# Distribution and Policy in the New Growth Literature [a]

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**Abstract:** This paper examines how economic activity and the distribution of income are related in endogenous growth models. I examine the different implications of models where inequality is due to differences in capital and labour endowments and of those with different types of labour. I argue that the new growth literature has done more than simply allow us to formalize old ideas: it emphasizes that growth and distribution are jointly determined, and thus allows us to explore the distributional implications of growth-enhancing policies. In contrast to the neoclassical framework, the new literature implies that there in not necessarily a tradeoff between redistribution and growth.

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## 1.Introduction

One of the main contributions of the new growth theories is the fact that they have rediscovered a role for government policy. Indeed, the contrast with the Solow-Swan model in which the long-run growth rate of the economy is determined solely by the rate of technological progress could not be more stark. The Solow-Swan model views technical change as exogenous, unaffected by the actions of consumers or producers, and consequently leaves no role for policy. In the new growth literature, policy intervention is both possible and desirable. It is possible because these theories maintain –in one or other of their versions- that the rate of growth is determined by the decisions of economic agents, such as the accumulation of physical capital, human capital investments, or firms' R&D expenditures, all of which can be affected by taxes and subsidies.

Policy is also desirable. The endogenous growth literature relies either on externalities or on monopoly power on the part of firms, and as a result the competitive equilibrium is not socially optimal. Economic policy can, to some extent, correct the externality or the distortion due to market power and hence increase welfare. Most of the existing models maintain that the competitive growth rate is lower than the socially optimal one.[1] Optimal policy then consists of a system of taxes and subsidies that increases the rate of growth and brings it closer to the first-best.

A number of measures have been argued to promote growth. The simplest approach to endogenous growth is the investment-led model, in which private investment in physical capital generates new knowledge that raises the economy-wide level of productivity. It hence implies that subsidies to capital accumulation can increase the rate of growth. R&D-led models emphasize the role of two types of policies. On the one hand, growth is seen as the result of research expenditures by private firms, and consequently R&D subsidies that increase the amount of research done would also accelerate growth. On the other, human capital is argued to be the main input of the research sector and policies that increase educational attainment would also increase the pool of researchers and thus the rate of technical change.

[1] The notable exception is the model of "creative destruction" of Aghion and Howitt (1992), where a new invention replaces an existing product. There is a negative externality as the producer of the new good does not take into account the destruction of the profits of the incumbent producer, and this may lead to an excessively high rate of technological change.

The question I want to address in this paper is what are the implications of these policies for the distribution of income. Subsidies to investment, education, or R&D have to be financed through taxes. In the absence of lump-sum taxation, these taxes will be distortionary and will affect different types of agents differently. Moreover, the subsidies will alter relative prices and will, per se, impact on factor rewards and hence on distribution.

The last decade has seen a revival of interest on the relationship between inequality and the rate of growth. The bulk of this literature has examined, both theoretically and empirically, how the given initial distribution of wealth or human capital affects, through a number of mechanisms, investment in human or physical capital and hence growth.[2] The approach I take in this paper is rather different. I am going to argue that a major contribution of the new growth theories is that they allow us to examine the joint determination of the growth rate and the distribution of income. Because growth is endogenous, it is going to depend on technological and preference parameter, the same parameters that also determine the rewards to the various production factors. If factor ownership varies across agents, we will have a correlation between growth and the distribution of income.

The joint determination of growth and the degree of inequality implies that growth-enhancing policies will have distributional implications. In this paper I consider three possible scenarios. I start in section 2 with a simple investment-led model where growth can be increased through investment subsidies. The subsidies are financed through a consumption tax, and agents are assumed to differ in the holdings of physical assets. The tax-subsidy system, by altering the price of capital relative to that of the consumption good, is going to affect the value of agents' endowments and hence their welfare. Section 3 considers a simple R&D-based model, where the stock of human capital and the rate of technical change are jointly determined. We will see that both R&D and education policies can increase the rate of growth, but they will have different effects on the wage of skilled workers relative to the unskilled, as the former increases the demand for and the latter the supply of skills. The next section addresses the question of whether redistribution necessarily reduces growth. I argue that, even when capital markets are perfect, this need not be the case once we allow for a two sectors and for productivity shocks. Section 5 concludes.

## 2. Endogenous Saving Propensities

Interest in the relationship between distribution and growth started in the 1950s with the work of the post-Keynesian economists. Kaldor (1956, 1957) and Pasinetti (1962) maintained that the saving propensity of capitalists is greater than that of workers, and that consequently aggregate savings depend on the distribution of income. These authors, as all their contemporaries, viewed the rate of economic growth as given. With constant saving propensities and the rate of investment determined by the exogenous growth rate, only the distribution of income could adjust to ensure equality between investment and savings. This meant that the rate of growth determined how income is distributed between capitalists and workers. In particular, faster growth required greater savings, and hence a higher share of income must accrue to capitalists.

The idea that saving propensities depend on the source of income has been reexamined in the context of the new growth literature by Alesina and Rodrik (1994) and Bertola (1993). An attractive feature of the investment-led models of growth is that the interest rate is constant and consequently there are no transitional dynamics. This, in turn, has two implications for the distribution of income. First, the propensity to save out of capital income differs from the propensity to save out of labour income. Second, and as a result of the above, the distribution of (relative) wealth reproduces itself over time. In contrast to the early literature, the endogenous growth formulation obtains saving behaviour from utility maximization, and sees causation as running from the technological parameters determining the interest rate to growth and savings. Growth and distribution are then jointly determined. In this context, unlike in the early literature, policy analysis becomes interesting, as measures aimed at affecting the growth rate will also impact on the distribution of income.

[2] See Galor and Zeira (1993), Perotti (1993), Alesina and Rodrik (1994), Persson and Tabellini (1994), Aghion and Bolton (1997), and Barro (2000) for empirical evidence. Aghion, Caroli and García-Peñalosa (1999) review the literature.

*Endogenous growth*

To understand how policy can work in the investment-based growth model, let us follow the exposition in Bertola (1993). Consider an economy where output is produced using capital and labour according to

$$Y_t = A_t K_t^{\alpha} L^{1-\alpha}, \tag{2.1}$$

$A_t$ being the level of productivity. Assuming perfect competition in the output and factor markets, the wage and the interest rate are, respectively,

$$w_t = \frac{(1-\alpha)Y_t}{L} \quad \text{and} \quad r_t = \frac{\alpha Y_t}{K_t}.$$

The economy is populated by $L$ agents indexed by $i$. Initially, agent $i$ owns one unit of labour and $K_{i0}$ units of capital, with $\sum_i K_{i0} = K_0$. She maximizes a utility function of the form[3]

$$U_{i0} = \int_0^{\infty} \frac{C^{1-\gamma} - 1}{1-\gamma} e^{-\beta t} dt \quad , \qquad \gamma > 1 \tag{2.2}$$

subject to her capital accumulation constraint

$$\dot{K}_{it} = r_t K_{it} + w_t - C_{it}. \tag{2.3}$$

The evolution of individual consumption is then given by the familiar Euler equation

$$\frac{\dot{C}_{it}}{C_{it}} = \frac{r_t - \beta}{\gamma} \quad . \tag{2.4}$$

Equation (2.4) implies that aggregate consumption grows at a constant rate only if the interest rate is constant. Assume that technical change is due to an externality stemming from the stock of capital. In particular, let us assume that $A_t = A_0 (K_t / L)^{1-\alpha}$, i.e. the higher the stock of capital per worker, the greater is. Then, the economy's rate of balanced growth is simply

$$g = \frac{\dot{Y}_t}{Y_t} = \frac{\dot{K}_t}{K_t} = \frac{\dot{C}_t}{C_t} = \frac{\alpha A_0 - \beta}{\gamma} \quad . \tag{2.5}$$

Equation (2.5) captures the main result of the investment-based endogenous growth models; namely that with constant returns to aggregate capital, the interest rate is

[3] See Obstfeld (1994) and Campbell (1996) for evidence on the intertemporal elasticity of substitution.

constant. As a result, the rate of growth of consumption is constant, different from zero, and exhibits no transitional dynamics.

*Saving rates*

Under our technological assumptions, the shares of labour and capital in total output are, respectively, $S_L = 1-\alpha$ and $S_K = \alpha$. We then have that a higher value of $\alpha$ results in a higher growth rate and a lower labour share. Since capital is more unequally distributed than labour, this implies that faster growth is associated with greater income inequality.

Define now the saving rate, *s*, as the proportion of output saved and added to the capital stock, i.e. $s = \dot{K}_t /(A_0 K_t)$. Using the expression for *g* above, we have

$$s = \frac{1}{\gamma}\left(\alpha - \frac{\beta}{A_0}\right). \tag{2.6}$$

There is a negative relationship between the saving rate and the labour share, which is the result of the different saving propensities of individuals with different stocks of capital. To see this, note that the intertemporal budget constraint of individual *i* is

$$\int_0^\infty c_{it} e^{-rt} dt \le \int_0^\infty (1-\alpha)\frac{Y_t}{L} e^{-rt} dt + K_{i0}$$

which can be expressed as

$$\int_0^\infty c_{i0} e^{-(r-g)t} dt \le \int_0^\infty (1-\alpha) A_0 K_0 L^{-1} e^{-(r-g)t} dt + K_{i0} .$$

This expression, together with the Euler equation, implies that the optimal consumption path of agent *i* grows at rate *g* starting from

$$c_{i0} = \left[(r-g)k_i + (1-\alpha)A_0 L^{-1}\right]K_0 , \tag{2.7}$$

where $k_i \equiv K_i / K$ is the relative wealth of agent *i*. The initial savings of individual *i* are simply $s_{i0} = y_{i0} - c_{i0}$, and grow at rate *g*. Using equation (2.7),

$$s_{i0} = gK_{i0} . \tag{2.8}$$

We can now examine how factor ownership affects savings. Equations (2.7) and (2.8) tell us that an individual will consume all her labour income plus a fraction of her capital income equal to $(r-g)K_{it}$, and she will save $gK_{it}$ in order to sustain a rate of growth of her capital holdings of *g*.

It follows that the distribution of (relative) factor ownership remains constant over time. Those with no initial capital, i.e. $k_{i0} = 0$, consume all their wage, $c_{it} = w_t$, and never save. They therefore continue to hold no physical assets. Those who are initially endowed with capital chose a rate of growth of capital *g* irrespective of their initial wealth. Since the aggregate capital stock also grows at rate *g*, the relative wealth of each agent, $k_i = K_{it} / K_t$, remains constant and the relative distribution of wealth is unchanged.

The endogenous growth model yields the post-Keynesian result that the saving propensities of capitalists are greater than those of workers. In particular, we have obtained a zero propensity to save out of wage income, a case studied by Kaldor (1956). The difference is that now both the rate of technical progress and the saving rate are determined within the model. This means that causality no longer runs from one to the other. Moreover, both can be simultaneously affected by policy instruments.

*Investment Subsidies*

It has been widely argued by the new growth literature that investment subsidies raise the growth rate, as they foster the accumulation of the factor that engenders technical change, physical capital. In the absence of lump-sum taxation, distortionary taxes have to be used, and the question is what are the distributional implications of such policy. Bertola (1993) considers a situation in which the investment subsidy is financed through a consumption tax. A priori, we would expect this policy to benefit the owners of capital more than the owners of labour, who see their purchasing power reduced but do not directly benefit from the subsidy since they never save. Yet, as we will see, the endogeneity of the growth rate is going to lead to the opposite outcome.

Let the price of consumption faced by agents be $p_c > 1$ and that of the investment good be $p_k < 1$. The government budget constraint requires that payments be equal to tax receipts, i.e. $(1 - p_k)\dot{K} = (p_c - 1)C$, which implies a consumption-good price $p_c = (A_0 - p_k g)/(A_0 - g)$. The effect of the tax-subsidy policy on the growth rate is straight-forward. The interest rate is now $r = \alpha A_0 / p_k$, and hence the Euler equation becomes

$$g = \frac{\alpha A_0 / p_k - \beta}{\gamma}, \tag{2.9}$$

which is greater the lower the investment good price is.

The AK technology implies that this policy has no impact on the distribution of income, but, because it changes the relative price of the investment good, it will affect the distribution of consumption and hence of welfare. Consider the budget constraint of individual *i*, now given by

$$\int_0^\infty c_{i0} e^{-(r-g)t} dt \leq \int_0^\infty (1-\alpha) A_0 K_0 L^{-1} e^{-(r-g)t} dt + \frac{p_k}{p_c} K_{i0} . \tag{2.10}$$

Using equation (2.10) together with the above expressions for the consumption price and *g*, implies that the initial consumption level of agent *i* is

$$c_{i0} = (A_0 - g)\left[k_i + \alpha B(g)\left(\frac{1}{L} - k_i\right)\right] K_0, \tag{2.11}$$

where *B*(*g*) is an increasing function of *g*. This expression illustrates that a higher rate of growth of consumption requires a lower initial level. A lower $p_k$ thus reduces $c_{i0}$ for all agents, although this negative impact on welfare can be offset by the positive effect of a higher growth rate.

What is interesting is that the tax-subsidy system will affect the distribution of relative consumption. Consider the consumption of agent *i* relative to the mean –that is, to that of an individual with wealth $k = 1/L$ - , defined as

$$\frac{c_{i0}}{c_0} = \frac{k_i + \alpha B(g)(1/L - k_i)}{1/L}.$$

Since $\partial B / \partial g > 0$, the sign of $\partial(c_{i0}/c_0)/\partial g$ is given by $(1/L - k_i)$. The introduction of the tax-subsidy system will have the effect of *reducing* the relative consumption of individuals with wealth holdings above the average, while those with below-average capital will experience an *increase* in their relative consumption. In other words, the distribution of consumption (and hence of welfare) becomes *less unequal*.

The intuition for this result is apparent in the budget constraint (2.10). On the one hand, the lower relative price of capital reduces the value of physical wealth in terms of the consumption good, and hence reduces the relative total wealth of those with large capital endowments. On the other, faster growth and a lower discount rate result in a greater present discounted value of the labour endowment and the consumption flow.

To sum up, in the investment-led growth model the rate of growth and the factor distribution of income are simultaneously determined by technological parameters. We have seen that a higher rate of growth is associated with a lower labour share and, if capital endowments are more unequally distributed than labour endowments, also with greater inequality in the distribution of income. Policy can, however, help ameliorate this tradeoff. A system of investment subsidies financed through indirect taxation can at the same time increase the rate of growth and reduce the extent of consumption inequality.

## 3. Biased Technical Change

We have just seen that faster growth is associated with greater inequality, the reason being that the technological characteristics that lead to fast growth -namely, a high $\alpha$ - also lead to a small labour share. In this setup there is no causal relationship between growth and distribution. But is there any reason to suppose that growth can directly affect distribution?

During the last decade, and largely in response to the increase in inequality observed in a number of OECD countries, a number of papers have addressed the question of whether growth itself can impact on the degree of inequality.[4] Now, if the rate of growth is to affect distribution it must be because technological change is *biased* toward certain factors of production, in the sense that it changes their productivity relative to that of other factors. The concept of biased technical change found its way into economics in the 1940s with the work of Hicks and Harrod, and was incorporated into the neoclassical growth model. If technical change is not neutral, then the rate of growth is to affect distribution through its impact on factor rewards. Yet, until recent years, the distributional implications of biased technical change had received little attention. This was largely due to the widespread use of a Cobb-Douglas production function, which, as we saw in the previous section results in constant factor shares.

It is straight-forward to show that under a more general technology the rate of growth does affect distribution even in the neoclassical model. To see this, consider the previous model with infinitely-lived agents, but let the production function take the form $Y = F(K, AL)$, where $A$ measures the level of technology. Technical

[4] See Eicher (1994), Galor and Tsiddon (1997), Greenwood and Yorukolgu (1997), Acemoglu (1998), and Caselli (1999).

progress is then said to be *labour-augmenting*, and grows at the constant exogenous rate $g$. The rate of growth of consumption is given by equation (2.4) above. Along the balanced growth path it must be equal to the rate of technical change, hence

$$\frac{r_t - \beta}{\gamma} = g \qquad (3.1)$$

We can also obtain that the share of labour in total output is $S_L = 1 - f'(k)k / f(k)$, where $f(k) = F(k,1)$ and $k = K / AL$.

With a Cobb-Douglas production function technical change is necessarily neutral, as the labour share is given by $1-\alpha$. A more interesting case arises when the production function is of the CES form, $Y = \left(\alpha K^{-\rho} + (1-\alpha)(AL)^{-\rho}\right)^{-1/\rho}$, where $\phi = 1/\left(1+\rho\right)$ is the elasticity of substitution between capital and labour. Differentiating with respect to the capital stock and substituting for the interest rate in the balanced growth condition (3.1), we obtain the equilibrium capital stock

$$k^* = \left(\frac{1}{1-\alpha}\left(\frac{\alpha}{\gamma g + \beta}\right)^{\rho/1+\rho} - \frac{\alpha}{1-\alpha}\right)^{-1/\rho}.$$

The share of labour in total output is now given by $S_L = (1-\alpha)\left(\alpha\left(k^*\right)^{-\rho} + (1-\alpha)\right)^{-1}$, and, through $k^*$, is a function of the rate of technical change. The sign of $\partial S_L / \partial g$ is given by $-\rho$: faster technical change increases the labour share if $\rho < 0$, and reduces it for $\rho > 0$. The degree of substitutability between factors determines the effect of biased technical change on factor shares, with faster labour-augmenting technical progress increasing the labour share only for high values of the elasticity of substitution.

### 3.1. Human capital and biased technical change

One of the problems of this simple formulation is that all workers are identical, or, if we think of $L$ as measuring efficiency units of labour, they are perfect substitutes. Technical change is therefore neutral as far as different types of labour are concerned. This framework of analysis is unsatisfactory for two reasons. First, inequality in labour incomes is a major component of income inequality and hence we would like to have some understanding of its determinants. Second, it has become apparent that certain types of innovations are particularly suited to be used by workers with particular skills. For example, the new information technologies have been said –and to a large extent shown- to be more complementary with educated than with non-educated workers (see Bartel and Lichtenberg, 1987, and Krueger, 1993).

The argument that the degree of complementarity between new technologies and different types of labour is not the same is not new. In his analysis of the relationship between human capital and inequality, Tinbergen (1975) suggested that inequality is ultimately determined by the opposing effects that technology and education exert, respectively, on the demand for and supply of skilled labour, and hence on the relative wage. He stipulated that the relationship between growth and inequality is determined by the "race between technological development and education" (1975, p. 97).

Although technological change can exert an upward pressure on the demand for skilled workers and thereby increase their wage premium over unskilled workers, education should eventually lead to an expanded supply of skilled labour and thereby to a fall in the wage differential. In what follows I argue that this is not necessarily the case. The section is based on a joint paper with Theo Eicher (see Eicher and García-Peñalosa, 2001) where we formalize Tinbergen's hypothesis to examine how technical change affects relative wages, but because the rate of technical change is itself endogenous some new results emerge. First, we are going to see that a greater stock of skilled labour may be associated with a higher or with a lower relative wage. Second, the effect of growth-enhancing policies on relative wages will depend on whether they target the demand for or the supply of labour.

*Production*

Suppose that the production function takes the form first introduced by Romer (1990),

$$Y_t = \sum_{i=1}^{D_t} n_{it}^{\alpha} H_t^{1-\alpha}. \qquad (3.2)$$

where $D$ represents the number of different intermediate goods used in production, $n_i$ is the quantity of the *i*th intermediate good employed, and $H$ is the skill-adjusted stock of labour. Technological change takes the form of an expansion of the number of different intermediate goods available. It is possible to show that the quantity of intermediary used is the same for all types, and that it is constant over time, which allows us to rewrite aggregate output as $Y_t = D_t n^{\alpha} H_t^{1-\alpha}$.

The economy consists of skilled workers, denoted $S_t$, and unskilled workers, $U_t$, and the population is normalized so that $U_t + S_t = 1$. The two types of labour differ not only in terms of productivities, but also in their technological capabilities. Following Nelson and Phelps' (1966) argument that skilled workers possess a greater capacity to absorb new technologies, we introduce the notion that technological change erodes the aggregate stock of human capital due to its effect on the productivity of uneducated workers. This assumption is captured by the following expression for the skill-adjusted stock of labour:[5]

$$H_t = \left( \frac{U_t^{-\rho}}{g_t} + \left(S_t^P\right)^{-\rho} \right)^{-1/\rho} . \tag{3.3}$$

where $S_t^P$ denotes skilled labour employed in production, and $g_t = \Delta D_t / D_{t-1}$ is the rate of technological change. As we saw in the previous subsection, the elasticity of substitution is a crucial determinant of the impacted of biased technical change on factor rewards. In what follows we assume that $-1 < \rho < 0$. That is, the elasticity of substitution, $\phi = 1/(1+\rho)$, falls in the interval $(1,\infty)$, implying that skilled and unskilled labour in production are imperfect substitutes.

From (3.2) and (3.3) the demand for labour can be derived as a function of the rate of technological change and the relative wage of skilled to unskilled workers, $\omega_t$. That is,

$$\omega_t \equiv \frac{w_t^S}{w_t^U} = \left( \frac{U_t}{S_t^P} \right)^{1+\rho} \frac{\Delta D_t}{D_{t-1}} . \tag{3.4}$$

On the production side, the relative wage is determined by two standard factors: relative factor supplies and relative productivity. The later is, however, determined endogenously by the rate of technological change.

*Factor Supplies*

Agents live for two periods, but work only when young. At the start of their working lives, they decide whether to invest in education or to remain unskilled. The cost of education is of the form $cw_t^U / a$, where $a$ denotes the agent's ability to learn and $c$

5 Galor and Moav (2000) and Gould et al. (2000) also assume that the productivity of uneducated workers depends on the rate of technical change. The main difference is that they consider a production function in which the two types of workers are perfect substitutes, hence the labour demand is always upwards-sloping and the equilibrium unique.

the direct cost of education. More able individuals can learn faster and therefore incur a lower cost, captured by *a* in the denominator.

The income of a skilled worker born at time *t* can be written as

$$Y_t^S = w_t^S - \frac{c w_t^U}{a}.$$

Agents choose to invest in skills if $Y_t^S$ exceeds the income obtained by remaining unskilled, $Y_t^U = w_t^U$. Equating these two expressions, and assuming that abilities are distributed uniformly in $[0,1]$, we obtain that the inverse labour supply is given by

$$\omega_t = 1 + \frac{c}{1 - S_t}. \tag{3.5}$$

Equation (3.5) simply says that the higher the relative wage and the lower the cost of education, the greater the number of educated workers will be.

*Technological change*

New technologies are generated through intentional R&D. Let us consider a formulation that has by now become standard in the new growth literature (see Romer, 1990), and assume that $\Delta D_t = S_{t-1}^R D_{t-1}$. The invention of new types of machinery is linear in the number of researchers, $S_t^R$, and in the existing number of blueprints. I abstract from the micro-foundations of R&D decisions, and simply assume that a fixed fraction of the skilled labour force, $\beta$, is employed in R&D. The economy then produces technological blueprints according to

$$\Delta D_t = \beta S_{t-1} D_{t-1}. \tag{3.6}$$

Substituting for technical change in equation (3.4), and using the labour market constraints $S_t^P + S_t^R = S_t$ and $U_t + S_t = 1$, we obtain the inverse relative labour demand,

$$\omega_t = \frac{\beta S_{t-1}}{(1-\beta)^{1+\rho}} \left( \frac{1 - S_t}{S_t} \right)^{1+\rho}, \tag{3.7}$$

Equation (3.7) implies that the demand for skilled labour is a lagged function of its supply, as the relative wage is decreasing in the current stock of skilled labour but increasing in the last period's stock. The reason for this is that a greater proportion of skilled labour in period *t*-1 results in faster technological change, which means that the productivity of skilled labour is growing more rapidly than that of unskilled labour. This raises the demand for skills at *t*, and therefore the wage ratio for any given supply**.**

*Stationary States*

The equilibrium of the model is obtained by equating the labour supply, given in equation (3.5), to the labour demand, (3.7), which renders a differential equation in $S_t$ and $S_{t-1}$. Imposing the steady state condition, $S_{t-1} = S_t = S$, we have

$$1+\frac{c}{1-S}=\frac{\beta}{(1-\beta)^{1+\rho}}S^{-\rho}(1-S)^{1+\rho} \tag{3.8}$$

This equation yields $S^*$ as a function of the parameters of the model. Once the equilibrium stock of skilled labour is obtained, it uniquely determines the relative wage and the rate of growth of the economy. Relative wages are given by the supply of labour function. To obtain the rate of output growth, note that in steady state all inputs except the number of intermediate goods available are constant. The steady state growth rate is then $g = \beta S^*$.

We can examine the solution to equation (3.8) graphically in the $(\omega, S)$ space. As we see in figure 1, the labour demand is initially upward sloping since more skilled labour allows for more R&D, which improves the productivity of skilled workers in production. Unskilled labour eventually becomes sufficiently scarce to exert downward pressure on the relative wage and the demand function becomes downward sloping. It reaches its maximum at $S = -\rho$; a higher elasticity of substitution between skilled and unskilled (that is, a lower $\rho$), prolongs the upward sloping section of the relative demand curve, as it slows down the rate at which the scarcity of unskilled labour reduces the relative wage.

**Figure 1 about here**

The first thing to note is the possibility of multiple equilibria. There is a high-growth equilibrium, $S_h$, a low-growth (unstable) equilibrium, $S_l$, and a poverty trap with no human capital and no technical change. Multiplicity emerges as the result of two features of our economy: skilled-biased technical change and the fact that new knowledge is generated by skilled labour. Essentially, a greater supply of skilled workers accelerates technical change, which in turn increases the relative demand for these workers in order to absorb the new technology. Because demand is high, there are enough incentives to invest in education and the greater stock of skilled labour is supported by equilibrium wages. The economy thus finds itself in a virtuous cycle. In the low-growth equilibrium, a low relative wage, caused by the fact that slow technical change implies a small demand for educated labour, generates no incentives to further invest in skills. Through the same mechanism, the economy can even be stuck in a no-growth trap.

The concept of biased technical change that we have just formalised is central to Tinbergen's (1975) hypothesis that the pattern of relative wages over time depends on the strength of the demand for skills exerted by technology and the supply of skills generated by education. What is new is that endogenous technical change creates an interdependence between demand and supply, which, in turn, gives rise to multiplicity.

Multiplicity results in poverty traps, where countries are trapped in a no-R&D equilibrium, even though a high growth equilibrium would be feasible for the economy's parameter values. Only if the initial stock of labour exceeds the level associated with the unstable, middle equilibrium, does the country converge to the stable R&D equilibrium. If the initial level of skilled labour is not sufficiently high, the country reverts to the development trap in which there is no technical change.

### 3.2. Education Policy versus R&D Policy

Two types of policy have been advocated by the new growth literature as being able to accelerate growth in the R&D-based models: education subsidies and R&D subsidies. In our setup, both have the standard effect on the growth rate, but their distributional implications are not the same.

Suppose first that the government can increase the fraction of the skilled labour force employed in research through subsidies to private R&D firms. This implies a higher value of $\beta$, which shifts upwards the labour demand function. The subsidies can be financed through a proportional tax on labour incomes, $\tau$. The arbitrage equation between skilled and unskilled is now $(1-\tau)\left(w_t^S - cw_t^U / a\right) = (1-\tau)w_t^U$. The tax thus reduces the incomes of skilled and unskilled workers by the same proportion, leaving the relative supply function unchanged.

For an economy already in a high-growth steady state, this policy increases the rate of growth and the wage ratio of the economy. Faster technical change is the result of two effects. First, for any $S$, the fraction of educated workers employed in R&D is higher. Second, in the new high-growth steady state there is a larger stock of skilled labour, as higher inequality induces more individuals to invest in human capital (see figure 2a). Faster growth is, thus, achieved at the expense of greater wage inequality. For a low-growth economy, this policy could move it out of its unstable equilibrium and into the high-growth steady state, although note that the R&D policy would *not* get a country with zero human capital out of its poverty trap.

**Figure 2 about here**

Suppose now that the government subsidizes the private education cost, reducing it from $c$ to $c'$. The subsidy can, as before, be financed by a proportional tax on labour incomes. Since the tax is neutral, the only effect of the policy is to shift the inverse labour supply function downwards, as with a lower cost of education more workers are willing to invest in skills for any level of the relative wage. The new high-growth steady state exhibits a larger stock of human capital and hence faster growth. The effect on the relative wage can, however, go either way, as illustrated in figures 3a and 3b. If the economy is on the downwards-sloping segment of the demand function, then we will witness a reduction in the relative wage, as predicted by Tinbergen. If, on the other hand, the economy is on the upwards segment, the higher growth rate will be associated with *increased* wage inequality. The elasticity of substitution between the two types of labour becomes a crucial parameter. A high elasticity of substitution implies that the range over which the demand function is upward-sloping is greater, and hence makes it more likely that a reduction in the cost of education increases the wage premium.

**Figure 3 about here**

To sum up, in a model where the source of growth is the level of human capital, technological policies indirectly increase the incentives to become educated by generating a greater skill premium. As a result, faster growth is attained at the expense of greater inequality between the skilled and the unskilled. In the case of education policies, a lower cost of education directly encourages the accumulation of skills. Yet, this does not necessarily imply that the relative wage will fall.

## 4. Redistribution in Volatile Economies

The textbook approach to redistribution emphasizes the idea, first formalized by James Mirrlees (1971), that there is necessarily a trade-off between productive efficiency and equality due to incentive considerations. The basic incentive argument carries over to the aggregate economy when capital markets are perfect. As we saw in section 2, in a Ramsey-Cass-Koopmans growth model with perfect capital markets, the rate of growth of individual consumption is given by the Euler equation $g = (r - \beta)/\gamma$. If all agents have the same preference parameters, this expression is also the aggregate rate of growth. By making the after-tax rate of interest smaller, greater taxation reduces the return to saving, thus lowering the incentives to accumulate capital and hence the rate of growth.

A number of recent papers have challenged this argument. If capital markets are imperfect, the positive effect of redistribution on agents' investment possibilities may overcome the negative incentive effect and result in faster growth.[6] In this section I want to examine how, even with perfect capital markets, it is possible for redistribution to foster growth.

What follows is based on joint work with Stephen Turnovsky (see García-Peñalosa and Turnovsky, 2001).[7] We consider the Ramsey-Cass-Koopmans model with an externality associated to the capital stock, and we introduce two modifications. First, we consider a two sector-economy, with a modern and a traditional sector, such that only the former uses capital. This means that even with constant returns to aggregate capital, the interest rate is not constant as it depends on how labour is allocated between the two sectors. Second, we assume that the production function in the modern sector is stochastic; that is, each period there is an shock that increases or reduces the output produced with a given amount of labour and capital. As we are going to see, the endogeneity of employment in the modern sector implies that there is a positive effect of redistribution, as well as the standard negative one.

**4.1. Volatility and factor shares**

Consider again the infinitely-lived agent economy, but let there be two sectors, a modern sector and an traditional or backyard one. There is a mass 1 of infinitely-lived agents in the economy. Assume that all agents are endowed with a unit of time each period that can be allocated either to the modern sector, *l*, or to operating the traditional technology, 1-*l*.

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6 See Perotti (1993), Banerjee and Newman (1993), and Aghion and Bolton (1997).

7 See also Turnovsky (1999) for a stochastic endogenous growth model.

In the modern sector firms are indexed by j. The representative firm produces output according to the stochastic production function

$$dY_j = AK_j^{\alpha}(Kl_j)^{1-\alpha}(dt + du) \tag{4.1a}$$

where $K_j$ denotes the individual firm's stock of capital, $K$ is the aggregate stock of capital, and $Kl_j$ the efficiency units of labour employed by the firm. The stochastic variable is temporally independent, with mean zero and variance $\sigma^2 dt$ over the instant $dt$. The realisation of the shock is the same for all firms at any particular point in time. All firms are identical, hence they all choose the same level of employment and capital, i.e. $K_j = \overline{K}$ and $l_j = \bar{l}$. A firm's stochastic production function thus exhibits constant returns to scale in private inputs, labour and capital, but aggregate output $\overline{Y}$ is linear in the stock of capital. Assuming that the realization of the shock is the same for all firms at a given point in time, we have

$$\overline{Y} = A\bar{l}^{1-\alpha}\overline{K}(dt + du). \tag{4.1b}$$

We assume perfect competition in factor markets, so that wages and rates of return on capital are determined by the usual marginal productivity conditions. In particular, the private rate of return on capital over the time interval ($t$,$t$+$dt$) is specified as $dR = r(dt + du)$, where $r \equiv \alpha A l^{1-\alpha}$. The return to labour over the same interval is $dW = w(dt + du)$, with $w = (1-\alpha)Al^{-\alpha}K \equiv \delta K$.

The traditional sector consists of a linear technology that can be operated by a single individual and which uses no capital. Let agent $i$'s output be given by

$$dQ = Z(1-l)dt \tag{4.2a}$$

The backyard technology is thus riskless.[8] We assume that there is an externality from the aggregate level of capital, so that, as before, labour productivity, $Z$, is proportional to the aggregate capital stock. That is, $dQ = q\overline{K}(1-l)dt$, and total output in the traditional sector is

$$d\overline{Q} = q\overline{K}(1-\bar{l})dt. \tag{4.2b}$$

*Consumers*

A consumer's expected lifettime utility is assumed to take the form,

[8] In García-Peñalosa and Turnovsky (2001) we consider an economy with shock to both sectors.

$$E_0 \int_0^{\infty} \frac{C_t^{1-\gamma}}{1-\gamma} e^{-\rho t} dt \quad , \qquad \gamma > 1 . \tag{4.3}$$

Her capital accumulation constraint is $dK = KdR + ldW + dQ - Cdt$, which can be expressed as

$$dK = \left( rK + \delta \overline{K} l + q\overline{K}(1-l) - C \right) dt + \left( rK + \delta \overline{K} l \right) du . \tag{4.4a}$$

Through both the equilibrium wage rate and the rate of return, the dynamic path of the individual's stock of capital depends on the aggregate stock of capital, which in turn evolves according to

$$d\overline{K} = \left( r\overline{K} + \delta \overline{K} \bar{l} + q\overline{K}(1-\bar{l}) - \overline{C} \right) dt + \left( r\overline{K} + \delta \overline{K} \bar{l} \right) du . \tag{4.4b}$$

The representative consumer then chooses consumption and the allocation of labour between the two sectors in order to maximize expected lifetime utility, equation (4.3), subject to (4.4). As is well-known in this type of models, both $r$ and $\delta$ are independent of the capital stock, making the two constraints linear in the capital stock. What makes the model tractable is precisely this linearity.

*Macroeconomic equilibrium*

First note that the aggregate resource constraint can be expressed as $dY + dQ = dC + dK$. Using (4.1), (4.2) and (4.4), this equation allows us to write the rate of growth of the capital stock as

$$\frac{dK}{K} = \left[ A\bar{l}^{1-\alpha} + q(1-\bar{l}) - \frac{\overline{C}}{\overline{K}} \right] dt + A\bar{l}^{1-\alpha} du \equiv gdt + dk .$$

That is, the rate of growth is stochastic, with mean $g$ and variance $\sigma_g^2 = \left( A\bar{l}^{1-\alpha} \right)^2 \sigma^2$.

The solution to the stochastic growth model is then given by two equations obtained from the consumers' maximization problem, namely

$$\delta - \gamma A \bar{l}^{1-\alpha} \delta \sigma^2 = q . \tag{$L$}$$

$$g = \frac{r-\beta}{\gamma} + \left[ \frac{\gamma - 1}{2} + (1-\alpha) \right] \left( A\bar{l}^{1-\alpha} \right)^2 \sigma^2 . \tag{$G$}$$

Equation ($L$) simply states that the risk-adjusted return to labour must be the same in the two sectors. In the absence of uncertainty, it would reduce to $\delta = q$. For risk-averse individuals, uncertainty in the modern sector has the effect of shifting labour to the traditional one. Equation ($G$) is a modified Euler equation. Inserting the equilibrium value of $\bar{l}$ obtained from ($L$) yields the average rate of growth.

The presence of uncertainty has both an income and a substitution effect on capital accumulation. For $\gamma > 1$, the income effect dominates and greater volatility tends to increase the rate of growth, as we can see in equation (*G*). But greater volatility also affects the allocation of labour between sectors, shifting employment away from the modern sector, and thus reducing the interest rate. For reasonable levels of the volatility parameter, this effect is never strong enough to offset the direct impact, implying that greater volatility results in faster growth.

An increase in $\sigma^2$ also affects the labour and capital shares. Because it shifts labour away from the modern sector, the marginal product of labour increases, and the overall share of labour in total output rises. Faster growth is then associated with a greater labour share.

Note that this result does not contradict our findings in section 2. In fact, in the stochastic growth model, an increase in $\alpha$ will also result in faster average growth and a lower labour share. Whether high growth rates are accompanied by a high or a low labour share then depends on whether fast growth is due to a high marginal productivity of capital or to high volatility.

**4.2. Growth and redistribution**

We can now examine whether it is always the case that redistributive polices imply slower growth. Suppose the government redistributes income by taxing capital income at a rate $\tau$, and using the proceeds to subsidize all labour earnings at rate *s*. The individual capital accumulation constraint then becomes

$$dK = \left(r(1-\tau)K + (1+s)(\delta l + q(1-l))\overline{K} - C\right)dt + \left(r(1-\tau)K + (1+s)\delta\overline{K}l\right)du\ . \tag{4.5}$$

Because all labour incomes are taxed at the same rate, the allocation of labour between sectors is unaffected, and it is still given by equation (*L*). Solving the new maximization problem we obtain that the average rate of growth is given by

$$g = \frac{r(1-\tau)-\beta}{\gamma} + \left[\frac{\gamma-1}{2} + (1-\alpha)(1+s)\right]\left(A\bar{l}^{1-\alpha}\right)^2\sigma^2\ . \tag{$G'$}$$

The direct effect of the tax is to reduce the interest rate, while the labour subsidy, by magnifying the effect of the shock on income, tends to foster capital accumulation. This effect can be shown to be weak for reasonable levels of $\sigma^2$. The tax-subsidy policy hence reduces the average growth rate.

Suppose now that only wages in the modern sector are subsidized. The allocation of labour is now governed by the following expression:

$$(1+s)\left(\delta - \gamma A\bar{l}^{1-\alpha}\delta\sigma^2\right) = q\,. \qquad (L')$$

The subsidy now increases the relative return to working in the modern sector, and shifts labour away from the traditional sector. The effect of redistribution on growth is ambiguous. From the ($G'$) schedule, a higher $\tau$ reduces the rate of growth. But because it also increases the subsidy and hence the supply of labour in the modern sector, the marginal product of capital increases. There are therefore two effects of the tax-subsidy system; a direct reduction in the net interest rate that tends to depress growth, and an indirect increase in the marginal product of capital due to higher employment which tends to accelerate growth.

Can the positive impact of redistribution ever dominate? Calibrating the model, it is possible to show that this is indeed the case. Suppose that the government taxes capital income at 30% and uses the proceeds to subsidize wages in the modern sector at 20%. In a riskless economy, the introduction of the tax-subsidy would reduce the growth rate from 3 to 2.6%, implying the usual tradeoff between growth and redistribution. As risk increases, the impact of the subsidy on the allocation of labour between sectors becomes stronger, and the effect of the increase in $\bar{l}$ on the interest rate eventually offsets the reduction due to the tax. For high-volatility economies, i.e. $\sigma = 0.4$,[9] the policy raises the share of wages from 76 to 79 per cent and *increases* the growth rate by 0.5 percentage points. That is, redistribution from capital to labour results in faster growth.

## 5. Conclusions

It has been widely argued that the new growth literature draws on old concepts such as the non-rivalry of knowledge, creative destruction, or learning-by-doing, and that its only contribution has been to formalize existing ideas. In this paper I have argued that this formalization has important implications. First, it has challenged the notion of causality. We have seen that the new growth theories can reproduce post-Keynesian arguments about different saving propensities of different individuals, as well as Tinbergen's analysis of how the race between education and technical change

[9] This level of risk implies a standard deviation of the rate of growth of between 9 and 12, depending on the tax, which are close to the highest levels observed in the Summers and Heston data set (see Breen and García-Peñalosa, 2000).

determines wage inequality. Yet, by drawing attention to the underlying decisions of consumers and producers, our analysis implies that the rate of growth and the distribution of income are jointly determined by preference and technology parameters.

Second, it has allowed us to ask new questions. The formalization of the concept of learning-by-doing has resulted in a growth model which is linear in the capital stock and consequently easy to deal with. As a result, more complex issues can be address than in the traditional neoclassical growth model. For example, as we saw in section 3, we have been able to solve a model where production is stochastic, and examine whether there is a correlation between output volatility and factor shares.

Lastly, the new growth theories emphasize the role of policy. Because they examine how the decisions of producers and consumers determine an economy's rate of growth, they imply that government policy, by impacting on these decisions, can affect growth. Since most of this literature concludes that the *laissez-faire* growth rate is lower than the social optimum, policies to accelerate growth are called forth. But because factor rewards and growth are jointly determined, policy will also affect the distribution of income (or consumption, or wages) across agents. We have seen that in investment-led models there may not be a conflict between growth and redistribution. When growth is driven by R&D investments and technical change is biased towards more educated workers, growth-enhancing policies may increase or decrease relative wages depending on whether they take the form of R&D or education subsidies.

One important question remains. In this paper I have concentrated on how policies affect distribution across contemporaneous agents which have different endowments of capital or skills. However, in an overlapping-generations framework agents' endowments change over their lifecycle and factor rewards then determine the incomes of different age groups. Growth-enhancing policies then affect the distribution of income between the young and the old and, in a world of changing population structures, it is important to understand how.

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**Figure 1: Steady State Equilibria**

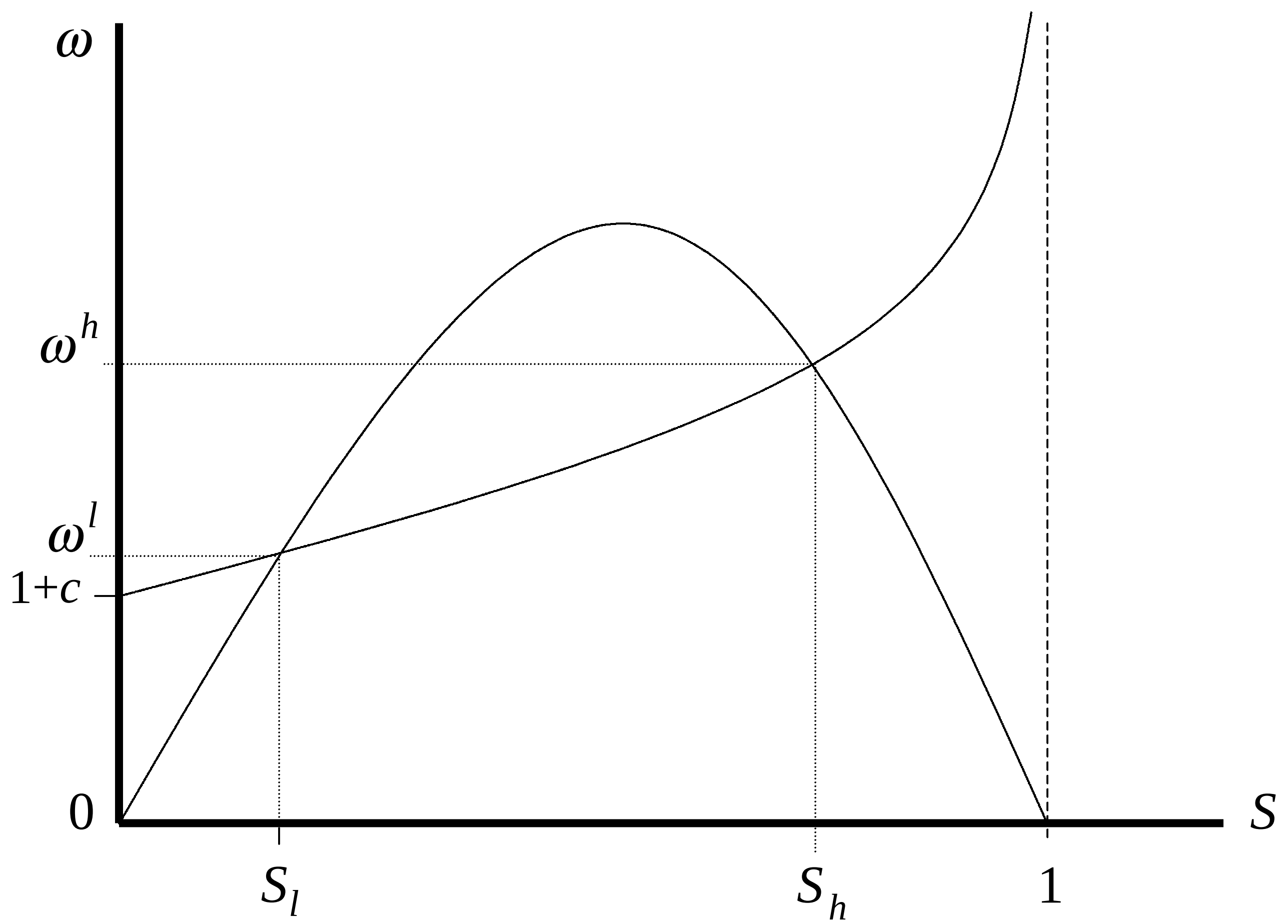

**Figure 2: R&D subsidies**

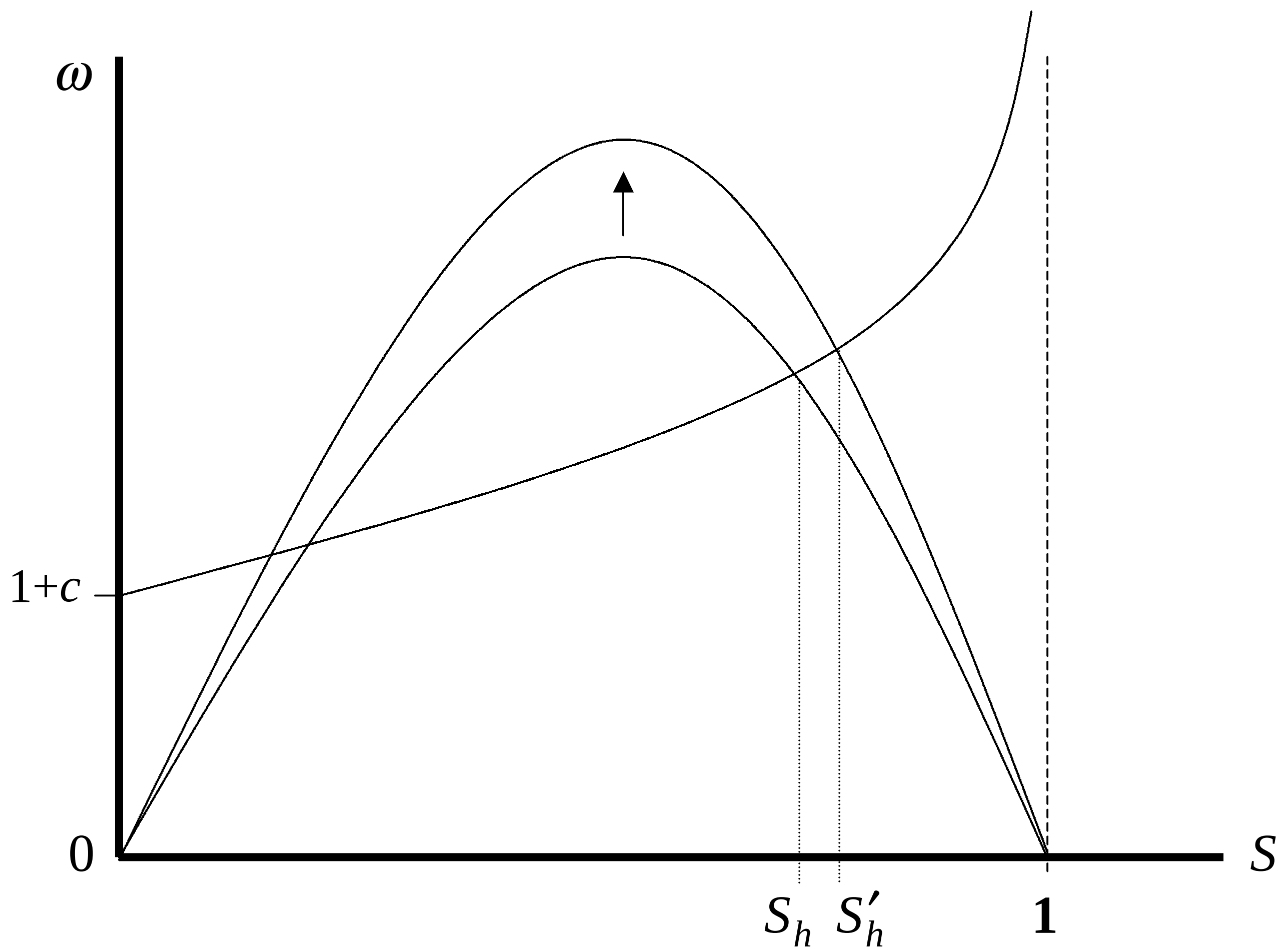

**Figure 3a: Education subsidies with a low elasticity of substitution**

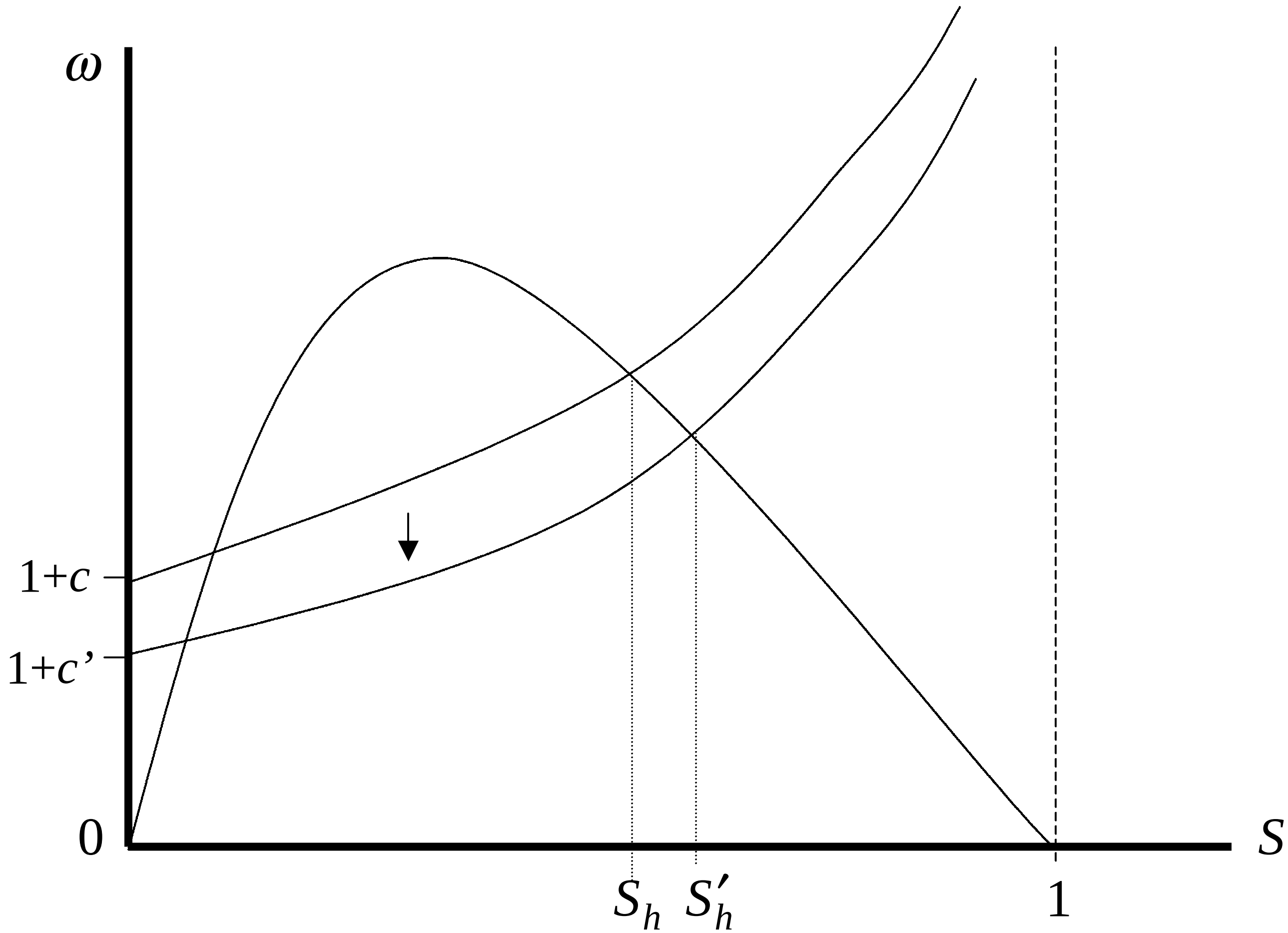

**Figure 3b: Education subsidies with a high elasticity of substitution**