

Social Capital and Investment in R&D: New Externalities

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Abstract

We introduce social capital in an endogenous growth model with physical capital, human capital and varieties, and we compare the market with the efficient solutions. As social capital is not tradable in the market and it favours research networks, it introduces new externalities in this framework. These externalities induce the market to invest less in social capital than a social planner would do and decrease the tendency to underinvestment in R&D. We quantify the distortions in the model. In some conditions, the new distortions are strong enough to overcome the usual result of underinvestment in R&D.

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1 Introduction

There are several recent articles that evaluate distortions in the decentralized market economy in models of endogenous economic growth. These models evaluate the differences that arise between the decentralized markets and the social planner choices due to several types of externalities: spillovers in the R&D process, duplications in the R&D process, gains from specialization due to new varieties, and erosion effects from R&D into human capital accumulation. However, social capital has not been considered in these models, despite its increasing interest in the economic growth literature. Social capital can introduce distortions in market allocations mainly due to two features of social capital: the failure of a market for social capital and the impact it can have in R&D due to research networks. The first reason is justified as firms do not pay for social capital when they contract workers; they pay for hours of work and at most for the level of qualifications. This may happen because the features usually included in social capital (confidence, truth, informal networks) are more difficult to evaluate and monitorize than degrees or years of schooling. The second reason is based on the importance of social networks between researchers in R&D productivity. Social networks can help knowledge sharing between researchers in an informal way, simply by proximity at work, “cheap talk” at lunch, etc. An example usually given is the importance of networks of researchers in Silicon Valley. Another can be the proximity of research staff in universities.

Social capital is a sociological concept that has been introduced recently in the economic growth literature. The definition of Putnam[20] refers to this concept as “features of social organization, such as trust, norms, and networks, that can improve the efficiency of society by facilitating coordinated actions”. Most of the empirical literature has found a positive influence of social capital on economic growth, although it varies substantially (examples include Knack and Keefer[17]; Temple and Johnson[29], Whiteley[31], and Rupasingha *et al.*[24]). The introduction of social capital in growth models is still very scarce, but a good example is Beugelsdijk and Smulders[5], who also test the model against empirical data using the European Values Survey. Economic agents like to socialize (*bonding*), which they do by losing consumption, since participation in social networks is time-consuming and reduces time available to work. Hence, higher levels of social capital may decrease economic growth. However, partic-

ipation in community networks (*bridging*) reduces the incentive for rent seeking and cheating, and so through this channel, higher level of social capital produces positive effects on economic growth.

The positive connection between social capital and human capital accumulation was first described in Coleman[6] and in Teachman *et al.*[28] in sociological studies about high school dropouts. Grafton *et al.*[10] test a theoretical growth model against empirical data to explain international country differences in productivity and find a positive impact of people’s knowledge connections on productivity. Dinda[8] uses an AK-type growth model to study the role of social capital in the production of human capital and in economic growth and compares theoretical results with empirical results finding a positive effect of social capital. Sequeira and Ferreira-Lopes[25] in an endogenous growth model framework also study the interactions between human and social capital and document the decline in social capital found by Putnam[21].

Literature about the connections of social capital, R&D, and economic growth is also very recent, scarce, and empirical. For example, Landry *et al.*[15], De Clercq and Dakhli[7] and Lee *at al.*[16] test empirically if there is indeed a connection and find positive effects of social capital in R&D and in innovation activities, although estimates vary widely.

No previous attempt that we know off brought the positive connection between social capital and R&D to an endogenous growth model. Our main contribution to the literature is to evaluate for the first time the impact of externalities caused by the presence of social capital in an endogenous growth model. Specifically, we want to determine the influence of social capital in the distortions between the decentralized equilibrium and the efficient solution. As already mentioned, social capital can introduce two types of new distortions in the market economy: first, because there is not a market for social capital, the social planner may choose higher levels of social capital than decentralized agents; second, because social capital influence R&D through research networks, which R&D firms do not consider, the social planner may also choose higher levels of social capital than decentralized agents. This is an important issue as opens the possibility of designing policies to enhance accumulation of social capital.

We also want to contribute to the discussion on “Too Much of a Good Thing?” or

on the optimality of R&D investments.¹ Thus, this paper is also inserted in the literature on the macroeconomic efficiency of R&D investments within endogenous growth models without scale effects, whose first contributions were Jones[12] and Jones and Williams[14]. The most common result in the literature tends to indicate that underinvestment in R&D happens in the real world (Romer[23]; Grossman and Helpman[11], and Aghion and Howitt[1] in endogenous growth models with scale effects and also Jones[12] and Jones and Williams[14] in models without scale effects, and Jones and Williams[13] in an empirical article). The exceptions are Stockey[26] and Benassy[4] that, in models with scale effects, discovered that for more general preferences or production, overinvestment in R&D can occur. Most recently, Reis and Sequeira[22] and Strulik[27] showed that overinvestment in R&D can be more plausible than has been thought before.

We build an increasing varieties model with different production sectors. A model with increasing varieties is appropriate as it always predicts more overinvestment in R&D than quality-ladders models or those that combine both increasing variety and quality-ladders. We argue that in this type of model the presence of social capital decreases the scope for underinvestment.

Section two presents the model and sections three and four present, respectively, optimal growth and the decentralized equilibrium. Section 5 compares the shares of human capital allocation in the social planner and in the decentralized equilibrium and discusses distortions in the decentralized equilibrium. In Section 6 we implement a calibration exercise to answer the question how much social capital influences the distortions between the efficient and the decentralized solution. Finally in section 7 we conclude.

2 Model

In this model we combine different types of capital: physical capital, human capital, social capital, and technological capital. Physical capital is used in the production of

¹When applied to the economics of investment in R&D this expression has been first used by Jones and Williams (2000) as part of the article's title.

the final good. Human capital has different uses: it is employed in the production of differentiated goods, in schools, where it is the main input to new human capital; it is used in the accumulation of social capital, as suggested by previous literature, and is also used in the innovation process. Social capital is used in the production of the final good, in facilitating the accumulation of embodied knowledge (human capital), in facilitating the research networks that increase R&D productivity, and in its own accumulation. In assuming these interactions between different capital types, we based on different bodies of economic literature, revised above. A crucial feature in the model is that there is not a market for social capital. Social capital is produced because it makes families happier. This follows the notion of *bonding* in Beugelsdijk and Smulders[5]. However, firms (both firms in the final good and in the R&D market) benefit from social capital, which follow the notion of *bridging* in the same article. As firms benefit from social capital without paying for it, this carries out externalities with less social capital in the market than in the efficient solution. The distortions caused by social capital act on the opposite direction of gains from specialization and spillovers in the R&D process.

2.1 Production Factors and Final Goods

2.1.1 Capital Accumulation

The accumulation of physical capital (K_P), arises through production that is not consumed, and is subject to depreciation:

$$\dot{K}_P = Y - C - \delta_P K_P \tag{1}$$

where Y denotes production of final goods, C is consumption, and δ_P represents depreciation.

As in the literature that began with Arnold[3], in this model human capital is the ‘ultimate’ source of growth. To have endogenous growth, one should have non-decreasing returns in the human capital production function, regardless of the con-

sidered inputs to human capital. Following most of the literature that deals with externalities in the last generation of endogenous growth models and also the evidence according to which human capital is the main input to human capital production, we propose that human capital K_H is produced using human capital allocated to schooling as well as the total amount of social capital, K_S , according to:

$$\dot{K}_H = \xi H_H + \gamma K_S - \delta_H K_H \quad (2)$$

where H_H are school hours, $\xi > 0$ is a parameter that measures productivity inside schools, $\gamma \geq 0$ measures the sensitivity of human capital accumulation to the stock of social capital, and $\delta_H \geq 0$ is the depreciation of human capital. This expression captures the idea of Coleman[6] and Teachman *et al.*[28] according to which social capital is important to the production of human capital. It also ensures that human and social capital are substitutes in the production of human capital.

Individual human capital can be divided into skills in final good production (H_Y), school attendance (H_H), networking for social capital accumulation (H_S), and doing R&D (H_R). Assuming that the different human capital activities aren't done cumulatively, we have:

$$K_H = H_Y + H_H + H_S + H_R \quad (3)$$

We based the choice of the functional form for the dynamic evolution of social capital on the literature that suggests a strong link between human capital and social capital. Also, some empirical literature on social capital has already calculated an economic payoff from it (e.g., Knack and Keefer[17] and Temple and Johnson[29]). Hence, social capital accumulation requires human capital to be allocated to its production but at each point in time it will also depend on the current stock of social capital, i.e.:

$$\dot{K}_S = \omega H_S + \Omega K_S \quad (4)$$

where ω measures the productivity of human capital in the production of social capital and $\Omega \leq 0$ measures the dynamic effect of social capital on its own production. If

$\Omega > 0$ existing social networks are strong enough to keep growing without additional human capital. Some types of social capital (such as cultural norms or values) are given by the family, which mean that people do not have to make efforts to acquire it. An alternative way of thinking about a positive Ω is that people with stronger social networks find it easier to continue improving networks than people with fewer. If $\Omega < 0$, on the other hand, there is a net depreciation effect.²

2.1.2 R&D Technology

Technological capital, or new varieties, K_R , is produced in a R&D sector with human capital employed in R&D labs (H_R), by the stock of disembodied knowledge (K_S), and is also influenced by the stock of social capital:

$$\dot{K}_R = \varepsilon H_R^v K_R^\phi K_S^\chi \quad (5)$$

where $\varepsilon > 0$ measures the productivity in the production of technological capital, v measures duplication effects, $0 < \phi < 1$ measures the degree of spillover externalities in R&D across time, as in Jones[12], and $0 < \chi < 1$ measures the positive effect of social networks in R&D productivity.³ The parameter χ measures an externality from social capital to R&D. Since agents, when deciding how much to invest in social capital, do not take into account the effect this have in the R&D firms, they invest less in social capital than it would be socially optimal. This externality acts in the same direction as the duplication effects (the parameter v in the equation) and in the opposite direction of spillovers (parameter ϕ in the equation), since it acts in favor of overinvestment in R&D.

²We choose to model social capital based on the yet scarce literature about it, i.e., we do not consider higher bounds for the stock of social capital. This is the same assumption we do for human capital, following the recent literature on human capital. There is no reason to consider that human capital grows without bounds, at a constant long-run rate, and to consider the opposite for social capital.

³Theoretically, one could generally assume that χ could have negative values and values above unity. However, for simplification we assume that it varies between 0 (no effect of researchers networks) and 1 (proportional effect of researchers networks). In fact in the calibration exercise, we reasonably assume that the effect of researchers networks is smaller than the effect of past technological knowledge ($\chi < \phi$). If $\chi = 0$, we would obtain the formulation for R&D technology used in Jones (1995).

2.1.3 Final Good Production

The final good is a differentiated one, produced with a Cobb-Douglas technology:⁴

$$Y = D^\beta K_S^\sigma H_Y^{1-\beta-\sigma} K_R^\eta, \beta \text{ and } \sigma < 1, \eta > 0 \quad (6)$$

D is an index of intermediate capital goods and is produced using the following Dixit-Stiglitz CES technology:

$$D = K_R \left[\frac{1}{K_R} \int_0^{K_R} x_i^\alpha \right]^{\frac{1}{\alpha}} \quad (7)$$

The elasticity of substitution between varieties is measured by $0 < \alpha < 1$. x_i is the intermediate capital good i and is produced in a differentiated goods sector using physical capital: $x_i = K_{P_{x_i}}$.⁵

This means that (6) can be re-written as:

$$Y = K_R^\eta K_P^\beta K_S^\sigma H_Y^{1-\beta-\sigma} \quad (8)$$

In what follows we will see that σ measures an externality from the household' to the firms' choice of social capital. Although households choose social capital comparing its marginal utility with its opportunity cost in terms of human capital, firms do not choose social capital, they face social capital as a 'gift' embodied in workers. This leads to another externality, which implies less social capital in the decentralized equilibrium than in the optimum and also tend to increase the scope for overinvestment in R&D.

⁴Using $\sigma > 1$ instead does not change our main results.

⁵We modelled taste for variety in this specific manner in order to isolate the gains of specialization (η) from the mark-up ($1/\alpha$) and from the share of physical capital in the final good production (β). This specification follows Alvarez-Pelaez and Groth[2] and allows us to separate important externalities in comparison to what happens in the standard specification.

2.2 Consumers

To capture the multi-faceted character of social capital the model for household preferences specifies it, along with consumption, as arguments of the intertemporal utility function:

$$U(C_t, K_{S_t}) = \frac{\tau}{\tau - 1} \int_0^{\infty} \left(C_t K_{S_t}^{\psi} \right)^{\frac{\tau-1}{\tau}} e^{-\rho t} dt \quad (9)$$

where ψ represents the preference for social capital and ρ is the utility discount rate.⁶

3 Optimal Growth

It is clear that when an economy faces the externalities already mentioned, the decentralized equilibrium will not maximize aggregate welfare. Thus we must solve a social planner's problem. In this section we derive the conditions associated with the maximization of (9) subject to the production function (6) as well as the transition equations for the different types of capital (1), (2), (4), and (5).⁷

The problem gives rise to the following Hamiltonian function:

$$\begin{aligned} \mathcal{H} = & \frac{\tau}{\tau - 1} \left(C K_S^{\psi} \right)^{\frac{\tau-1}{\tau}} + \lambda_P \left(K_R^{\eta} K_P^{\beta} K_S^{\sigma} H_Y^{1-\beta-\sigma} - C - \delta_P K_P \right) + \\ & + \lambda_H (\xi H_H + \gamma K_S - \delta_H K_H) + \lambda_S (\omega H_S + \Omega K_S) + \lambda_R (\varepsilon H_R^{\nu} K_R^{\phi} K_S^{\chi}) \end{aligned} \quad (10)$$

where the λ_j are the co-state variables for each stock K_j , with $j = P, H, S, R$. Considering choice variables C, H_Y, H_S , and H_R (and substituting H_H for $K_H - H_Y - H_S - H_R$ using (3)), the first order conditions yield:

⁶The t subscripts are dropped in the remaining sections for ease of notation.

⁷In this section we are dealing with aggregated variables.

$$\frac{\partial U}{\partial C} = \lambda_P \quad (11)$$

$$\lambda_H = \frac{\lambda_P(1 - \beta - \sigma)Y}{\xi H_Y} \quad (12)$$

$$\lambda_H = \frac{\lambda_S \omega}{\xi} \quad (13)$$

$$\lambda_R = \frac{\xi \lambda_H}{\varepsilon \nu H_R^{\nu-1} K_R^\phi K_S^\chi} \quad (14)$$

as well as:

$$\frac{\dot{\lambda}_P}{\lambda_P} = \rho + \delta_P - \frac{\beta Y}{K_P} \quad (15)$$

$$\frac{\dot{\lambda}_H}{\lambda_H} = \rho + \delta_H - \xi \quad (16)$$

$$\begin{aligned} \dot{\lambda}_S &= \rho \lambda_S - \left(\frac{\partial U}{\partial K_S} + \frac{\lambda_P \sigma Y}{K_S} + \lambda_H \gamma + \lambda_S \Omega + \lambda_R \varepsilon \chi H_R^\nu K_R^\phi K_S^{\chi-1} \right) \\ \dot{\lambda}_R &= \rho \lambda_R - \left(\eta \frac{Y}{K_R} \right) \lambda_P - \lambda_R \varepsilon \phi H_R^\nu K_R^{\phi-1} K_S^\chi \end{aligned} \quad (17)$$

with $\frac{\partial U}{\partial C} = C^{-\frac{1}{\tau}} K_S^{\psi(1-\frac{1}{\tau})}$, $\frac{\partial U}{\partial K_S} = \psi C^{(1-\frac{1}{\tau})} K_S^{\psi(1-\frac{1}{\tau})-1}$ representing the marginal utilities of consumption and social capital respectively.

3.1 Optimal Growth Rates

Growth rates will, by definition, be constant, so equation (1) tells us that K_P , Y , and C all grow at the same rate. Furthermore, K_S and K_H components will also be

growing at that same rate, respecting equations (2) to (4).⁸

Denote the growth rate of technological capital as g_{K_R} and the growth rate of human capital as g_{K_H} . From equation (5) we can see that these two growth rates have to respect this relation: $g_{K_H} = \frac{(1-\phi)}{\chi+\nu} g_{K_R}$.

In the steady-state, we can obtain the human capital growth rate as follows. From (12) we find $g_{\lambda_H} = g_{\lambda_P} + g_Y - g_{K_H}$ and using equation (16) we can then replace the previous two equations in $-\frac{1}{\tau}g_Y + \psi \left(1 - \frac{1}{\tau}\right) g_{K_H} = \frac{\lambda_P}{\lambda_P}$, which we calculated from (11). Then, using equations (5) and (8) we get:

$$g_{K_H}^* = \frac{\xi - \delta_H - \rho}{\left(\frac{\eta\left(\frac{\chi+\nu}{1-\phi}\right)}{1-\beta} + \psi\right) \left(\frac{1}{\tau} - 1\right) + \frac{1}{\tau}} \quad (18)$$

Using the fact that $g_{K_H} = \frac{(1-\phi)}{\chi+\nu} g_{K_R}$ we solve for the growth rate of technological capital:

$$g_{K_R}^* = \frac{\frac{\chi+\nu}{(1-\phi)}(\xi - \delta_H - \rho)}{\left(\frac{\eta\left(\frac{\nu+\chi}{1-\phi}\right)}{1-\beta} + \psi\right) \left(\frac{1}{\tau} - 1\right) + \frac{1}{\tau}} \quad (19)$$

From (8) and $g_{K_H} = \frac{(1-\phi)}{(\chi+\nu)} g_{K_R}$ we find $g_Y = g_{K_H} \left(\frac{\eta\left(\frac{\chi+\nu}{1-\phi}\right)}{1-\beta} + 1\right)$. By substituting (18) in the previous equality we find:

$$g_Y^* = \frac{(\xi - \delta_H - \rho) \left(\frac{\eta\left(\frac{\chi+\nu}{1-\phi}\right)}{1-\beta} + 1\right)}{\left(\frac{\eta\left(\frac{\chi+\nu}{1-\phi}\right)}{1-\beta} + \psi\right) \left(\frac{1}{\tau} - 1\right) + \frac{1}{\tau}} \quad (20)$$

While the impact of the social capital share (σ) is positive in growth rates, the impact of preference for social capital (ψ) is negative as it has a trade-off with consumption. This has a parallel with the effects of *bonding* and *bridging* in growth rates in the article from Beugelsdijk and Smulders[5]. Optimal growth rates depend on parameters of the model as usual in non-scale models of endogenous growth.

⁸In this work we did not analyze the transitional dynamics of the model. This is a topic for further research.

4 Decentralized Equilibrium

In the decentralized equilibrium both consumers and firms make choices that maximize, respectively, their own felicity or profits.⁹ Consumers maximize their intertemporal utility function:

$$\frac{\tau}{\tau - 1} \int_0^{\infty} \left(C_t K_{St}^\psi \right)^{\frac{\tau-1}{\tau}} e^{-\rho t} dt$$

subject to the budget constraint:

$$\dot{a} = (r - \delta_p)a + W_H (K_H - H_H - H_S - H_R) - C \quad (21)$$

where a represents the family physical assets, r is the return on physical capital, and W_H is the market wage. The market price for the consumption good is normalized to 1. Since it is making an intertemporal choice, the family also takes into account equations (2) and (4), which represent human and social capital accumulation, respectively.¹⁰

The markets for purchased production factors are assumed to be competitive. However, we assume that the firm cannot buy social capital, as there is, in effect, no market for it. Social capital is treated here as exogenous, although it affects the firm's production. Hence, consumer decisions will carry social capital externalities.

From this problem we know that returns on production are as follows:

$$W_H = \frac{(1 - \beta - \sigma) Y}{H_Y} \quad (22)$$

$$p_D = \frac{\beta Y}{D}, \quad (23)$$

where p_D represents the price for the index of intermediate capital goods.

Each firm in the intermediate goods sector owns an infinitely-lived patent for selling

⁹In this section we are working with individual variables.

¹⁰See Appendix A and B respectively for the FOC and growth rates in the decentralized equilibrium.

its variety x_i . Producers of differentiated goods act under monopolistic competition in which they sell their own variety of the intermediate capital good x_i and maximize operating profits, π_i :

$$\pi_i = (p_i - r)x_i, \quad (24)$$

where p_i denotes the price of intermediate good i and r is the unit cost of x_i . The demand for each intermediate good results from the maximization of profits in the final goods sector. Profit maximization in this sector implies that each firm charges a price of:

$$p_i = p = r/\alpha. \quad (25)$$

With identical technologies and symmetric demand, the quantity supplied is the same for all goods, $x_i = x$. Hence, equation (7) can be written as:

$$D = K_R x. \quad (26)$$

From $p_D D = p x K_R$, together with (23) and (25), we obtain:

$$x K_R = K_P = \frac{\alpha \beta Y}{r}. \quad (27)$$

After insertion of equations (25) and (27) into (24), profits can be rewritten as:

$$\pi = (1 - \alpha) \beta Y / K_R \quad (28)$$

Let v denote the value of an innovation, defined by:

$$v_t = \int_t^\infty e^{-[R(\tau) - R(t)]} \pi(\tau) d\tau, \text{ where } R(\tau) = \int_0^\tau r(\tau) d\tau. \quad (29)$$

Taking into account the cost of an innovation as determined by eq.(5), free-entry in

R&D implies that,

$$wH_R = \nu \varepsilon H_R^\nu K_R^\phi K_S^\chi \text{ if } \dot{K}_R > 0 \quad (H_R > 0); \quad (30)$$

$$wH_R > \nu \varepsilon H_R^\nu K_R^\phi K_S^\chi \text{ if } \dot{K}_R = 0 \quad (H_R = 0). \quad (31)$$

Finally, the no-arbitrage condition requires that investing in patents has the same return as investing in bonds:

$$\frac{\dot{\nu}}{\nu} = (r - \delta_P) - \pi/\nu. \quad (32)$$

This fully describes the economy.

5 Optimality of Human Capital Allocations

Using the FOC obtained from the social planner solution (11) to (17) and the equations that describe the evolution of the four capital stocks (1), (2), (4), and (5), it is possible to obtain the shares of human capital allocated to the different sectors in the economy (final good, human capital, social capital, and R&D). The share of human capital allocated to the different sectors are:

$$u_Y^* = \frac{H_Y}{K_H} = \frac{\left[\xi - \delta_H - \frac{\omega\gamma}{\xi} - \Omega \right] \left(\frac{K_S}{K_H} \right)^* - \frac{\omega\chi}{\nu} u_R^*}{\frac{\omega}{(1-\beta-\sigma)} \left[\psi_Y^C + \sigma \right]} \quad (33)$$

$$u_S^* = \frac{H_S}{K_H} = \left(\frac{g_{K_S}^* - \Omega}{\omega} \right) \left(\frac{K_S}{K_H} \right)^* \quad (34)$$

$$u_H^* = \frac{H_H}{K_H} = \frac{1}{\xi} (g_{K_H}^* + \delta_H) - \frac{\gamma}{\xi} \left(\frac{K_S}{K_H} \right)^* \quad (35)$$

$$u_R^* = \frac{H_R}{K_H} = \frac{\frac{\eta\nu}{(1-\beta-\sigma)} g_{K_R}^*}{\xi - \delta_H + g_{K_R}^* \left[(v-1+\chi) \left(\frac{1-\phi}{\chi+\nu} \right) \right]} u_Y^* \quad (36)$$

$$u_Y^* = \frac{H_Y}{K_H} = \frac{[\xi - \delta_H - \frac{\omega\gamma}{\xi} - \Omega] \frac{K_S}{K_H}^* - \frac{\omega\chi}{\nu} u_R^*}{\frac{\omega}{(1-\beta-\sigma)} [\psi_Y^C + \sigma]} = \frac{[\xi - \delta_H - \frac{\omega\gamma}{\xi} - \Omega] \frac{K_S}{K_H}^*}{\frac{\omega}{(1-\beta-\sigma)} [\psi_Y^C + \sigma] + \frac{\frac{\omega\chi}{\nu} \frac{\eta\nu}{(1-\beta-\sigma)} g_{K_R}^*}{\xi - \delta_H + g_{K_R}^* [(v-1+\chi) \left(\frac{1-\phi}{\chi+\nu}\right)]}}$$

The equations that were presented in this section provide a basis for a complete analysis of all the relationships between the different capital stocks and also a basis for the comparison with the decentralized equilibrium solution. Using the restriction that $u_Y^* + u_S^* + u_H^* + u_R^* = 1$, we obtain the social to human capital ratio:

$$\left(\frac{K_S}{K_H}\right)^* = \frac{1 - \frac{1}{\xi} (g_{K_H}^{DE} + \delta_H)}{\Phi^* + \frac{g_{K_S}^{DE} - \Omega}{\omega} - \frac{\gamma}{\xi}} \quad (37)$$

where

$$\Phi^* = \frac{\frac{[\xi - \delta_H - \frac{\omega\gamma}{\xi} - \Omega]}{\frac{\omega}{(1-\beta-\sigma)} [\psi_Y^C + \sigma]}}{1 + \frac{\frac{\omega\chi}{\nu} \frac{\eta\nu}{(1-\beta-\sigma)}}{\frac{\omega}{(1-\beta-\sigma)} [\psi_Y^C + \sigma]} \frac{\eta\nu}{(1-\beta-\sigma)} g_{K_R}^*} \left(1 + \frac{\frac{\eta\nu}{(1-\beta-\sigma)}}{\xi - \delta_H + g_{K_R}^* [(v-1+\chi) \left(\frac{1-\phi}{\chi+\nu}\right)]} g_{K_R}^* \right). \quad (38)$$

Using the FOC obtained for the decentralized equilibrium solution, equations (45) to (50), the equations that describe the evolution of the four capital stocks (1), (2), (4), and (5), and also equations (22), (28), (30), and (32), it is possible to obtain the shares of human capital allocated to the different sectors in the economy: final good, human capital, social capital, and R&D. The share of human capital allocated to the different sectors in the decentralized equilibrium are:

$$u_Y^{DE} = \frac{H_Y}{K_H} = \frac{\xi - \delta_H - \frac{\omega\gamma}{\xi} - \Omega}{\frac{\omega}{(1-\beta-\sigma)} [\psi_Y^C]} \left(\frac{K_S}{K_H}\right)^{DE} \quad (39)$$

$$u_S^{DE} = \frac{H_S}{K_H} = \left(\frac{g_{K_S}^{DE} - \Omega}{\omega}\right) \left(\frac{K_S}{K_H}\right)^{DE} \quad (40)$$

$$u_H^{DE} = \frac{H_H}{K_H} = \frac{1}{\xi} (g_{K_H}^{DE} + \delta_H) - \frac{\gamma}{\xi} \left(\frac{K_S}{K_H}\right)^{DE} \quad (41)$$

$$u_R^{DE} = \frac{H_R}{K_H} = \frac{\frac{\beta(1-\alpha)}{(1-\beta-\sigma)} g_{K_R}^{DE}}{\xi - \delta_H + g_{K_R}^{DE} \left[\left(\frac{1-\phi}{\chi+\nu}\right) (\chi + v - 1) + \phi \right]} u_Y^{DE} \quad (42)$$

Using the restriction that $u_Y^{DE} + u_S^{DE} + u_H^{DE} + u_R^{DE} = 1$, we obtain the social to human capital ratio:

$$\left(\frac{K_S}{K_H}\right)^{DE} = \frac{1 - \frac{1}{\xi} (g_{K_H}^{DE} + \delta_H)}{\Phi^{DE} + \frac{g_{K_S}^{DE} - \Omega}{\omega} - \frac{\gamma}{\xi}} \quad (43)$$

where

$$\Phi^{DE} = \frac{\left[\xi - \delta_H - \frac{\omega\gamma}{\xi} - \Omega\right]}{\left[\frac{\omega}{(1-\beta-\sigma)} \left[\psi \frac{C}{Y}\right]\right]} \left(1 + \frac{\frac{\beta(1-\alpha)}{(1-\beta-\sigma)}}{\xi - \delta_H + g_{K_R}^* \left[(v-1+\chi) \left(\frac{1-\phi}{\chi+\nu}\right) + \phi\right]} g_{K_R}^*\right). \quad (44)$$

As growth rates and the consumption to output ratio are equal in the social planner and decentralized equilibrium solutions, the differences from the two solutions are spillovers in R&D, duplication effect in R&D, the specialization gains, and the externalities from social capital. As in Alvarez-Palaez and Groth[2], the social gains from specialization (η) compare with the private gain from an innovation ($\beta(1-\alpha)$).¹¹ From the comparison of (33)-(36) to (39)-(42) taking into account the comparison between (44) and (38), it is possible to write the following proposition.

Proposition 1 *The Decentralized Equilibrium yields a sub-optimal or over-optimal social capital to human capital ratio and R&D effort, depending on the opposite effects of the following externalities:*

(i) *the social capital externalities (σ and χ) that increases the social to human capital ratio in the social planner solution, increases the human capital allocated to social capital production, and decreases human capital allocated to ‘schools’, final good, and R&D sectors;*

¹¹See Appendix B for proof.

(ii) the spillover externality (ϕ) that decreases human capital allocated to R&D in the market, increases the social to human capital ratio, and then increases allocations to the final good and to social capital production but decreases the allocation to the education sector in the market;

(iii) the duplication externality (v) that decreases human capital allocated to R&D in the planner's solution, increases the social to human capital ratio, and then increases allocations to the final good and to the social capital production but decreases allocation to the education sector in the planner's solution;

(iv) the difference between the social gain from specialization and the private gain from specialization ($\eta \neq \beta(1 - \alpha)$), that decreases social to human capital ratio in the social planner's solution, decreases human capital allocated to the final good and to the social capital production, and increases allocation to all the other sectors in the economy.

Thus, relatively high social capital shares in the final good production and R&D technology may contribute to decrease the under-investment in R&D. Spillovers and social gains from specialization acts in favor of underinvestment and duplication and social capital externalities act in favor of overinvestment.

As usual in the studies that intend to evaluate distortions between the social planner and decentralized equilibrium solutions, this evaluation is a quantitative issue. Thus we now implement a calibration exercise to evaluate the distortions.

6 Results and Calibration

6.1 Calibration Procedure

It is not easy to take a model with social capital to data, as research dealing with social capital is still scarce. Some parameters in our model are quite standard in the literature: the intertemporal substitution parameter ($\tau = 0.5$), the intertemporal discount factor ($\rho = 0.02$), the share of physical capital in income ($\beta = 0.36$), the markup ($1/\alpha = 1.33$), and the productivity of R&D ($\epsilon = 0.1$), hence we are not discussing them.¹² For others, there are a range of plausible values: the depreciation rates (δ_K , δ_H), the productivity of human capital accumulation (ξ), the contribution of social capital to economic growth (σ), spillovers (ϕ) and duplication effects (v). For these values we discuss our options. For other parameters there is greater uncertainty. For γ and ω , we concluded that changes in them are not crucial for the distortion evaluation. Thus we had fixed a value of 0.01 for them. For the preference for social capital (ψ) we have tested different values and concluded that values higher than 0 and less than 1 (i.e., consumers prefer consumption to social capital, which seems reasonable) do not change conclusions on distortions. Thus we have chosen an intermediate value of $\psi = 0.5$. For the spillover and duplication effects we have chosen $\phi = 0.4$ and $v = 0.5$ as reasonable values pointed out by the literature.¹³ For the externality of social capital in the R&D technology we have picked one half of the spillover value, reasonably assuming that the effect of research networks in R&D is much lower than the ‘standing on shoulders’ effect.

For the depreciation of physical capital, it is clear from the observation of equations in the social planner solution and in decentralized equilibrium that it does not enter in the determination of distortion. Thus, we set $\delta_K = 0$. In fact, in previous articles that simultaneously consider human and physical capital accumulation, a zero depreciation is considered. We consider $\delta_H = 0$ and $\delta_H = 0.05$ in different exercises. For the parameter Ω that can measure a positive effect of social capital in its accumulation

¹²For the markup value, we use a median value from Norrbin[18].

¹³See Reis and Sequeira[22] for a discussion about the value of ϕ in models with human capital accumulation and Pessoa[19] for estimations of ϕ and v .

or a depreciation of social capital, we use alternatively 0.01 and -0.01. For each of these exercises, we set the steady-state economic growth rate to be equal to 1.85%, which gives us a value for ξ . This procedure yields us values in the range used by human capital literature (e.g. Funke and Strulik[9]). For the impact of social capital in economic growth, we use a lower bound estimate for σ of 0.08 as in Knack and Keefer[17], for whom a 10% increase in trust implied a 0.8% increase in the economic growth rate. We also use a high bound for $\sigma = 1 - \beta - \sigma = 0.32$, suggested by the evidence in Whiteley[31] that points out an effect of social capital as big as the effect of human capital and approximating the evidence on World Bank [30] that pointed out a share of 0.78 to intangible capital, which included both human and social capital. For the consumption-output ratio (C/Y) we use the reasonable value of 0.6.

Table 1 below summarizes the calibration values. We use two sets of calibration values. The first, which we call benchmark, show the distortion caused by social capital in the absence of any other distortion (in this calibration there are no spillovers, duplication effects, specialization gains). In the second (designated by "Reasonable"), we set spillovers to 0.4 (see Reis and Sequeira[22]), duplication to 0.5 (see Pessoa[19]), specialization gains to 0.196 (see Jones and Williams[14]) and the social capital share to a value between 0.08 and 0.32 (see above).

Table 1: Calibration Values

Basic Parameters		Parameters for Externalities		
parameter	Benchmark/Reasonable	parameter	Benchmark	Reasonable
τ	2	χ	varies	0.2
β	0.36	σ	varies	0.08 or 0.32
ρ	0.02	ϕ	0	0.4
α	0.75	ν	1	0.5
δ_H	0 or 0.05	η	$\beta(1 - \alpha)$	0.196
δ_K	0	Calibrated Variables		
γ, ω	0.01	ξ	depends on g_Y ; [0.05; 0.1]	
Ω	0.01/-0.01	C/Y	0.6	
		g_Y	0.0185	

6.2 Distortions from Social Capital

In the next lines we present the differences between the decentralized equilibrium and the optimal solution when there are only distortions from social capital. Thus, we apply benchmark calibration values. In Figure 1 we present the different values of the K_S/K_H ratio through different values for the share of social capital in production. In

Figure 2 we show the change of the allocation of human capital to the social capital sector. In Figure 3, we show the change in the allocation of human capital to the R&D sector through different values of the same share. Then we also present three figures with the change in the ratio K_S/K_H , the share u_S , and the share u_R through different values for the externality of social capital in the R&D technology.

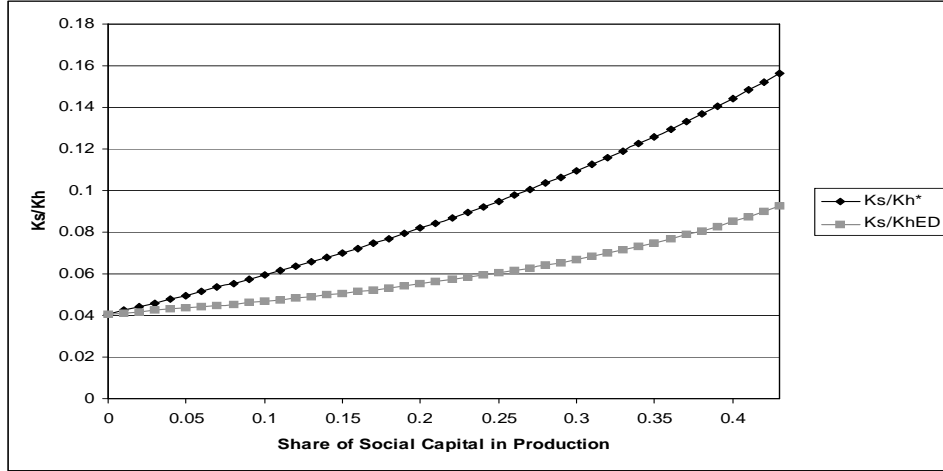


Figure 1 - Comparison between $(K_S/K_H)^{DE}$ and $(K_S/K_H)^*$ for different values of the share of social capital in production

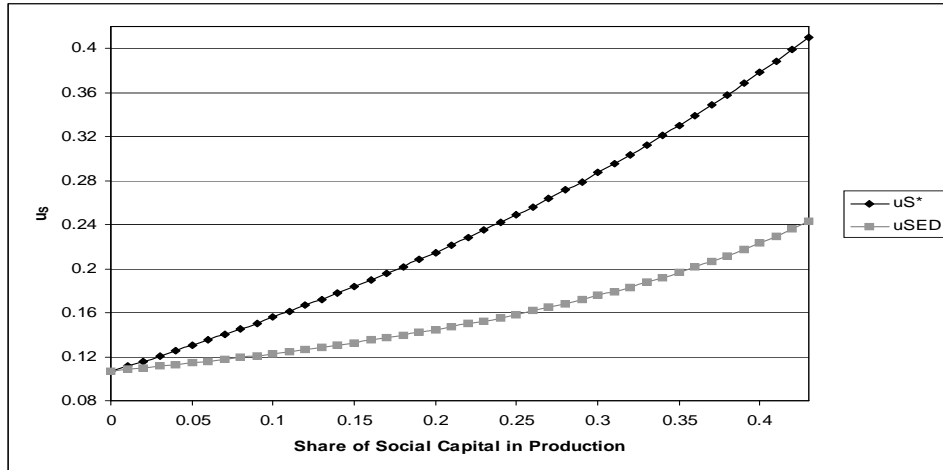


Figure 2 - Comparison between u_S^{DE} and u_S^* for different values of the share of social capital in production

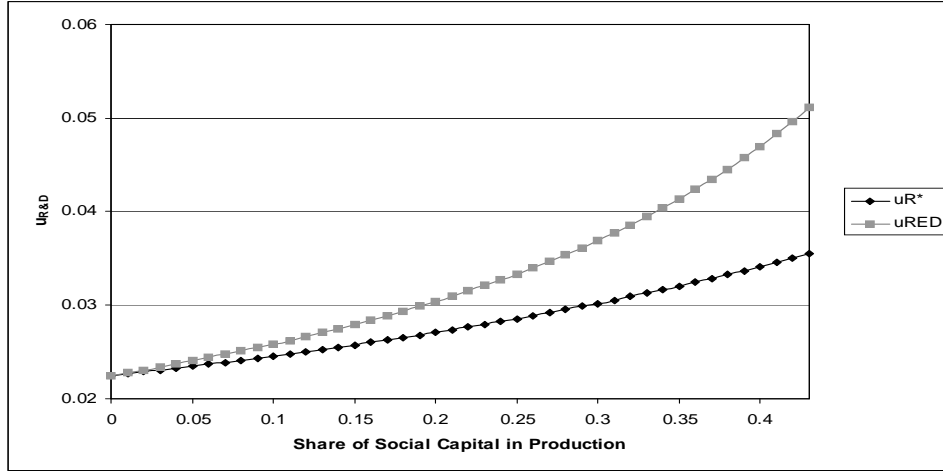


Figure 3 - Comparison between u_R^{DE} and u_R^* for different values of the share of social capital in production

From Figures 1 to 3 we can note that increasing the value of the share of social capital in the final good production increases the distortions in the decentralized economy, increasing the differences between the social desired ratio of social to human capital and the ratio obtained by the decentralized action of different agents (Figure 1). This distortion clearly causes underallocation of human capital to the social capital sector (Figure 2) and overinvestment in R&D as can be seen from Figure 3. While the ratio K_S/K_H rises 4 times until $\sigma = 0.43$ in the optimal solution, it only rises 2 times in the decentralized economy. The difference between the efficient allocation to the R&D sector and the market allocation can rise up to 1.5%, while the difference between efficient allocation to social capital and the market allocation can go up to 16%.

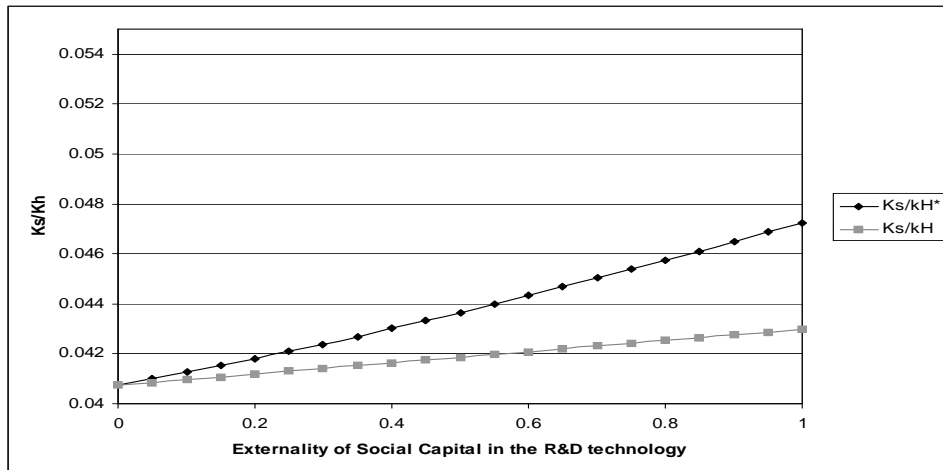


Figure 4 - Comparison between $(K_S/K_H)^{DE}$ and $(K_S/K_H)^*$ for different values of the share of social capital in $R\&D$

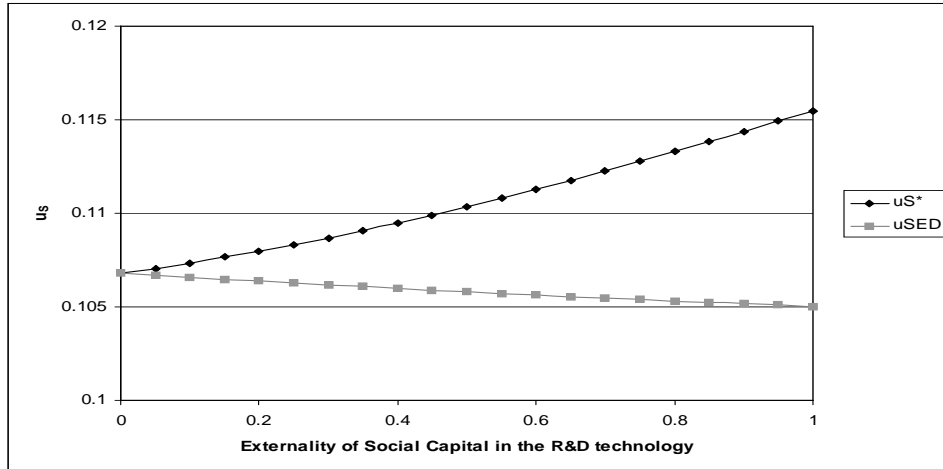


Figure 5 - Comparison between u_S^{DE} and u_S^* for different values of the share of social capital in $R\&D$

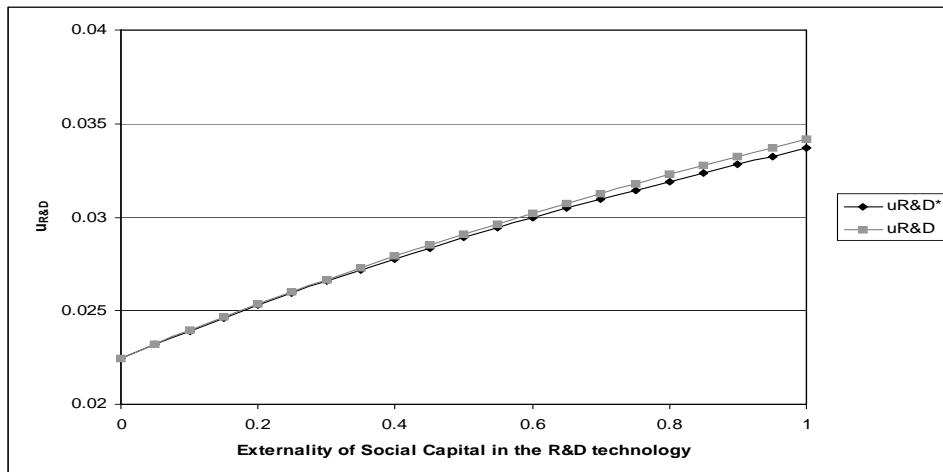


Figure 6 - Comparison between u_R^{DE} and u_R^* for different values of the share of social capital in $R\&D$

From Figures 4 to 6 we can see that increasing the effect of social capital in $R\&D$ technology also increases distortions but less than the rise in distortions caused by the final good social capital share. In this case a change from $\chi = 0$ to $\chi = 1$ implies a rise in K_S/K_H by 0.05, the change caused in u_S is about 1% and finally the change implied in u_R is near 0.001%. We have also a tendency for underinvestment in social capital and overinvestment to $R\&D$.

The next step is to evaluate how much decrease in the distortion can social capital impose when all other distortions are present.

6.3 Taking all Distortions Together

In this section, we present results from quantitative exercises in which we apply the calibration values depicted as ‘Reasonable’ in Table 1. Tables 2 to 4 compare the social planner allocations to the decentralized equilibrium ones. We show three different exercises: the first eliminates the distortions due to social capital and sets other distortions at reasonable levels, given by parameter values discussed above; the second considers a lower limit for the social capital share in production and a reasonable value for the externality of social capital in the R&D technology and keeping other values for parameters at the level used in the first exercise; the third exercise is equal to the second, except for the share of social capital in production that increases to 0.32. The unique difference in Table 3 (from Table 2) is that it uses a depreciation for human capital of $\delta_H = 0.05$. The unique difference in Table 4 (also from Table 2) is to consider a depreciation of social capital ($\Omega = -0.01$). In all these exercises g_{K_H} oscillate from 1.36% to 1.47% and g_{K_R} from 1.23% to 1.59%.

Table 2: Results from Reasonable Calibrations ($\delta_H = 0, \Omega = 0.01$)

σ	$\sigma = 0$			$\sigma = 0.08$			$\sigma = 0.32$		
	$\chi = 0$			$\chi = 0.2$			$\chi = 0.2$		
χ	SP	DE	SP/DE	SP	DE	SP/DE	SP	DE	SP/DE
K_S/K_H	0.068	0.068	0.99	0.105	0.082	1.29	0.274	0.137	2.00
u_Y	71.07%	71.45%	0.99	71.23%	72.27%	0.99	65.73%	69.17%	0.95
u_S	3.22%	3.24%	0.99	3.82%	2.97%	1.29	9.96%	4.98%	2.00
u_H	23.20%	23.19%	1.00	21.34%	21.73%	0.98	18.47%	20.79%	0.89
u_R	2.51%	2.12%	1.18	3.61%	3.02%	1.20	5.84%	5.05%	1.15

Table 3: Results from Reasonable Calibrations ($\delta_H = 0.05, \Omega = 0.01$)

σ	$\sigma = 0$			$\sigma = 0.08$			$\sigma = 0.32$		
	$\chi = 0$			$\chi = 0.2$			$\chi = 0.2$		
χ	SP	DE	SP/DE	SP	DE	SP/DE	SP	DE	SP/DE
K_S/K_H	0.037	0.037	0.99	0.056	0.043	1.28	0.142	0.072	1.97
u_Y	38.70%	38.91%	0.99	38.15%	38.80%	0.98	34.66%	36.94%	0.94
u_S	1.73%	1.74%	0.99	2.02%	1.57%	1.28	5.17%	2.62%	1.97
u_H	58.20%	58.20%	1.00	57.90%	58.01%	1.00	57.10%	57.74%	0.99
u_R	1.37%	1.16%	1.18	1.94%	1.62%	1.19	3.08%	2.70%	1.14

Table 4: Results from Reasonable Calibrations ($\delta_H = 0.05$, $\Omega = -0.01$)

σ	$\sigma = 0$			$\sigma = 0.08$			$\sigma = 0.32$		
χ	$\chi = 0$			$\chi = 0.2$			$\chi = 0.2$		
	SP	DE	SP/DE	SP	DE	SP/DE	SP	DE	SP/DE
K_S/K_H	0.023	0.023	1.00	0.033	0.027	1.24	0.069	0.041	1.67
u_Y	34.69%	34.85%	1.00	32.39%	34.08%	0.95	23.80%	30.01%	0.79
u_S	5.77%	5.80%	1.00	7.86%	6.34%	1.24	16.31%	9.77%	1.67
u_H	58.32%	58.32%	1.00	58.10%	58.16%	1.00	57.77%	58.03%	1.00
u_R	1.23%	1.04%	1.18	1.64%	1.42%	1.16	2.11%	2.19%	0.96

Without the distortions introduced in this article ($\sigma = 0$, $\chi = 0$), we note that the tendency for underinvestment in R&D is high, as previous literature also predicted (see e.g. Jones and Williams[14]). Human capital allocation in the decentralized economy is almost at the optimal level and there are over-allocations to the final good production and to the social capital sector. It is worth noting that due to the distortions from social gains from specialization, spillovers, and duplication, there is a relatively higher social capital to human capital ratio in the market economy when compared to the social planner choice.

When we consider positive values for σ and χ we note that now the social to human capital ratio is higher in the efficient solution than in the market economy, which is due to the distortions introduced in this article. The absence of a market for social capital is responsible for having relatively lower social capital in the market than in the case in which social welfare would be taken into account. This is reflected in the allocation of human capital to social capital production, which should also be higher than it is in the market economy. Because of that, allocation of human capital to the human capital accumulation sector is above the optimal level and the level of underinvestment in R&D is reduced. In the third exercise, the distortion in the social capital sector is so high that the social planner would allocate to that sector nearly twice the human capital allocated by the market economy (from 4.98% to 9.96% in Table 2; from 2.62% to 5.17% in Table 3, and from 9.77% to 16.31% in Table 4). Thus in these scenarios the social planner would reallocate human capital from final good production and schools to social capital accumulation sectors and to R&D firms. This means that some policies can be designed to enhance the production of social capital. Considering a positive depreciation for human capital as we do in Table 3, introduces almost no differences in distortions from the social planner allocations. Such a high depreciation in human capital predicts however an implausible share of

human capital allocated to the human capital accumulation sector. Nevertheless, when we introduce a depreciation in social capital accumulation, as in Table 4, we note some important differences. The share of human capital allocated to social capital production sector is higher than in previous exercises because human capital allocated to that sector must compensate the depreciation effect, while in previous exercises this did not happen because social capital could grow by itself (exogenously). The most important implication is that underinvestment in R&D is much reduced (from $u_R^*/u_R = 1.15$ to $u_R^*/u_R = 0.96$), opening the possibility to overinvestment in R&D. This means that the threshold level for the share of social capital in production (σ) above which there is overinvestment in R&D is below 0.32, which is in the range of plausible values, according to World Bank[30]. The higher the depreciation for social capital, the lower the threshold value for its share in production above which overinvestment in R&D occurs. In fact, in the case of the third exercise in Table 2, we can observe that considering a 1% depreciation for social capital, we can obtain overinvestment to R&D and keeping reasonable values for the allocations through sectors in the economy, with the highest allocation to the final good production.

7 Conclusion

We motivate this article from the increasing importance of social capital in the economic growth analysis, both in theoretical and empirical perspectives. The interaction between social capital and R&D has been pointed out essentially due to research networks. We build the production side of the model taking into account the interactions between the different types of capital that have been pointed out in previous literature. In particular, we note the importance of the use of human capital in the social capital accumulation and the importance of this last factor in the production of the final good, and also in the discovery of new ideas.

Social capital can introduce distortions in market allocations mainly due to two features of social capital: the failure of a market for social capital and the impact it can have in R&D due to research networks. The first reason is justified as firms do not pay for social capital when contract workers; they pay for hours of work and at

most for the level of qualifications. This may happen because the features usually classified as social capital (confidence, truth, networks) are more difficult to evaluate and monitorize than degrees or years of schooling. The second reason is based on the importance of social networks between researchers in the R&D productivity. This means that social capital is produced because agents like to socialize but it is used in production side in a way that enhance firms productivity without any payment for it.

In the model, we also consider the most important distortions present in previous models: the social benefit from specialization, spillovers, and duplication in R&D. We implement a calibration exercise in order to evaluate the strength of the new distortions from social capital. First we show that both new distortions lead to underinvestment in social capital, both when we compare the social to human capital ratio and when we compare allocations of human capital to the social capital accumulation sector. Second, we also show that the presence of these distortions decrease the tendency to underinvestment in R&D. However, quantitatively, these distortions are not strong enough to get overinvestment in R&D when social capital has a positive effect in its own accumulation. The opposite result is obtained when social capital depreciates. In fact, in this case, the social capital externalities introduced in this article are capable of generating overinvestment in R&D. This complements the recent literature (Strulik[27] and Reis and Sequeira[22]) that presented more arguments in favor of overinvestment. Moreover, our results pointed out a share of human capital in social capital accumulation which oscillates in the decentralized equilibrium from 2% to 10% which is an additional quantitative reason to integrate social capital in an endogenous growth model with R&D and human capital accumulation, as we did in this article.

References

- [1] Aghion, P. and P. Howitt (1998), *Endogenous Growth Theory*, MIT press.
- [2] Alvarez-Palaez, M. and C. Groth (2005), "Too Little or Too Much R&D?", *European Economic Review* 49, 437-456.

- [3] Arnold, L. (1998), "Growth, Welfare and Trade in an Integrated Model of Human-Capital Accumulation and Research", *Journal of Macroeconomics*, 20(1): 81-105.
- [4] Benassy, J. P. (1998), "Is There Always Too Little Research in Endogenous Growth With Expanding Product Variety?", *European Economic Review* 42, 61-69.
- [5] Beugelsdijk, S. and S. Smulders (2004), "Social Capital and Economic Growth", Tilburg University, Department of Economics, *Mimeo*.
- [6] Coleman, J. (1988), "Social Capital in the Creation of Human Capital", *American Journal of Sociology*, 94, S95-S120.
- [7] De Clercq, D. and M. Dakhli (2004), "Human Capital, Social Capital, and Innovation: A Multi-Country Study", *Entrepreneurship and Regional Development*, Vol. 16, Number 2, March, 107-128.
- [8] Dinda, S. (2008), "Social Capital in the Creation of Human Capital and Economic Growth: A Productive Consumption Approach", *The Journal of Socio-Economics*, 37, 2020-2033.
- [9] Funke, M. and H. Strulik (2000), "On Endogenous Growth with Physical Capital, Human Capital and Product Variety", *European Economic Review* 44, 491-515.
- [10] Grafton, R. Q. ; Kompas, T., and P. D. Owen (2007), "Bridging the Barriers: Knowledge Connections, Productivity and Capital Accumulation", *Journal of Productivity Analysis* 28, 219-231.
- [11] Grossman, G. and E. Helpman (1991), *Innovation and Growth in the Global Economy*, MIT press.
- [12] Jones, C. I. (1995), "R&D-Based Models of Economic Growth", *Journal of Political Economy*, Vol. 103, Issue 4, August, 759-784.
- [13] Jones, C. and J. Williams (1998), "Measuring the Social Return to R&D", *The Quarterly Journal of Economics*, November, 1119-1135.

- [14] Jones, C. and J. Williams (2000), "Too Much of a Good Thing? The Economics of Investment in R&D", *Journal of Economic Growth* 5, March, 65-85.
- [15] Landry, R. , Amara, N., and M. Lamari (2002), "Does Social Capital Determine Innovation? To What Extent?", *Technological Forecasting and Social Change*, Vol. 69, 681-701.
- [16] Lee, S.H., Wong, P.K., and C. L. Chong (2005), "Human and Social Capital Explanations for R&D Outcomes", *IEEE Transactions on Engineering Management*, Vol. 52, No. 1, February, 59-68.
- [17] Knack, S. and P. Keefer (1997), "Does Social Capital Have an Economic Payoff? A Cross-Country Investigation", *The Quarterly Journal of Economics*, 112, 1251-88.
- [18] Norrbin, S. (1993), "The Relation Between Price and Marginal Cost in U.S. Industry: A Contradiction", *Journal of Political Economy*, Vol. 101, No. 6, 1149-1164.
- [19] Pessoa, A. (2005), "Ideas' Driven Growth: the OECD Evidence", *Portuguese Economic Journal*, 4(1), 46-67.
- [20] Putnam, R. (1993), *Making Democracy Work: Civic Traditions in Modern Italy*, Princeton, Princeton University Press.
- [21] Putnam, R. (2000), *Bowling Alone: The Collapse and Revival of American Community*, New York: Simon and Schuster.
- [22] Reis, A.B. and T. N. Sequeira (2007), "Human Capital and Overinvestment in R&D", *Scandinavian Journal of Economics* 109(3), 573-591.
- [23] Romer, P. (1990), "Endogenous Technological Change", *Journal of Political Economy* 98, 71-102.
- [24] Rupasingha A., Goetz, S. J., and D. Freshwater (2000), "Social Capital and Economic Growth: A County-Level Analysis", *Journal of Agricultural and Applied Economics*, 32(3), 565-72.

- [25] Sequeira, T.N. and A. Ferreira-Lopes (2008) "An Endogenous Growth Model with Human and Social Capital Interactions", *ERC Working Paper 09/08*.
- [26] Stokey, N. (1995), "R&D and Economic Growth", *Review of Economic Studies* 62, February, 469-489.
- [27] Strulik, H. (2007), "Too Much of a Good Thing? The Quantitative Economics of R&D Driven Growth Revisited", *Scandinavian Journal of Economics*, 109(2), 369-386.
- [28] Teachman J. D., Paasch, K., and K. Carver (1997), "Social Capital and the Generation of Human Capital", *Social Forces*, 75(4), 1343-1359.
- [29] Temple, J. and P.A. Johnson (1998), "Social Capability and Economic Growth", *The Quarterly Journal of Economics*, 113(3), 965-990.
- [30] World Bank (2006), "Where is the Wealth of Nations? Measuring Capital for the 21st Century", The World Bank, Washington D.C.
- [31] Whiteley, P. (2000), "Economic Growth and Social Capital", *Political Studies*, 48(3), 443-466.

A First Order Conditions for the Decentralized Equilibrium

The choice variables for the consumers are C , H_H , and H_S , so the first order conditions for the consumer problem yield:

$$\frac{\partial U}{\partial C} = \lambda_a \tag{45}$$

$$\lambda'_H = \frac{\lambda_a W_H}{\xi} \tag{46}$$

$$\lambda'_S = \frac{\lambda_a W_H}{\omega} \tag{47}$$

as well as:

$$\frac{\dot{\lambda}_a}{\lambda_a} = \rho + \delta_P - r \quad (48)$$

$$\frac{\dot{\lambda}'_H}{\lambda'_H} = \rho + \delta_H - \xi \quad (49)$$

$$\dot{\lambda}'_S = \rho\lambda'_S - \left(\frac{\partial U}{\partial K_S} + \lambda'_H\gamma + \lambda'_S\Omega \right) \quad (50)$$

where λ_a is the co-state variable for the budget constraint, and λ'_H and λ'_S are co-state variables for the stocks of human and social capital, respectively.

B Growth Rates in the Decentralized Equilibrium

In the steady-state, we can obtain the human capital growth rate of the decentralized equilibrium as follows. By using equation(49) and replacing it in $g_{\lambda'_H} = g_{\lambda_a} + g_W$ which we get by (46), we find $\frac{\dot{\lambda}'_H}{\lambda'_H} = \rho + \delta_H - \xi - g_W$. From (22)we get $g_W = g_Y - g_{K_H}$. Substituting this last equation in the previous one and introducing both in $-\frac{1}{\tau}g_y + \psi \left(1 - \frac{1}{\tau}\right) g_{K_H} = \frac{\dot{\lambda}_a}{\lambda_a}$ which we find in (45) and using equations (5) and (8) we get:

$$g_{K_H}^{DE} = \frac{\xi - \delta_H - \rho}{\left(\frac{\eta \left(\frac{\nu+\chi}{1-\phi} \right)}{1-\beta} + \psi \right) \left(\frac{1}{\tau} - 1 \right) + \frac{1}{\tau}} \quad (51)$$

Using the fact that $g_{K_H} = \frac{(1-\phi)}{\nu+\chi} g_{K_R}$ we solve for the growth rate of technological capital:

$$g_{K_R}^{DE} = \frac{\frac{\nu+\chi}{(1-\phi)} (\xi - \delta_H - \rho)}{\left(\frac{\eta \left(\frac{\nu+\chi}{1-\phi} \right)}{1-\beta} + \psi \right) \left(\frac{1}{\tau} - 1 \right) + \frac{1}{\tau}} \quad (52)$$

From (8) and $g_{K_H} = \frac{(1-\phi)}{\nu+\chi} g_{K_R}$ we find $g_Y = g_{K_H} \left(\frac{\eta \left(\frac{\nu+\chi}{1-\phi} \right)}{1-\beta} + 1 \right)$. By substituting (18) in the previous equality we find:

$$g_Y^{DE} = \frac{(\xi - \delta_H - \rho) \left(\frac{\eta \left(\frac{\nu + \chi}{1 - \phi} \right) + 1}{1 - \beta} \right)}{\left(\frac{\eta \left(\frac{\nu + \chi}{1 - \phi} \right) + \psi}{1 - \beta} \right) \left(\frac{1}{\tau} - 1 \right) + \frac{1}{\tau}} \quad (53)$$

These three growth rates are equal to the ones that we found in the social planner problem.

Now we also show that the consumption to output ratio is equal in the decentralized equilibrium and in the social planner solution.

From equation (1) we get:

$$\frac{\dot{K}_P}{K_P} = \frac{Y}{K_P} - \frac{C}{K_P} - \delta_P \quad (54)$$

Also, from this equation we get $g_{K_P} = g_Y = g_C$ because the growth rates have to be constant in steady state. Since we have shown that $(g_{K_P} = g_Y = g_C)^* = (g_{K_P} = g_Y = g_C)^{DE}$ the left hand-side of equation (54) is equal in the social planner and in the decentralized equilibrium and δ_P is a constant.

In the social planner problem by transforming equation (11) we obtain $-\frac{\dot{\lambda}_P}{\lambda_P} = -\frac{1}{\tau}g_C + \psi(1 - \frac{1}{\tau})g_{K_S}$. Replacing this last equation in equation(15) we get $-\frac{\beta Y}{K_P} = \rho + \delta_P + \frac{1}{\tau}g_C - \psi(1 - \frac{1}{\tau})g_{K_S}$.

Since we have shown that $g_{K_P}^* = g_{K_P}^{DE}$ hence $\left(\frac{Y}{K_P} - \frac{C}{K_P} \right)^* = \left(\frac{Y}{K_P} - \frac{C}{K_P} \right)^{DE}$. Using the fact that $\frac{C}{K_P}$ can be written has $\frac{C}{Y} \frac{Y}{K_P}$ and putting $\frac{Y}{K_P}$ in evidence, we obtain that $\left(\frac{Y}{K_P} \right)^* \left(1 - \frac{C}{Y} \right)^* = \left(\frac{Y}{K_P} \right)^{DE} \left(1 - \frac{C}{Y} \right)^{DE}$. From (27) we note that $\left(\frac{Y}{K_P} \right)^{DE} = \frac{r}{\alpha\beta}$ and that $r = \alpha P m g_K$, thus $\left(\frac{Y}{K_P} \right)^{DE} = \frac{P m g_K}{\beta} = \left(\frac{Y}{K_P} \right)^*$. Finally $\left(\frac{C}{Y} \right)^* = \left(\frac{C}{Y} \right)^{DE}$.