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ABSTRACT

Labour Income Taxation, Human Capital and Growth: The Role of Child Care*

This paper studies the effects of labour income taxation on growth in an OLG model where both formal schooling and child care enter the human capital production function as complements. We compare them with the effects obtained in a model where only formal schooling matters for skill formation. Using a numerical analysis we find that the omission of child care from the technology of skills' formation can significantly bias the results related to the effects of labour income taxation on growth.

JEL Classification: H31 and J22
Keywords: child care, growth, human capital, labour supply and taxation

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1 Introduction

This paper studies if and how introducing child care in the human capital production function influences the effects of labor income taxation on growth.

There is an extensive literature on taxation and growth (see Stokey and Rebelo 1995, Myles 2000 and for a recent survey Myles 2007). Models where growth is driven by human capital accumulation focus on the disincentive that labor income taxation may create to the decision to acquire formal schooling. Most of the existing research however ignores or does not elaborate on the role of child care in the human capital formation process.[1] This is in contrast with the results of the research on the role of early environments on children's human capital acquisition. The issue has been widely analyzed, especially in the psychology and sociology literature. Economists have more recently recognized the importance of child care on skills' acquisition (see Bernal 2008 for a review of the most recent contributions) and studied the complementarity between early and late investments in human capital (see the seminal work by Cunha and Heckman 2007). Child care depends on parental time and on the purchase of goods and services which may impinge on child development: both can be affected by taxation. These arguments suggest that an explicit inclusion of child care in the skill formation process is relevant to correctly assess the effects of taxation on growth.

We develop a three-period OLG growth model where formal schooling and child care enter the production function of human capital as complements. Child care depends on the time that parents dedicate to child rearing and on the expenditure on goods and services which may affect the child's skill acquisition (e.g books or toys, day care centers' services, pre-school programs, baby-sitting). We compare such a model with one where child care does not affect child development and where human capital is simply produced by the schooling process. While in the latter set-up labor income taxation affects human capital accumulation only through the decision to invest in formal schooling, in the first framework, it also influences - both directly and indirectly - the growth rate through the change in the time parents devote to child care and via the variation in the amount of child care expenditure. The direct effect goes through the impact of the change in child care on human capital, for a given level of formal schooling; the indirect effect passes through the complementarity between formal schooling and child care in the process of skills' formation. These are the new channels identified by the

[1] Glomm and Kaganovich (2003, 2008) - which include effective parental time in the children's human capital accumulation - are the only exceptions we are aware of.

paper through which taxation has an impact on growth.

To explore these new channels and quantitatively assess their relevance we perform a numerical analysis of the model. When taxes are reduced, the net wage goes up inducing people to work more and dedicate less time to child care; this reduction in parental care is not compensated by the increase in the amount of child care expenditure. The overall impact is such that the rate of transmission of skills during childhood is weakened and the growth rate rises less than in a model where child care does not affect human capital accumulation. Quantitatively, the omission of child care from the technology of skills' formation can significantly bias the results related to the effects of taxation on growth: the elasticity of the growth rate to labor income taxation depends on the wage elasticity of the uncompensated labor supply but it is always at least 1.8 times higher in a model which ignores the role played by child care in human capital development.

The paper is organized as follows. In Section 2 we provide some evidence supporting the main mechanisms at work in our framework. In Section 3 we describe the building blocks of the model, we derive the first order conditions for consumers and firms and we define the intertemporal equilibrium and the balanced growth path. In Section 4 we perform a numerical analysis of the effects of taxation, comparing a model where child care matters for the process of skills' formation with a model where it does not. Section 5 concludes.

2 Empirical evidence

There are two main mechanisms at work in our paper: the existence of a trade-off between time devoted to market work and time devoted to child care and the impact of child care arrangements on human capital development.

To support the view that changes in market work affect time dedicated to child care, we analyze data on time use taken from HETUS (Harmonised European Time Use Survey). We consider 9 countries (Belgium, Finland, France, Germany, Italy, Norway, Spain, Sweden and UK) and look at the sample of married or cohabiting individuals with the youngest dependent child below 6. We look for a measure of child care provided by parents: to this end, we select the activities recorded as "Physical care and supervision of child" and "Teaching, reading and talking with child" and coded as primary activities; we then add secondary child care.[2] This

[2] In HETUS, people are required to report both the main/primary activity they are involved in ("What did you do?") and the parallel/secondary activity they are doing ("Did you do anything else? If so, what?")

is a relatively narrow notion of child care as it does not include the time that parents spend not engaged in explicit child-related activities, but still in the presence of the children. We think that the narrow notion of child care we use better represents deliberate time devoted to kids, which is the choice variable in our model.

In Figure 1 we look at the percentages of those reporting any time in either primary or secondary child care and in Figure 2 we plot the minutes they devote to these activities. We distinguish between working and non-working individuals[3] and find that, within each country, non-working individuals have higher participation rates to the above mentioned activities and dedicate them more time.[4,5] These correlations suggests that within each country there is a trade-off between market work and parental time devoted to child care.[6] Cawley and Liu (2007), using ATUS (American Time Use Survey) data, provide evidence of the existence of a causal relationship between maternal employment and time devoted to children. They control for various characteristics of mothers (e.g. education, race, marital status, age, number of children, age of the youngest children, whether the spouse - if any - is working or not) and show that employed women spend significantly less time reading to their children, helping them with homework, and in educational activities in general.

The importance of parental time (and more specifically of maternal employment) in influencing children abilities is analyzed in the empirical literature. The earlier contributions - as surveyed for instance by Ruhm (2004) - reached mixed conclusions. Some more recent studies tend to identify a negative impact of maternal employment on children performance. Baker, Gruber, and Milligan (2005) for example, using Canadian data from the National Longitudinal Survey of Children and Youth (NLSCY), find that the increase in maternal employment

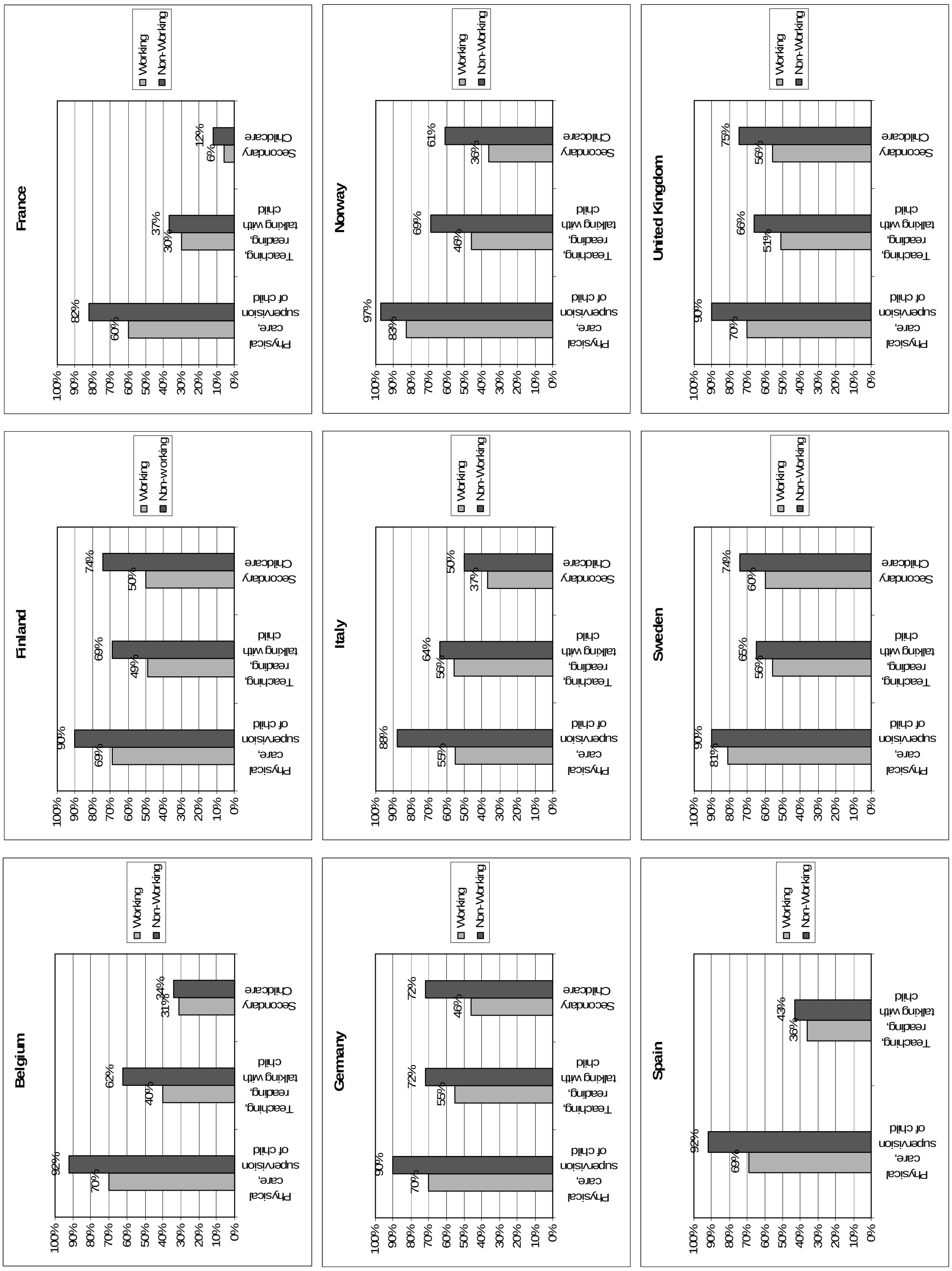
[3]Working parents include the categories “Employed full time” and “Employed part time”; non-working parents include the following categories: “On leave”, “Unemployed”, “Fulfilling domestic tasks”, “On retirement”.

[4]The only partial exception concerns secondary child care in France. As we can see in Figure 2, average time devoted to this activity - conditional on participation - is slightly higher for working individuals. However notice that, since non-working people participate more in secondary child care, the overall average time devoted to this activity (given by the participation rate times minutes dedicated to the activity by those participating) is still higher for non-working parents.

[5]We have also checked that this holds even when controlling for the number of children.

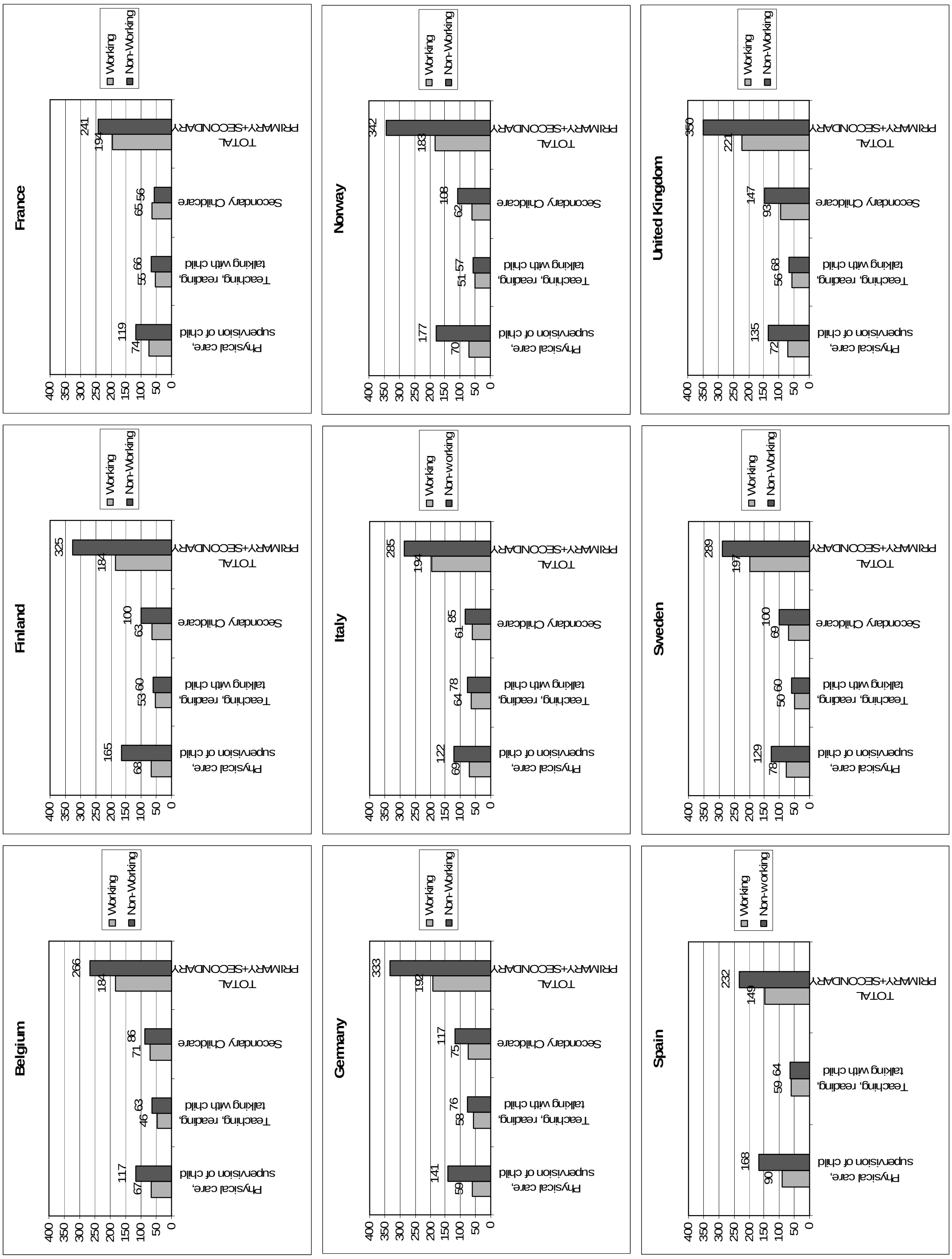
[6]Starting from the seminal work of Prescott (2004), recent literature (e.g. Rogerson 2007, Ragan 2006, Ohanian, Raffo, and Rogerson 2007) finds that cross-country differences in labour income taxation contribute to explain cross-country differences in time allocation, with leisure and home production being, ceteris paribus, higher in countries where taxation is higher. Checking whether their results hold also for the more restrictive notion of child care is an interesting issue which we leave for future research.

Figure 1: Percentage of individuals reporting any time on primary and secondary childcare activities



Year considered: **Belgium** -2005-; **Finland** – 1999/ 2000-; **France** -1998/1999-; **Germany** – 2000/2001 -; **Italy** – 2002/ 2003 -; **Norway** 2000/2001;
Spain – 2002/2003 - Sec. Childcare: Missing Value; **Sweden** – 2000/ 2001-; **UK** -2000/ 2001-.
"Primary activities"= "Physical care, Supervision of child" and "Teaching, reading, talking with child"

Figure 2: Number of minutes (per day) spent on primary and secondary childcare activities



Year considered: **Belgium** -2005-; **Finland** – 1999/ 2000-; **France** -1998/1999-; **Germany** – 2000/2001 -; **Italy** – 2002/ 2003 -; **Norway** 2000/2001; **Spain** – 2002/2003 - Sec. Childcare: Missing Value; **Sweden** – 2000/ 2001-; **UK** -2000/ 2001-.
"Primary activities"= "Physical care, Supervision of child" and "Teaching, reading, talking with child"

following the introduction of universal child care in Quebec at the end of the Nineties made children worse off in a variety of behavioral and health-related dimensions. Other papers use US data from the National Longitudinal Survey of Youth (NLSY): Baum (2003) shows that maternal work in the first year of a child's life has detrimental effects on his cognitive skills. Bernal (2008) and Bernal and Keane (2007, 2008) also find that, on average, the substitution of maternal time with other child care sources produces negative and rather sizable effects on children skills. However, the last two papers show that this result masks some differences across types of child care and maternal education. Only informal care leads to significant reductions in child achievement; formal care (i.e. center-based care and preschool) does not have an adverse effect on cognitive outcomes. All in all, the indication coming from this literature is that not only genetics but also parental choices in terms of time allocation and purchase of services affect the children's process of skill formation.

Finally, we remark that what happens early in life affects the entire individual's skill formation process. The latter is described by recent literature (see Cuhna et al. 2005 for a review) as a dynamic process, characterized by strong complementarities between its different phases. Since there are critical and sensitive periods for the development of both cognitive and non-cognitive abilities, later remediation for early deficits in the formation of some important abilities is difficult and costly. Some evidence suggests for example that the IQ can be affected by the environment in which the children live until the age of 10, but not later. Early investments not only have a direct impact on the level of human capital of an individual. As there is complementarity between investments at different stages, they make further investments more productive (skill begets skill). Carneiro and Heckman (2002, 2003), for instance, suggest that the most important factor explaining the positive relation between income and college enrollment in the US is not related to short term liquidity constraints that poor individuals may face, but to the fact that they lived in early environments which were unable to form the cognitive and non-cognitive abilities required for success in school. This complementarity between formal schooling and skills acquired during childhood is also documented in Leibowitz (2003) and it is another key ingredient in our modeling strategy.

3 The model

We develop an OLG model with intragenerational homogeneity and endogenous growth driven by human capital accumulation. The model is set up in discrete time, from 0 to infinity. Agents have perfect foresight on future variables. They live for three periods and they have one child in the second period of life; the population growth rate is zero and fertility is exogenous; the size of each generation is normalized to 1.

Our formalization of the allocation of time and resources - whose details are presented in Section 3.1 - is quite standard and it has been for example used by Rogerson (2007) and Ragan (2006) to discuss the effect of taxation on the allocation of time between labor, leisure and home production; the home produced good is interpreted as child care provided by parents through their own time and through the purchase of goods and services (e.g books or toys, day care centers' services, pre-school programs, baby-sitting).

The distinctive feature of our model relies in the technology of human capital accumulation, which is described in Section 3.2: following the evidence reported in the previous Section, we explore the possibility that human capital not only depends on schooling but also on child care. In other terms, we study the consequences (as far as the growth impact of labor income taxation is concerned) of treating the home produced good not simply as a consumption good but also as a good which fosters human capital accumulation.

First order conditions for the optimization problems of the consumers and firms are presented in Section 3.3. Section 3.4 defines the intertemporal equilibrium and the balanced growth path.

3.1 Basic set-up

The time structure of individual choices is the following. In the first period of life, the child/the young receives child care and invests in formal schooling, borrowing on the capital market. In the second period of life the middle-aged/the parent pays back her loan and decides: how much to consume and save; how much time to devote to labor, leisure and child care; how much to spend on child care. In the third period of life, the old agent retires and consumes all her income.

In each period one physical good is produced using capital and labor measured in efficiency units. This good can be used for consumption, for investment in physical capital, for schooling expenditure and for child care expenditure.

Preferences

Preferences of an agent born at t are described by the following utility function:

$$U_t = i_1 \log c^m_{t+1} + i_2 \frac{(z_{t+1})^\kappa}{\kappa} + i_3 \log x_{t+1} + \theta \log c^o_{t+2} \tag{1}$$

where c^m_{t+1} and c^o_{t+2} denote respectively consumption when middle-aged and old as no consumption takes place, by assumption, during childhood; z_{t+1} stands for leisure time; x_{t+1} indicates the home produced good; i_j with $j = 1, 2, 3$ and $\sum_j i_j = 1$ are positive parameters determining the weight of consumption, leisure and home production in the utility function; $0 < \theta < 1$ is the subjective discount factor; κ is a parameter ≤ 1.

As we said, we interpret the home produced good x_{t+1} as child care.

Child care

Child care x_{t+1} is developed according to the following production function:

$$x_{t+1} = [\sigma(\varphi_{t+1})^\nu + (1-\sigma)(n_{t+1}h_{t+1})^\nu]^{\frac{1}{\nu}} \tag{2}$$

where φ_{t+1} indicates child care expenditure; n_{t+1} is the time parents devote to child rearing; h_{t+1} is parents' human capital; $0 < \sigma < 1$ is a parameter determining the relative importance of child care expenditure and family time in the production of child care; $\nu \leq 1$ is a parameter governing the elasticity of substitution between φ_{t+1} and $n_{t+1}h_{t+1}$, $\zeta_\nu = \frac{1}{1-\nu}$.

As equation (2) suggests, child care outcomes depend on the productivity of the time devoted to it, that is, they depend on the human capital of the providers: parents with a high level of human capital h_{t+1} can provide a given level of child care x_{t+1} devoting to it a lower amount of time n_{t+1} than low educated parents.

Government's budget constraint

The government budget constraint at $t+1$ is the following:

$$\tau_{t+1} w_{t+1} h_{t+1} l_{t+1} = T_{t+1} \tag{3}$$

where τ_{t+1} is the tax rate on labor income; w_{t+1} is the wage; l_{t+1} is the labor supply of the middle-aged; T_{t+1} is the lump-sum transfer paid back to them. We consider τ_{t+1} as the exogenous policy variable, while T_{t+1} is endogenously determined to guarantee the equilibrium in the budget constraint.

The assumption that tax proceeds are returned to the same individual as lump-sum transfers excludes intergenerational redistribution, it allows to isolate the effects of taxation from those of government expenditure and it is often present in the literature (e.g. King and Rebelo 1990, Stokey and Rebelo 1995, Ihori 2001).

Individual budget constraints

A child born at time t decides the amount of resources e_t to devote to her own formal schooling. We assume that she borrows at the interest rate r_{t+1} on the capital market and she pays back her loan in the second period.

The time and budget constraints are:

$$l_{t+1} + z_{t+1} + n_{t+1} = 1 \tag{4}$$

$$c^m_{t+1} = w_{t+1}h_{t+1}l_{t+1}(1-\tau_{t+1}) - s_{t+1} + T_{t+1} - \varphi_{t+1} - (1+r_{t+1})e_t \tag{5}$$

$$c^o_{t+2} = (1+r_{t+2})s_{t+1} \tag{6}$$

where s_{t+1} are savings and where all the other variables have the same meaning as elucidated before.

Production function

Output y_{t+1} is produced according to the following technology:

$$y_{t+1} = K^{\delta}_{t+1}L^{1-\delta}_{t+1} \tag{7}$$

where K_{t+1} is the capital stock, $L_{t+1} = l_{t+1}h_{t+1}$ is the labor supply in efficiency units, and $0 < \delta < 1$ is the share of capital income in output.

3.2 Human capital production function

We consider two alternative human capital production functions. In the first one, human capital h_{t+1} depends both on formal schooling e_t and on child care x_t:

$$h_{t+1} = q\left[\lambda(e_t)^{\rho} + (1-\lambda)(x_t)^{\rho}\right]^{\frac{1}{\rho}} \tag{8}$$

where $q > 0$; $0 < \lambda < 1$ is a parameter determining the relative importance of formal schooling and child care in the production of human capital; $\rho \leq 1$ is a parameter governing the elasticity of substitution between formal schooling and child care $\zeta_{\rho} = \frac{1}{1-\rho}$. The above production function captures the idea that, depending on the degree of complementarity/substitutability between e_t and x_t, early investments via child care can have permanent effects on educational outcomes and that early additions to a child's human capital may enhance the return of schooling investments.

In the second one, human capital depends, as it is usual, on schooling and on the human capital of the previous generation:

$$h_{t+1} = q\left[\lambda(e_t)^\rho + (1-\lambda)(h_t)^\rho\right]^{\frac{1}{\rho}}. \tag{9}$$

The comparison between these two technologies allows us to assess the relevance of considering child care in the process of skills' formation, as far as the effects of taxation on growth are concerned.

Notice that early environments feature in both formalizations of the human capital production function: indeed, one may interpret the human capital of the previous generation in (9) as a measure of early environments. These, however, are not the result of choices over child care, as it happens in (8).

3.3 First order conditions

Consumer's optimization problem

We solve the consumer optimization problem in two steps.

In the first step the representative individual born at t chooses time n_{t+1} and expenditure φ_{t+1} in order to minimize the cost of producing a given amount of child care x_{t+1}. Such a cost is equal to:

$$\varphi_{t+1} + (1-\tau_{t+1})w_{t+1}h_{t+1}n_{t+1} \tag{10}$$

that is, expenditure on child care plus forgone earnings due to the time spent in child care. Thus the agent minimizes equation (10) subject to the technology of child care production (2). This is a standard minimization problem which gives as a solution the following expenditure function

$$C_{t+1}(x_{t+1}, \nu, \sigma, \tau_{t+1}) = \Gamma(\nu, \sigma, \tau_{t+1})x_{t+1} \tag{11}$$

and the conditional demand functions

$$n_{t+1}(x_{t+1}, \nu, \sigma, \tau_{t+1}) = \frac{(1-\sigma)}{(1-\tau_{t+1})w_{t+1}}^{\frac{1}{1-\nu}}\Gamma(\nu, \sigma, \tau_{t+1})\frac{x_{t+1}}{h_{t+1}} \tag{12}$$

$$\varphi_{t+1}(x_{t+1}, \nu, \sigma, \tau_{t+1}) = \sigma^{\frac{1}{1-\nu}}\Gamma(\nu, \sigma, \tau_{t+1})x_{t+1} \tag{13}$$

where

$$\Gamma(\nu, \sigma, \tau_{t+1}) = \left\{\sigma^{-\frac{1}{(\nu-1)}} + (1-\sigma)^{-\frac{1}{(\nu-1)}} [(1-\tau_{t+1})w_{t+1}]^{\frac{\nu}{(\nu-1)}}\right\}^{\frac{\nu-1}{\nu}} \tag{14}$$

is the resource cost of producing one unit of child care. Since we are going to discuss the effects of taxation, it is useful for later reference to know that:

(15)

$$\frac{\partial\Gamma(\nu, \sigma, \tau_{t+1})}{\partial\tau_{t+1}} = -\left\{\sigma^{-\frac{1}{(\nu-1)}} + (1-\sigma)^{-\frac{1}{(\nu-1)}} [(1-\tau_{t+1})w_{t+1}]^{\frac{\nu}{(\nu-1)}}\right\}^{-\frac{1}{\nu}} (1-\sigma)^{-\frac{1}{\nu-1}} w^{\frac{\nu}{\nu-1}} (1-\tau_{t+1})^{\frac{1}{\nu-1}} < 0$$

that is, $\Gamma(\nu, \sigma, \tau_{t+1})$ is decreasing in τ_{t+1}. Indeed, foregone earnings due to time devoted to child rearing are higher when the tax rate is lower.

In the second step of the optimization problem, the agent chooses e_t, x_{t+1}, l_{t+1}, s_{t+1}, taking into account the results of the minimization problem solved above. Using the time constraint (4), the budget constraint of the adult (5) can be rewritten as:

$$c^m_{t+1} = (1-\tau_{t+1})w_{t+1}h_{t+1}(1-z_{t+1}-n_{t+1}) - \varphi_{t+1} - s_{t+1} + T_{t+1} - (1+r_{t+1})e_t \tag{16}$$

Using the expenditure function (11), equation (16) becomes:

$$c^m_{t+1} = (1-\tau_{t+1})w_{t+1}h_{t+1}(1-z_{t+1}) - \Gamma(\nu, \sigma, \tau_{t+1})x_{t+1} - s_{t+1} + T_{t+1} - (1+r_{t+1})e_t \tag{17}$$

Thus the agent maximizes the utility function (1) subject to the new budget constraint (17), the budget constraint (6), the time constraint (4) and the technology of skill formation (8) or (9).

Independently of the technology of skills' formation, the first order conditions for the choice of x_{t+1}, l_{t+1}, s_{t+1} are:

$$s_{t+1} : i_1 \frac{1}{c^m_{t+1}} = (1+r_{t+2})\theta \frac{1}{c^o_{t+2}} \tag{18}$$

$$l_{t+1} : i_2 (z_{t+1})^{\kappa-1} = i_1 \frac{1}{c^m_{t+1}} (1-\tau_{t+1})w_{t+1}h_{t+1} \tag{19}$$

$$x_{t+1} : i_1 \frac{1}{c^m_{t+1}} \Gamma(\nu, \sigma, \tau_{t+1}) = i_3 \frac{1}{x_{t+1}}. \tag{20}$$

The first order conditions for saving and labor, respectively given by equations (18) and (19), are the usual ones. Equation (20) concerns the choice of the home produced good, i.e. child care. The right hand side is the marginal benefit of the home produced good x_{t+1}. The left hand side is its marginal cost: it is given by the amount of consumption an agents should give up in order to produce one unit of child care, i.e. $\Gamma(\nu, \sigma, \tau_{t+1})$, times the marginal utility of consumption, i.e. $i_1 \frac{1}{c^m_{t+1}}$.

When the human capital production function is given by equation (8), the choice of the investment in education e_t is characterized by:

$$e_t : (1 + r_{t+1}) = \lambda q(1 - \tau_{t+1}) w_{t+1} l_{t+1} \frac{[\lambda (e_t)^\rho + (1-\lambda)(x_t)^\rho]^{\frac{1-\rho}{\rho}}}{(e_t)^{1-\rho}}. \quad (21)$$

If skills are accumulated according to equation (9), the first order condition for the choice of e_t is given by:

$$e_t : (1 + r_{t+1}) = \lambda q(1 - \tau_{t+1}) w_{t+1} l_{t+1} \frac{[\lambda (e_t)^\rho + (1-\lambda)(h_t)^\rho]^{\frac{1-\rho}{\rho}}}{(e_t)^{1-\rho}}. \quad (22)$$

The left hand side of equations (21) and (22) is the cost of an additional unit of e_t and it depends on the interest rate, since young agents borrow resources on the capital market to finance their investment in schooling. The right hand side is the marginal benefit of schooling which is the change in net labor income due to the increased human capital level.[7] Notice that, differently from equation (22), in equation (21) child care choices affect the return from schooling: a higher value of child care increases, *ceteris paribus*, the return from investing in schooling. We take up this remark later when we discuss the effects of taxation on growth (see Section 4.2).

Firm's optimization problem

Full depreciation of capital is assumed. Profit maximizing behavior of the competitive firms implies that the interest rate is:

$$1 + r_{t+1} = \delta \left(\frac{K_{t+1}}{L_{t+1}} \right)^{\delta - 1} \quad (23)$$

and that the wage in efficiency units is:

$$w_{t+1} = (1-\delta) \left(\frac{K_{t+1}}{L_{t+1}} \right)^{\delta} \quad (24)$$

which are the standard conditions.

[7] In deriving equations (21) and (22) we assume that agents invest in education to enhance their own productivity on the labor market. The fact that human capital of a generation is also relevant for the human capital of the next one is treated, as it is often done, as an externality.

3.4 Intertemporal equilibrium and balanced growth path

We here define the intertemporal equilibrium. We focus on the case of a small open economy, in which the interest rate is exogenously fixed at the world level and it is assumed to be constant over time; as a consequence, the wage rate, according to the firm's first order conditions (23) and (24), is also constant.

Taking as given the initial level of savings s_{-1} and of human capital h_0, the sequence of the exogenous policy parameter $\{\tau_t\}_0^\infty$, the interest rate r and the wage w, an intertemporal equilibrium is defined by a sequence $\{e_t,c_t^m,s_t,c_t^o,l_t,\varphi_t,z_t,n_t,h_t,K_t,T_t\}_0^\infty$ that satisfies: the government budget constraint (3); the technology for the final output (7); the production function for human capital (8) or (9); the agent's maximization problem, characterized by equations (4), (6), (12) - (14), (17) - (20) and (21) or (22) and the clearing condition for the labor market.

Dividing the equations defining the intertemporal equilibrium by the level of human capital, it is possible to obtain their stationarized version. A balanced growth path (BGP) is, by definition, the steady state of such stationarized system and its existence requires the assumption that $\tau_t = \tau$ for all t. In other terms, a BGP is as an intertemporal equilibrium such that $\{l_t,z_t,n_t\}$ are constant and $\{e_t,c_t^m,s_t,c_t^o,\varphi_t,h_t,K_t,T_t\}$ grow at a constant common rate $g_{t+1} = g = \frac{h_{t+1}}{h_t}$.

If the human capital equation is (8), g can be written as:

$$g = q\left[\lambda(\widetilde{e})^\rho + (1-\lambda)(\widetilde{x})^\rho\right]^{\frac{1}{\rho}} \tag{25}$$

where $\widetilde{e} = \frac{e_t}{h_t}$ and $\widetilde{x} = \frac{x_t}{h_t}$.

If the human capital equation is (9), g is equal to:

$$g = q\left[\lambda(\widetilde{e})^\rho + (1-\lambda)\right]^{\frac{1}{\rho}} \tag{26}$$

In our analysis, we focus on the effects of a change in taxation on the balanced growth path.[8]

According to equation (25), the growth rate is a function of $\widetilde{e}$ and of $\widetilde{x}$. Intuitively, taxation affects, on the one hand, the returns to education because it alters both the net wage and the working time: this is the standard effect studied in the literature, which is also captured by equation (26). On the other hand, it changes the time parents devote to child care and it modifies the amount of child care expenditure: if the role played by child care in the process

[8] Though the focus is not directly on individual utility and social welfare, we stress that in the long run the higher the growth rate, the higher the individual utility.

of skills' formation is recognized, as it is in (25), these changes in early environments have an impact on human capital accumulation.

To explore these effects and investigate how they combine and affect the growth rate, in the following Section we perform a numerical analysis of the model.

4 Numerical analysis

In this Section we perform a quantitative comparison, as far as the effects of taxation are concerned, of the two model economies described in Section 3, which only differ in the technology of skills' formation. In the first economy (henceforth: Model 1) human capital is produced according to the technology (8) and the growth rate can be written as in equation (25). The second model (henceforth: Model 2) is characterized by the human capital production function (9) and thus the growth rate is given by equation (26).

The purpose of such a comparison is to understand if and how the recognition of the role played by child care in the process of skills formation affects the growth impact of taxation.

4.1 Parameterization and Calibration

We assume that each period has a length of 25 years. The world annual interest rate is set to 4.8%. The intertemporal discount factor θ is set to 0.37 (the quarterly discount factor is 0.99). We choose δ, which is the share of capital income in national product, equal to 0.29 (see Bouzahzah, de la Croix, and Docquier 2002).

The parameter q of the human capital production function is chosen in order to obtain an annual growth rate equal to 1.8%.

We choose i_j with $j = 1, 2, 3$ in order to generate a realistic allocation of time between labor, child care and leisure. For this purpose we consider average data coming from the Harmonized European Time Use Survey (HETUS).[9] Assuming, as it is usually done (e.g. Ragan 2006, Cardia and Ng 2003, Juster 1985), that non-personal time available for discretionary use amounts to 100 hours per week, we have: $l = 32\%$, $n = 6\%$ and $z = 62\%$. Two remarks are important in interpreting these data. First, child care is simply defined as the sum of the minutes registered as devoted to primary and secondary child care: this amount of time,

[9] The countries we consider are, again: Belgium, Finland, France, Germany, Italy, Norway, Spain, Sweden and UK. Data refer to people in the age group 25-50, which corresponds in our three period OLG model to the second period of life.

as stressed in Section 2, is lower than the total time spent with children. Second, leisure is here defined as a residual category, that is, it is the time not spent either working or doing primary and secondary child care: as a consequence, it is not a measure of pure leisure as it also includes housework.

As far as the choice of λ, σ and τ is concerned, we use average data computed for the same set of countries considered for determining the allocation of time. In particular, the parameter λ is set in order to match a ratio between expenditure on formal schooling and GDP equal to 5.1%, which is the average of the total (public plus private) expenditure on education.[10] The parameter σ is chosen to match a value for the ratio of total (public plus private) child care and early education expenditure over GDP equal to 0.9%.[11] Though we do not have either public education or public child care in the model, we consider the total expenditure on education and child care and not just the private one since our government budget constraint (3) is consistent with perfect substitution between public and private expenditure. The policy parameter τ is set to 53%, which is the average of the marginal tax rates on labor income computed by Dhont and Heylen (2008) using OECD data.

The parameter κ in the utility function (1) is chosen in order to obtain a realistic wage elasticity of the uncompensated labor supply, which we denote by ϵ.[12] Microeconometric estimates suggest low values for this elasticity (see for instance Evers, De Mooij, and Van Vuren 2008 and Meghir and Phillips 2008). However, it has been stressed that macro and micro elasticities need not to be the same: the former can be higher than the latter (Rogerson and Wallenius 2007). There is no consensus on the precise value of ϵ to be used in a macro model; Rogerson (2007) argues that reasonable values for ϵ should lie in the interval $[0.4, 0.7]$.[13]

[10] We exclude pre-primary education which, as we will see, is included in our measure of child care expenditure. We consider an average for the period $1999 - 2004$.

[11] The OECD Family Database reports (for the year 2003) data on public expenditure both on child care (children in the 0-3 age group) and on early education (pre-primary school, i.e. children in the 3-6 age group). Direct information concerning private expenditure can solely be found for early education (we use the data in OECD 2006a). In order to obtain the amount of private child care expenditure we assume that the relative weight of public and private expenditure in early education applies also to child care.

[12] The wage elasticity of the uncompensated labor supply ϵ is defined as the percentage change in hours worked as a result of a one percent change in the *net wage rate* $(1-\tau)w$. It can be computed as $\epsilon = \frac{1-\tau}{\tau}\eta$ where η is the elasticity of the uncompensated labor supply with respect to the *tax rate* τ, that is $\eta = \frac{\frac{\Delta l}{l}}{\frac{\Delta\tau}{\tau}}$. The values of η can be derived using line 4 of Table 2 (which reports the values for $\frac{\Delta l}{l} + 1$) and recalling that in our numerical example $\frac{\Delta\tau}{\tau} = 10\%$.

[13] These are the values implied by his choices on the parameter that characterizes the utility of leisure.

Given that our focus is only on prime age workers (the 25-50 age group) and not on the whole population, the appropriate macro elasticity to be used in our model is likely to be lower than 0.7: indeed, the old are usually thought to have a higher elasticity than prime age workers. We allow for different values of κ to explore the effect of different implied values of ϵ still belonging to the above mentioned range.

Finally, we need to set ν and ρ, which - we recall - respectively determine the elasticity of substitution between child care expenditure and parental time $\zeta_\nu = \frac{1}{1-\nu}$ and the elasticity of substitution between formal schooling and child care $\zeta_\rho = \frac{1}{1-\rho}$.

As far as ν is concerned, some estimates - though on home production rather than on child care - are available. Estimates coming both from aggregate data (McGrattan, Rogerson, and Wright 1997 and Chang and Schorfheide 2003) and from micro data (Rupert, Rogerson, and Wright 1995 and Aguiar and Hurst 2005) suggest a value in the range $[0.4, 0.6]$, which corresponds to an elasticity of substitution between 1.7 and 2.5. However, these estimates refer to a large set of home produced goods; when the focus is on child care, the estimates could be different. We choose $\nu = 0.6$.[14]

There are reasons to think that the degree of substitutability between child care and formal schooling is quite low (see the references in Section 2). In standard macroeconomic models, which describe human capital accumulation using equation (9), the choice is usually $\rho = 0$, i.e. a Cobb-Douglas specification. We adopt this parameterization too. [15]

The assumptions underlying the numerical simulation are summarized in Table 1. We stress that the target values for all the calibrated parameters are the same in Model 1 and 2: in other terms, we want to compare economies which differ in the technology of skills' formation but are observationally equivalent.

[14] We performed a sensitivity analysis which shows that our results are not affected by lower or higher values of the degree of substitutability between parental time and child care services, as long as κ is re-calibrated to get a given value of the wage elasticity of uncompensated labor supply. More precisely, we performed the computations for $\nu = 0$, $\nu = 0.4$ and $\nu = 0.8$. Details are available upon requests.

[15] Choosing lower values of ρ, that is a higher complementarity between child care and formal schooling, would strengthen our results: the indirect impact of child care on human capital accumulation would indeed be higher in this case (this remark will be clearer after the discussion of our findings in Section 4.2).

Table 1: Parameterization and Calibration

Tax rate	τ	53.3%
Share of capital income	δ	29%
Discount factor	θ	0.37
Weights in the utility function	i_j	chosen to match the allocation of time between labor (32%), time devoted to children (6%) and leisure (62%).
Weight of formal schooling	λ	chosen to match a ratio between total expenditure on formal schooling and GDP equal to 5.1%
Weight of childcare expenditure	σ	chosen to match a value for the ratio of child care and early education expenditures over GDP equal to 0.9%
Parameter of the utility of leisure	κ	chosen to get a wage elasticity of uncompensated labor supply (ϵ) between 0.4 and 0.7
Elasticity of substitution between child care expenditures and parental time	$\zeta_\nu = \frac{1}{1-\nu}$	$= 2.5$ ($\nu = 0.6$)
Elasticity of substitution between formal schooling and early environments	$\zeta_\rho = \frac{1}{1-\rho}$	$= 1$ ($\rho = 0$ i.e. Cobb-Douglas case)

4.2 Simulation's results

We compute the effects of a 10% reduction in labor income taxation, i.e. a reduction of τ from 53% to 47.7%, both in Model 1 and in Model 2. The results are presented in Table 2, in which values relative to $\tau = 53\%$ are reported.[16] The $\sim$ denotes a stationarized variable.

In the description of the results of Table 2, we begin by focusing on the qualitative patterns, which are all independent of the value of ϵ.

Comparing Model 1 and Model 2, the effects of taxation are the same for all the variables but for g and $\widetilde{e}$, whose reactions to τ depend on the presence of child care in the process of skills' formation. For this reason we first discuss the change in $\widetilde{x}$. Then we turn to the explanation of the different results for g and $\widetilde{e}$ that are obtained in Model 1 and in Model 2, i.e. when $\widetilde{x}$ is respectively included in and omitted from the human capital production function.

As one can see from Table 2, $\widetilde{x}$ decreases. The mechanisms determining the changes of $\widetilde{x}$ can be intuitively grasped as follows. Dividing both sides of equation (20) by the level of human capital, it is possible to characterize the choice of $\widetilde{x}$ through the following stationarized

[16] In other terms, Table 2 reports the ratio between the value of a variable when $\tau = 47.7\%$ and when $\tau = 53\%$.

Table 2: Effects of a 10% reduction in the tax rate on labor income

	$\kappa=-0.5$ ($\epsilon=0.7$)		$\kappa=-1$ ($\epsilon=0.6$)		$\kappa=-2$ ($\epsilon=0.5$)		$\kappa=-4$ ($\epsilon=0.4$)	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
g	1.11	1.20	1.09	1.19	1.05	1.18	1.02	1.17
$\widetilde{e}$	1.26	1.31	1.24	1.30	1.21	1.28	1.18	1.26
$\widetilde{x}$	0.96		0.96		0.95		0.94	
l	1.08		1.07		1.06		1.05	
n	0.93		0.92		0.91		0.90	
z	0.97		0.97		0.98		0.98	
$\widetilde{\varphi}$	1.21		1.20		1.19		1.18	
$\widetilde{c}^m$	1.06		1.05		1.04		1.03	
$\Gamma(\nu,\sigma,\tau)$	1.10		1.10		1.10		1.10	

version of the first order condition for child care:

$$i_1 \frac{1}{\widetilde{c}^m}\Gamma(\nu,\sigma,\tau) = i_3 \frac{1}{\widetilde{x}} \tag{27}$$

where $\widetilde{c}^m = \frac{c_t^m}{h_t}$. As it can be seen from equation (15), a decrease in the tax rate rises $\Gamma(\nu,\sigma,\tau)$, that is the amount of consumption an agent should give up in order to produce one unit of child care: indeed, foregone earnings due to time devoted to child rearing are now higher. However the evaluation of $\Gamma(\nu,\sigma,\tau)$ in terms of utility decreases, since the marginal utility of consumption goes down as $\widetilde{c}^m$ rises in our computational experiment. In other terms, there are what we could call a substitution effect - passing through $\Gamma(\nu,\sigma,\tau)$ - and an income effect - passing through $\widetilde{c}^m$ - which go in opposite directions: the substitution effect dominates and $\widetilde{x}$ decreases.

The change in $\widetilde{x}$ is driven by adjustments in the inputs of child care, that is parental time and child care expenditure. In our simulation, parental care n always decreases and child care expenditure as a share of human capital $\widetilde{\varphi} = \frac{\varphi_t}{h_t}$ always rises, with the latter variation not compensating the former.

Once discussed the changes in $\widetilde{x}$, we can now focus on the different effect that taxation has on the growth rate and on the stationarized investment in formal schooling in Model 1 and 2.

In Model 2, the growth rate g only depends on $\widetilde{e}$, whose choice is characterized by the following stationarized version of equation (22)(with $\rho = 0$):

$$(1+r) = q(1-\tau)wl\lambda \left(\frac{1}{\widetilde{e}}\right)^{1-\lambda} \tag{28}$$

Once the tax rate is reduced, the net wage $(1-\tau)w$ and the labor supply l rise, increasing the benefit from investing in formal schooling: this tends to induce a higher level of $\widetilde{e}$.

In Model 1, formal schooling is not the only way to produce skills: child care plays a role in the process of human capital accumulation. The reduction in $\widetilde{x}$ discussed above affect both directly and indirectly the growth rate. The direct effect goes through the impact of the change in child care on human capital, for a given level of formal schooling: this can be immediately understood from equation (25). The indirect impact passes through the complementarity between formal schooling and child care, which implies that $\widetilde{e}$ is affected by a variation of $\widetilde{x}$, as it can be realized from the following stationarized version of the first order condition (21) (with $\rho = 0$):

$$(1+r) = q(1-\tau)wl\lambda \left(\frac{\widetilde{x}}{\widetilde{e}}\right)^{1-\lambda} \tag{29}$$

This indirect channel can be singled out looking at the different impact that taxation has on $\widetilde{e}$ in Model 1 and 2 (see Table 2): the change of $\widetilde{e}$ is lower in the former model, since $\widetilde{x}$ decreases. These effects (both the direct and the indirect one) explain why, in Table 2, the growth rate rises less in Model 1 than in Model 2.

To correctly interpret the results, it is important to remind that $\widetilde{x}$ is defined as $\frac{x_t}{h_t}$, i.e. the ratio between the skills received during childhood x_t and the human capital of the previous generation h_t. In other terms, $\widetilde{x}$ can be viewed in Model 1 as the rate of intergenerational transmission of skills in early environments. As a consequence, a reduction in $\widetilde{x}$ caused by a tax cut should be read as a decrease in the *rate of transmission* of skills during childhood and not necessarily as a reduction in their *absolute level* x_t, as long as h_t rises. Actually, in our computational experiment, since the growth rate is higher when taxes are lower, we are sure that in the very long run the level of human capital will be high enough to guarantee that the skills received during childhood x_t always increase after a cut in τ, even when $\widetilde{x}$ goes down. Indeed, a highly educated generation transmitting to its children a low fraction of its own human capital can still provide its kids with a higher level of skills than a low educated generation transmitting a higher fraction of its given (lower) abilities.

We can thus summarize the main difference between the two models in the following way. In Model 2 the effect of early environments on the process of skills' formation is simply captured by the human capital of the previous generation which is automatically inherited by children. As a consequence, the rate of transmission of skills during childhood is constant and it does not depend on the tax rate. This is not true in the case of Model 1, in which human capital accumulation is affected by child care choices: in this situation the rate of transmission of skills $\widetilde{x}$ reacts to taxation and more precisely it turns out to be reduced by a cut in the tax rate. As a consequence, the growth impact of taxation is higher in Model 2 than in Model 1.

Now we focus on the quantitative findings. The ratio between the elasticity of the growth rate to labor income taxation[17] in Model 2 and in Model 1 is about: 1.8 if $\kappa = -0.5$ ($\epsilon = 0.7$); 2.1 if $\kappa = -1$ ($\epsilon = 0.6$); 3.6 if $\kappa = -2$ ($\epsilon = 0.5$) and 8.5 if $\kappa = -4$ ($\epsilon = 0.4$). Thus, the lower the wage elasticity of uncompensated labour supply, the higher the difference in the growth impact of taxation between the two models. The basic intuition for this result can be grasped looking at equation (27): as we have already explained, following a cut in the tax rate, the change of $\widetilde{x}$ depends on a substitution effect related to the increase in $\Gamma(\nu, \sigma, \tau)$ and on an income effect due to $\widetilde{c}^m$. The size of the change in $\Gamma(\nu, \sigma, \tau)$ is unaffected by κ, as we can see from equation (15). On the other hand, the size of the increase in $\widetilde{c}^m$ turns out to be lower when κ is reduced, - see Table 2 -, since the increase in the labor supply and thus in labor income is less strong.

We can conclude that, for all the values of the wage elasticity of the uncompensated labor supply we have considered, the omission of child care from the technology of skills' formation can significantly bias the results related to the effects of taxation on growth. The elasticity of the growth rate is always at least 1.8 times higher in the model where child care is omitted from the human capital production function.

5 Conclusions

The notion of household production has proved to be useful in many fields of economic research (see Gronau 1986, 1997). Macroeconomists, for instance, have shown that the inclusion of the home sector improves the performance of the real business cycle models (see e.g. Benhabib, Rogerson, and Wright 1991). The macroeconomic consequences of including some components

[17] The elasticity of the growth rate to labor income taxation is defined as the percentage change in the growth rate as a result of a one percent change in the tax rate on labor income. The values of this elasticity can be immediately derived from the numbers presented in line 1 in Table 2, following the same procedure described in footnote 12.

of household production, namely child care, in the process of skill formation are however rather unexplored. The effects of parental time and alternative child care arrangements on human capital accumulation are, on the contrary, the focus of recent empirical work, as we documented in Section 2. The policy debate is also devoting increasing attention to child care arrangements as a key factor in promoting children's skills and in allowing work-life balance (see OECD 2006b, 2007).

The paper shows that the role played by child care in the process of skills' formation is crucial in determining the long-run effects of taxation. The omission of child care from the technology of skills' formation determines a bias in the estimates of the impact of labor income taxation on growth, making them more negative.

The analysis we have performed can be developed in several directions. The introduction of endogenous fertility, agents' heterogeneity and an explicit gender dimension, seem the most natural avenues to pursue. Allowing for government intervention in regulating, financing and providing child care services would further enrich the set up developed here. These extensions are left for future research.

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