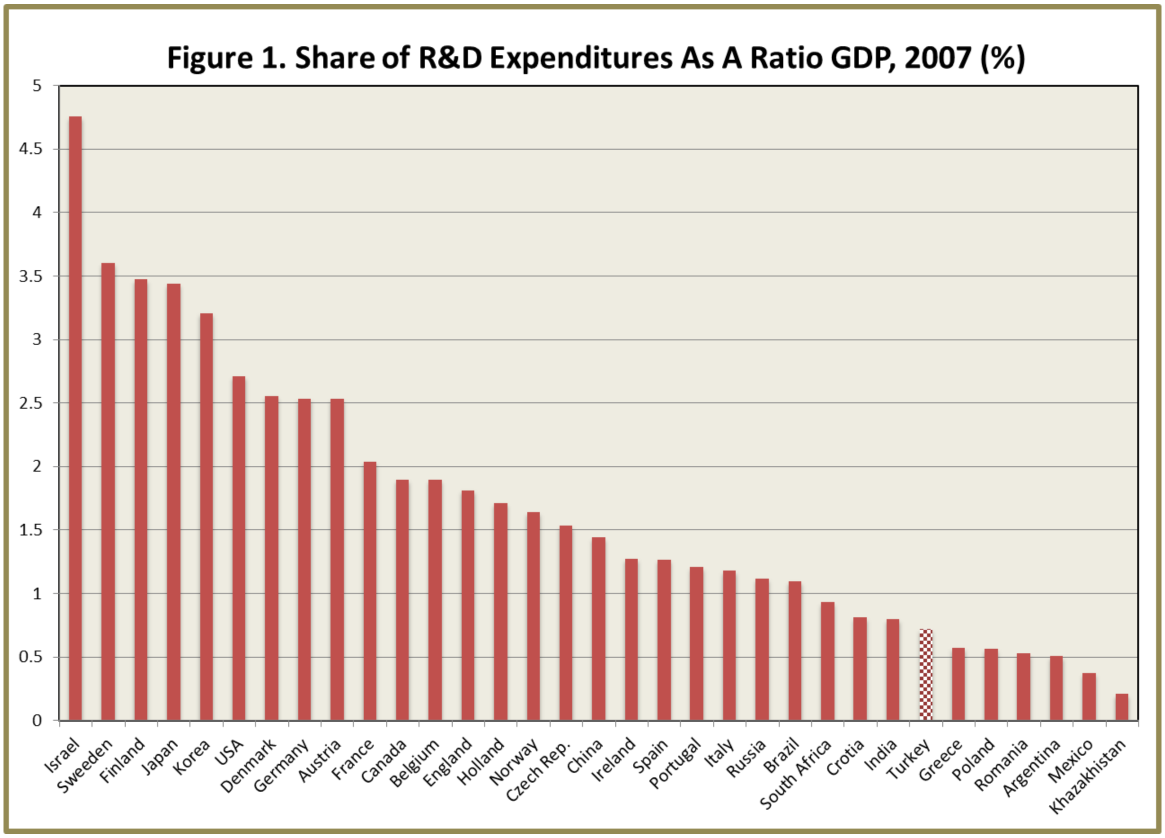


Figure 1. Share of R&D Expenditures As A Ratio GDP, 2007 (%)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Israel
Sweeden
Finland
Japan
Korea
USA
Denmark
Germany
Austria
France
Canada
Belgium
England
Holland
Norway
Czech Rep.
China
Ireland
Spain
Portugal
Italy
Russia
Brazil
South Africa
Crotia
India
Turkey
Greece
Poland
Romania
Argentina
Mexico
Khazakhistan

Table 4. Public spending on education, total (% of GDP)					
Country Name	**2004**	**2005**	**2006**	**2007**	**2008**
Argentina	3.78		4.52	4.93	5.39
Austria	5.52	5.48	5.45	5.37	5.46
Belgium	5.96	5.93	6.00	6.02	6.46
Brazil	4.01	4.53	4.95	5.08	
Canada		4.93		4.92	4.77
China					
Colombia	4.08	3.99	3.89	4.06	3.94
Croatia	3.87	4.31	4.27	4.02	4.46
Cuba	10.27	10.56	9.06	11.87	13.63
Cyprus	6.70	6.92	7.02	6.93	7.41
Czech Republic	4.37	4.26	4.60	4.20	4.08
Denmark	8.43	8.30	7.97	7.83	7.75
Finland	6.43	6.31	6.19	5.90	6.13
France	5.81	5.65	5.58	5.59	5.58
Germany			4.40	4.49	
Greece	3.82	4.04			
India	3.40	3.13	3.09		
Ireland	4.70	4.75	4.76	4.90	5.62
Israel	6.35	6.11	6.08	5.90	5.92
Italy	4.58	4.43	4.73	4.29	4.58
Japan	3.66	3.52	3.48	3.46	3.42
Kazakhstan	2.26	2.26	2.63	2.83	
Korea, Rep.	4.36	4.15	4.22	4.23	4.80
Malaysia	5.92	7.48	4.66	4.53	4.11
Mexico	4.87	5.01	4.81	4.81	
Netherlands	5.46	5.48	5.46	5.32	5.46
Norway	7.47	7.02	6.55	6.76	6.44
Poland	5.41	5.47	5.25	4.91	
Portugal	5.16	5.23	5.09		4.89
Romania	3.29	3.48		4.28	
Russian Federation	3.55	3.77	3.87		4.09
South Africa	5.28	5.28	5.29	5.27	5.09
Spain	4.25	4.23	4.27	4.35	4.62
Sweden	7.09	6.89	6.75	6.56	6.74
Switzerland	5.91	5.71	5.46	5.18	5.37
Turkey	3.12				
United Kingdom	5.23	5.42	5.55	5.47	5.42
United States	5.51	5.27	5.61	5.45	5.46
East Asia & Pacific (all income levels)	4.30	4.15	3.91	3.68	3.42
East Asia & Pacific (developing only)	2.75			3.53	3.29
Euro area	5.31	5.35	5.45	5.11	5.52
European Union	5.21	5.42	5.34	4.96	5.46
Latin America & Caribbean (all income levels)	3.95		3.89	4.03	
Latin America & Caribbean (developing only)	3.95		3.89	4.03	3.94
OECD members	5.32	5.35	5.43	5.05	5.42
World	4.37	4.43	4.53	4.38	4.45

Source: OECD (2011) Education At A Glance, Paris.

Table 5. Schooling Ratio According to Age Brackets				
	Ages 3-4	Ages 5-14	Ages 15-19	Ages 20-29
Turkey	7.9	91.9	45.9	12.9
OECD Average	71.5	98.9	81.5	24.9
AB-19 Average	79.8	99	84.9	25.1
Source: Ministry of Education; OECD, 2011.				

Figure 2. GDP under the Base-Path
(Billions TL, Fixed 2005 Prices)

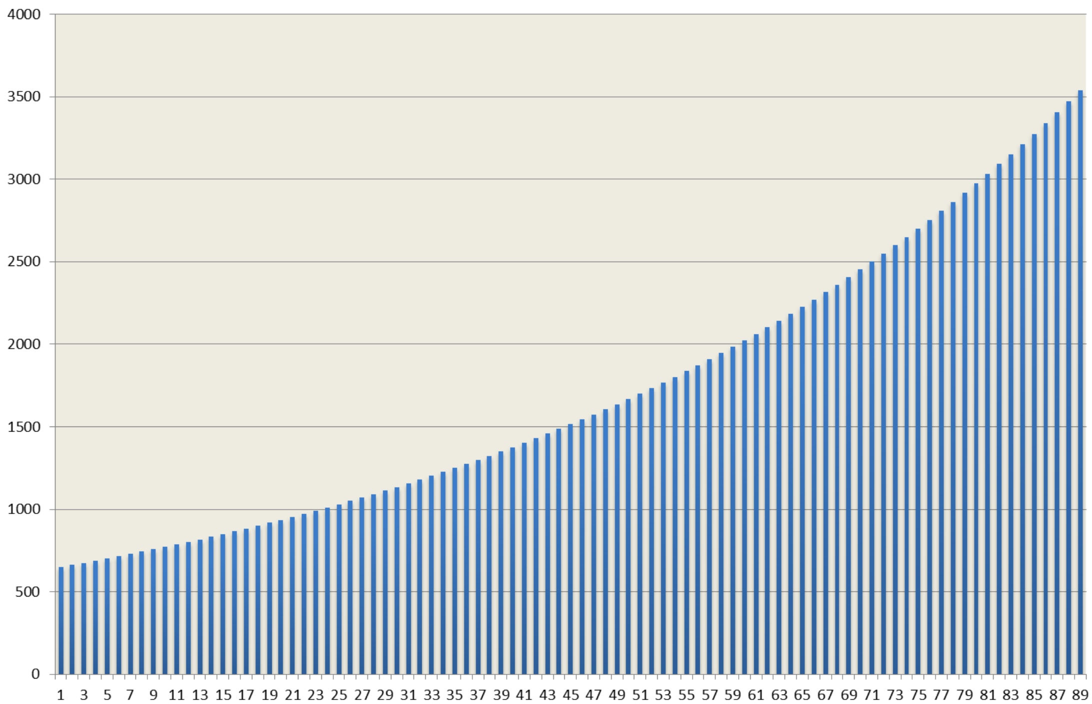


Figure 3. Evolution of the Human Capital Stock under the Base-Path
Index Values, Period 1 = 1.00

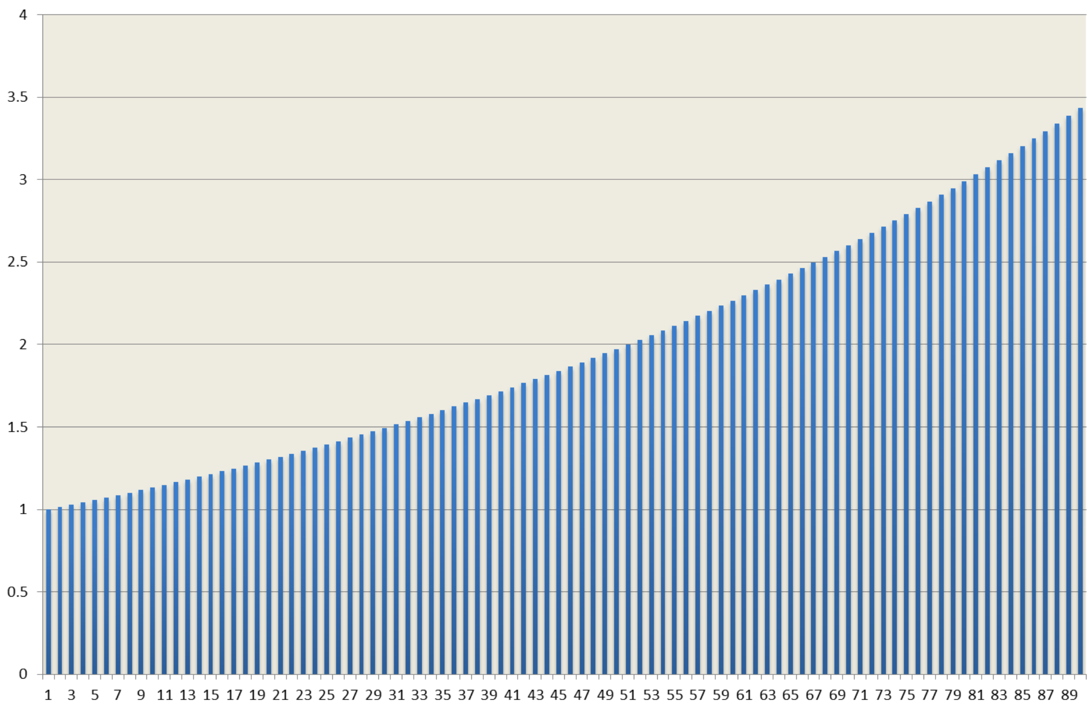


Figure 4. Aggregate R&D Stock under the Base-Path
Index Values, Period 1 = 1.00

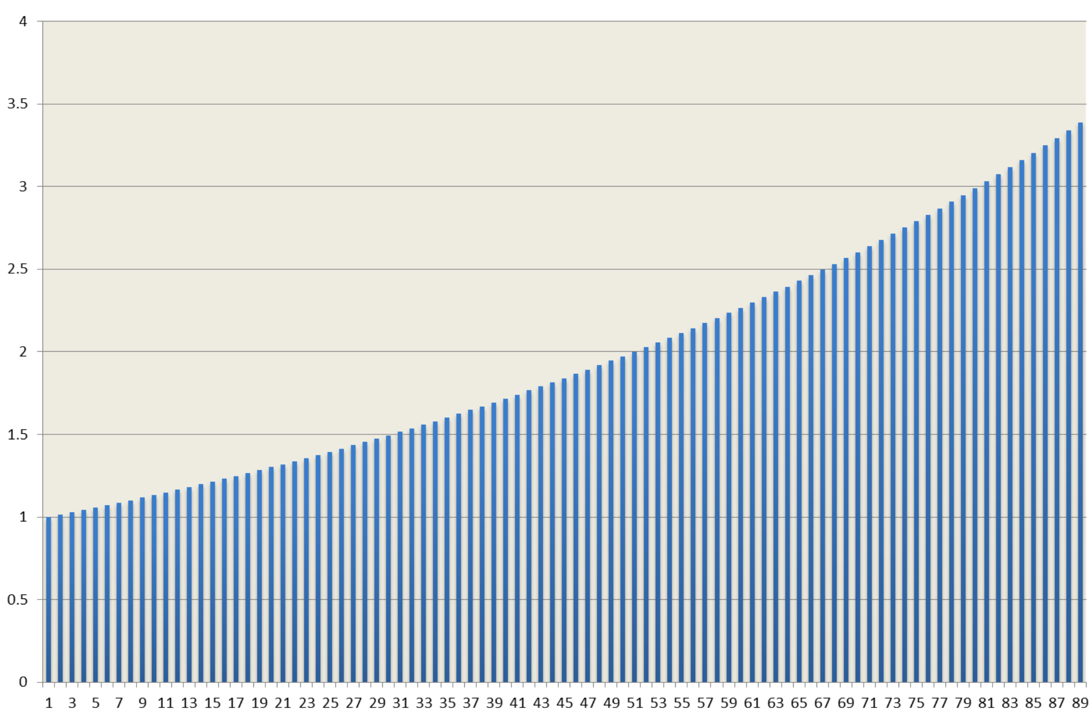


Figure 5
GDP Under Alternative Subsidization Programs (As A Ratio to the Base Path)

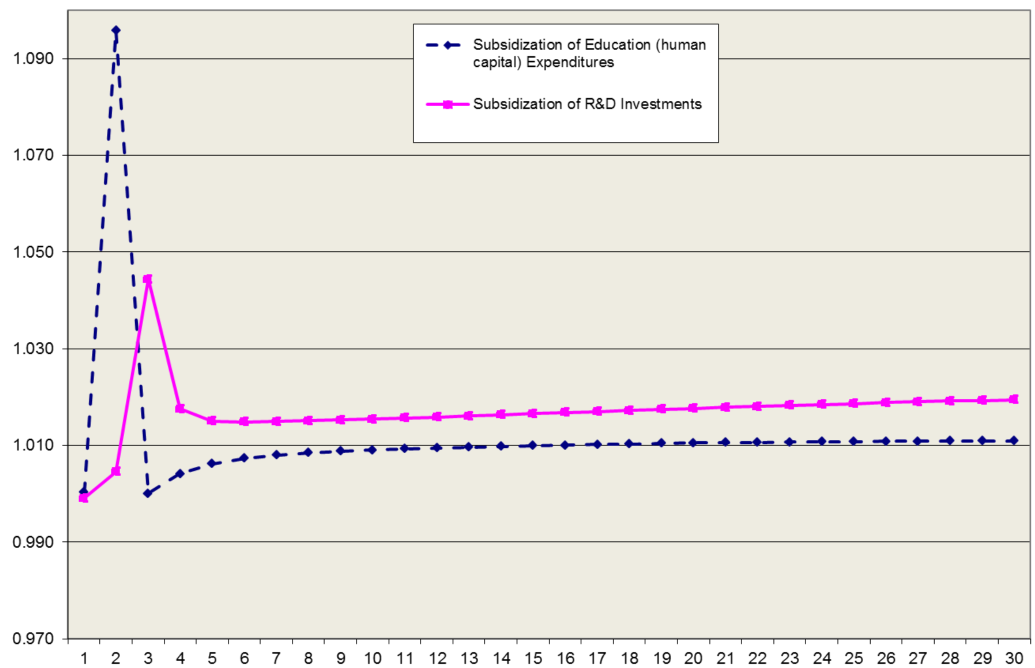


Figure 6
Stock of R&D Under Alternative Subsidization Programs
(As A Ratio to the Base Path)

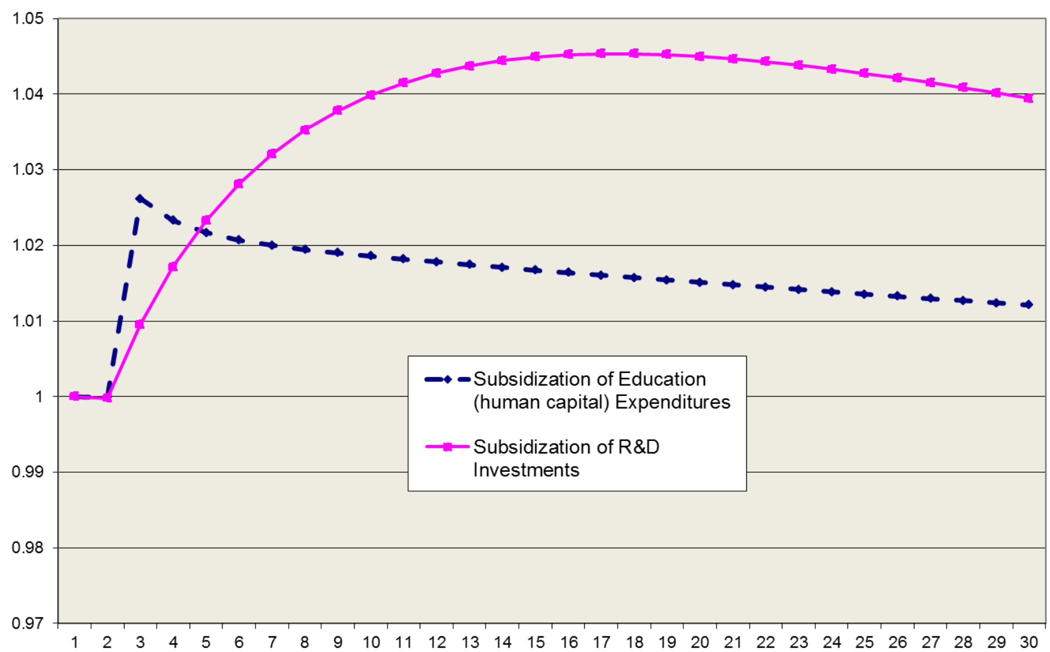


Figure 7
Stock of Human Capital Under Alternative Subsidization Programs
(As A Ratio to the Base Path)

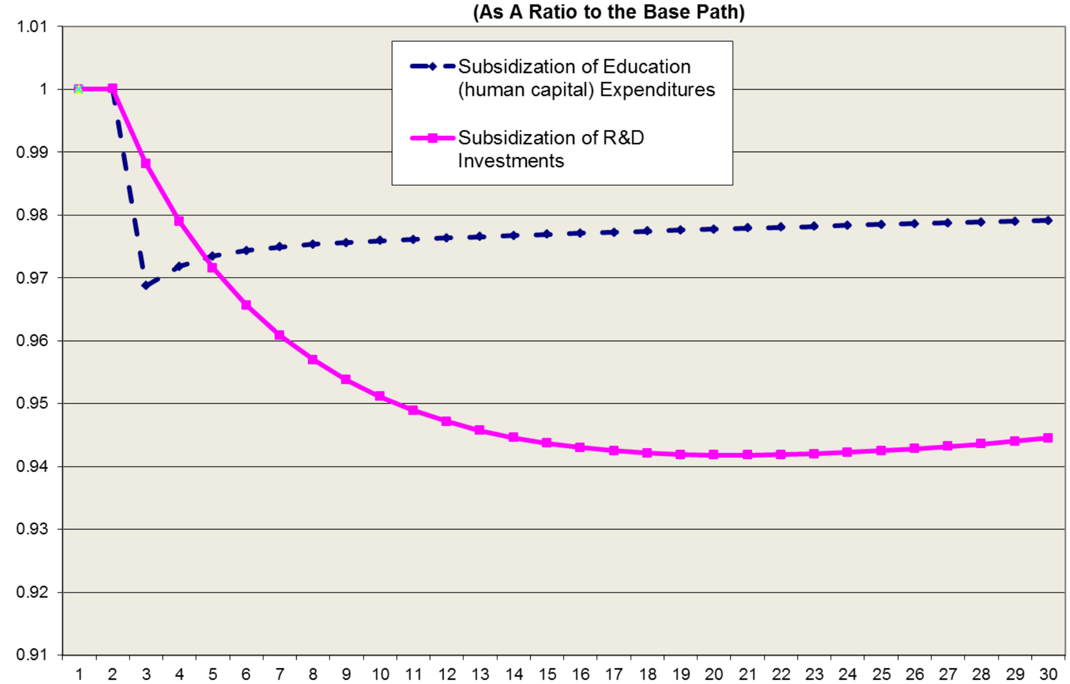
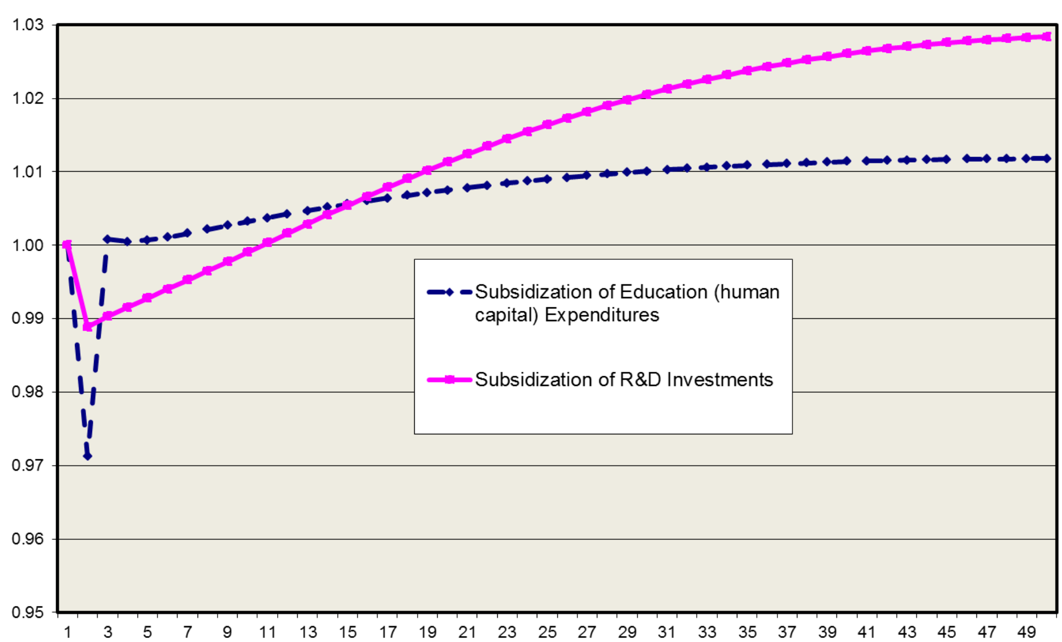


Figure 8
Differentiated Capital Varieties Under Alternative Subsidization Programs
(As A Ratio to the Base Path)



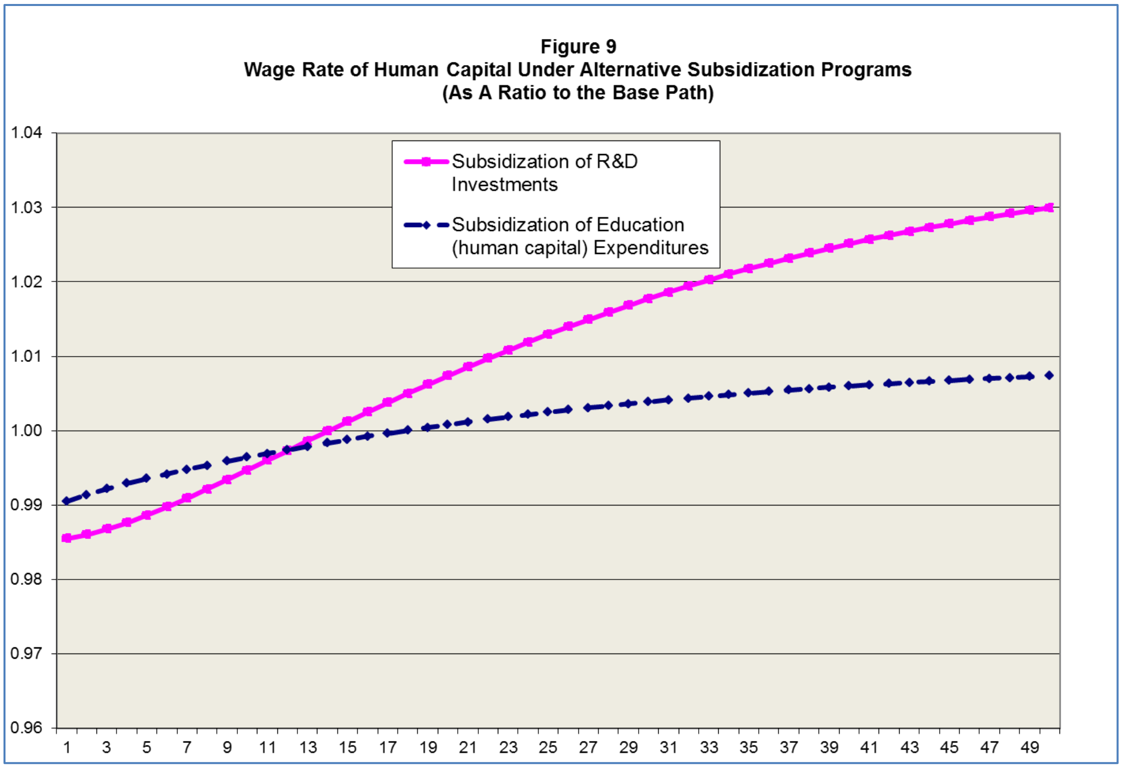


Figure 9
Wage Rate of Human Capital Under Alternative Subsidization Programs
(As A Ratio to the Base Path)
Subsidization of R&D Investments
Subsidization of Education (human capital) Expenditures
1.04
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49