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Abstract

What are the effects of child care subsidies on education, fertility and the sectoral allocation of the labour force? In a general equilibrium setting the availability of affordable professional child care will have an impact on the relative supplies of educated and uneducated workers and the cross-sectional fertility pattern. In absence of taxes and subsidies the optimal choice of financial assets early in life (taking marriage market conditions into account) is such that individuals who decide to attend college save relatively little. As a consequence, a couple with an uneducated wife and an educated husband has the most children, while parents who are both educated have the least. Introducing an ad valorem subsidy on child care financed by a proportional tax on income leads to an increase in fertility for all households. As more uneducated workers are employed in the service sector the college wage premium goes down and college graduation rates drop. This latter consequence is even more pronounced if the tax system is progressive. If the aim of the subsidy is to stimulate fertility, then this can be more effectively done by providing a specific subsidy per child. However, this reduces the supply of labour, especially by uneducated married women.

Keywords: Child care subsidies, fertility, education
JEL: D13, D91, E20, H20, J13

1 Introduction

What are the effects of child care subsidies on education, fertility and the sectoral allocation of the labour force? Keeping everything else constant, subsidies on care lower the cost of bringing up a child and thereby increase the demand for children. If parents do not need to provide child care themselves then they have more time available for work and this would increase the return to education. However, the story does not end here. In order to finance the subsidization program the government might have to levy distorting taxes. In addition, demand for affordable professional child care will draw uneducated workers away from production and into the service sector. This

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will affect the wage premium earned by a college educated worker and thereby fertility decisions and education choices.

A proper investigation of the economic consequences of a child care subsidy program needs to take all these feedback effects into account and that is exactly the aim of this paper. Its focus is on the long-run equilibrium of a developed country in which the knowledge and availability of contraceptive methods make fertility a conscientious choice. I compare the demographic and economic steady states that result under various assumptions regarding taxation and the subsidization of child care.

The contribution of this paper is twofold. First, it adds to the literature on child care subsidies. Most papers in this field focus on the implications for (female) labour supply decisions while keeping the number of children and productivity type of the parents constant. For example, Domeij and Klein (2013) derive that in an economy with pre-existing distortionary taxes on labour it can be welfare improving to subsidize day care. In a numerical application with German data they show that under an optimal subsidy rate of 50% the labour supply of mothers with small children nearly doubles. A second example is the recent contribution by Guner et al. (2013). They develop a quantitative model with heterogeneous households and calibrate it to the US economy in order to study the welfare effects of an expansion of current subsidy arrangements. Their conclusion is that child care subsidies lead to a substantial reallocation of hours worked from males to females and generate aggregate welfare losses.

In contrast to the above mentioned studies, in this paper the choice of education and fertility are endogenous. I take into account that the first is usually an individual decision while the latter is made by a couple. In addition, I carefully model the labour required for child care services (or 'nanny time') in a general equilibrium setting with an endogenous wage premium for educated labour. I find that an ad valorem subsidy on child care financed by a proportional tax on income leads to an increase in fertility for all households. As more uneducated workers are employed in the service sector the college wage premium goes down and college graduation rates drop. This latter consequence is even more pronounced if the tax system is progressive. If the aim of the subsidy is to stimulate fertility, then this can be more effectively done by providing a specific subsidy per child. However, this reduces the supply of labour, especially by uneducated married women.

The second strand of research to which this paper is related is the economics of fertility, see Hotz et al. (1997) for a survey. The starting point of the pioneering work by Becker (1960) is the observation that empirical studies tend to find a negative relationship between the number of children and a measure of income (usually male wages), both in cross-section and over time. This might be a statistiscal fluke resulting from a missing variable that can explain both low income and high fertility, such as knowledge of contraceptive methods or a strong preference for children over consumption goods. Nevertheless, economic models of fertility have attempted to explain this 'stylized fact' (see Jones et al. (2010)). In a static setting these explanations rely on the existence of time costs of child care (which are higher for high-wage parents) or a trade-off between the quantity and 'quality' of the offspring (the latter of which is assumed to be relatively cheap for high-wage parents). I add to this discussion by looking at the role of intertemporal dynamics (such as marriage expectations and savings choices) and institutional features (such as taxes and subsidies) in explaining the cross-sectional fertility pattern.

In the context of my model I find that in the absence of taxes and subsidies the optimal choice of financial assets early in life (taking marriage market conditions into account) is such that individuals who decide to attend college save relatively little. As a consequence, a couple with an uneducated wife and an educated husband has the most children, while parents who are both educated have the least. Introducing an ad valorem subsidy on child care tends to favour the birth rates of high-wage individuals because they find it easier to afford professional child care. If there is a fixed subsidy per child instead then uneducated parents get the most children as for them the subsidy is largest relative to household wealth.

The remainder of this paper is organized as follows. Section 2 describes in detail the model, followed by a numerical assessment of different child care subsidy policies in Section 3. The last section concludes.

2 Model

I construct a general equilibrium model of a small open economy with overlapping generations of households, firms that produce tradable goods and child care services and a government sector. In order to answer the central question of this paper, three model elements are crucial. First, fertility is endogenous. Couples optimally decide about the number of children they want to have, taking into account that child care requires time from either parents or professional care takers. Second, individuals make choices about education based on marriage market expectations and the college wage premium. Third, the general equilibrium framework requires individual decisions to be consistent on the aggregate level. For example, any child care subsidies provided by the government will have to be financed by (potentially distorting) taxes, the demand for nannies will have to be met by domestic labour and changes in the supply of educated and uneducated workers will affect relative wages.

In this paper I restrict attention to the steady state of the model in which prices are constant while household decisions depend only on the life-cycle stage that an individual is in and not his or her date of birth.

The remainder of this section describes the behaviour of households, firms, the government and the rest of the world. This ultimately leads to a description of the macroeconomic equilibrium.

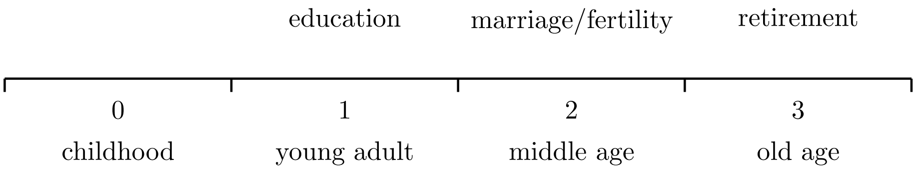
2.1 Households[1]

The population consists of equal numbers of males (indicated with superscript $j = m$) and females ($j = f$). Every individual lives for four periods or 'life-cycle stages', see Figure 1. The first of these (stage 0) is spent passively in the parental household. The remaining three constitute the life span of an adult individual. In stage 1 he or she decides whether to obtain a college degree

[1] Households are modelled in a very similar way to Reijnders (2014). The only differences are that there are no fixed costs, consumption is equal among household members and child care can be outsourced.

($E^j = 1$, 'educated') or not ($E^j = 0$, 'uneducated'). At the start of stage 2 chance determines which individuals get married and who remains single. Married couples then jointly decide about fertility and child care. In the final stage an exogenous fraction R of time is spent in retirement.

Figure 1: Life-cycle stages



In every period both singles and couples make consumption and savings decisions. I assume that there are no bequests from parents, so that each individual enters adulthood with zero financial assets and leaves nothing behind after death. Labour supply is exogenous, in that the share of the unit time endowment not spent in college, retirement, or child care is sold on the labour market. Preferences over consumption c and the number of children b can be represented by the following felicity function:

$$u(c,b) = \begin{cases} \dfrac{\left[c^{\phi}(1+b)^{1-\phi}\right]^{1-1/\sigma} - 1}{1-1/\sigma} & \text{if } \sigma > 0 \text{ and } \sigma \neq 1 \\ \phi \ln c + (1-\phi)\ln(1+b) & \text{if } \sigma = 1 \end{cases} \tag{1}$$

where $0 < \phi < 1$ represents the weight of consumption and σ is the intertemporal substitution elasticity of the consumption-fertility composite. In general, with $\sigma \neq 1$, preferences are non-separable in the sense that the marginal felicity of consumption depends on the number of children and vice versa.

2.1.1 Education decision

Upon entering adulthood at the start of life-cycle stage 1 each individual learns his or her utility cost of schooling θ^j which is drawn from a distribution F.[2] This heterogeneity in learning ability ensures that not everyone makes the same education decision. For example, an adult female with utility cost θ^f takes the matching probabilities in the marriage market and the characteristics of potential spouses as given and chooses education E^f, consumption c_1^f and savings a_1^f so as to maximize expected life-time uility. Her value function can be written as:

$$\begin{aligned} \mathcal{S}_1^f(\theta^f) = \max_{E^f, c_1^f, a_1^f} & \Bigg\{ u(c_1^f, 0) - \theta^f E^f + \frac{1}{1+\rho}\Bigg[(1-q)\mathcal{S}_2(E^f, a_1^f) \\ & + q\Big[\pi_f^m(0|E^f)\mathcal{M}_2(E^f, 0, a_1^f, a_1^m(0)) + \pi_f^m(1|E^f)\mathcal{M}_2(E^f, 1, a_1^f, a_1^m(1))\Big]\Bigg]\Bigg\} \\ \text{s.t.} \quad & a_1^f = (1-\tau)w(E^f)[1-\epsilon E^f] - \upsilon E^f - \bar{\tau} - c_1^f \end{aligned} \tag{2}$$

[2] This distribution is assumed to be the same for men and women. See Reijnders (2014) for an application with gender-specific cost distributions.

where $\rho > 0$ is the rate of time preference. The first two terms in curly brackets are the immediate felicity from consumption and the utility cost of education (which is only incurred if $E^f = 1$). The remaining terms capture the expected discounted utility from stage 2 onward. With probability $1-q$ this woman stays single and her remaining life-time utility is represented by the value function $\mathcal{S}_2(E^f, a_1^f)$, which is specified more fully below. If she marries then there is a probability $\pi_f^m(0|E^f)$ of being matched to an uneducated male and a probability $\pi_f^m(1|E^f)$ of finding an educated spouse. Importantly, these probabilities are conditional on her educational attainment. The associated value function when married $\mathcal{M}_2(E^f, E^m, a_1^f, a_1^m)$ depends on both her own education level and asset choice and that of her future husband.

Labour income consists of education-dependent wages $w(E^f)$ earned over the time not spent in school, with ϵ the time cost of a college degree. Savings are what remains of labour income after deducting proportional labour income taxes at rate τ, lump-sum taxes $\bar{\tau}$, the tuition fee υ and consumption expenditures. There is a limit on borrowing, in that it is only possible to raise funds against own future after-tax earnings and not the income of a hypothetical spouse:

$$a_1^f > -\frac{1}{1+r}\left\{(1-\tau)w(E^j)\left[1+\frac{1-R}{1+r}\right] - \frac{2+r}{1+r}\bar{\tau}\right\}, \tag{3}$$

where r is the interest rate. Since the cost of education is monotonically increasing in θ^f while the benefit is independent of it, the optimal choice of education is characterized by a threshold rule. That is, there is a critial level $\bar{\theta}^f$ such that:

$$E^f = \begin{cases} 1 & \text{if } \theta^f \le \bar{\theta}^f \\ 0 & \text{if } \theta^f > \bar{\theta}^f \end{cases} \tag{4}$$

It follows that the fraction of women with a college degree is $\pi^f(1) = F(\bar{\theta}^f)$. The problem of an adult male is analogous. At the end of stage 1 there will be four types of individuals in a cohort, distinguished by their sex $j \in \{f, m\}$ and education level $E^j \in \{0, 1\}$ and accompanied by a stock of financial assets $a_1^j(E^j)$ which depends on both. Given that expectations regarding marriage play an important role in both the education and the savings decisions of individuals, the next two sections describe in detail the behaviour of singles and married couples in life-cycle stages 2 and 3.

2.1.2 Singles

A person who does not get married at the start of stage 2 will remain single for the rest of his or her life. Under the assumption that only couples can have children $b = 0$. Remaining life-time utility is then given by:

$$\begin{aligned} \mathcal{S}_2(E^j, a_1^j) &= \max_{c_2^j, c_3^j} \left\{ u(c_2^j, 0) + \frac{u(c_3^j, 0)}{1+\rho} \right\} \\ \text{s.t.} \quad 0 &= (1+r)a_1^j + (1-\tau)w(E^j)\left[1+\frac{1-R}{1+r}\right] - \frac{2+r}{1+r}\bar{\tau} - c_2^j - \frac{c_3^j}{1+r} \end{aligned} \tag{5}$$

All financial assets and total wage income will be used to finance consumption expenditures and lump-sum taxes. The optimal solution is fully characterized by the budget constraint above and the individual's Euler equation:

$$\frac{c_3^j}{c_2^j} = \left(\frac{1+r}{1+\rho}\right)^{\sigma^*}, \tag{6}$$

where σ^* is the intertemporal substitution elasticity of consumption:

$$\sigma^* \equiv -\frac{u_c(c,b)}{u_{cc}(c,b)c} = \frac{\sigma}{1-(1-\phi)(1-\sigma)}. \tag{7}$$

It follows that σ^* is smaller than unity if and only if σ is. The magnitude of this parameter determines the degree of curvature in the felicity function, empirical estimates suggest that $0 < \sigma^* < 1$.

2.1.3 Couples

To derive the value function of a married individual I need to make some assumptions regarding intra-household allocations. I impose that consumption is equalized across household members. Put differently, individuals want (or are morally obliged) to provide their spouse and children with a standard of living similar to their own.[3] As children are a public good and consumption is equal it follows that felicity is the same for husband and wife. If a married couple decides to have b children then all of these are born at the start of stage 2 and they remain with their parents for exactly 1 period. The cost of having children is three-fold. First, they increase the consumption expenditures that the household has to incur. Second, child bearing decreases the time endowment of the mother by an amount $T_b b$. Finally, there is a fixed amount of child care $N_b b$ that has to be provided. Child care is created using time inputs of the mother n_2^f, the father n_2^m and professional care takers ('nannies') n_2^n:

$$\Omega(n_2^f, n_2^m, n_2^n) = \left[n_2^p\right]^{\psi}\left[n_2^p + n_2^n\right]^{1-\psi}, \quad 0 < \psi \leq 1, \tag{8}$$

where n_2^p is an aggregate measure of 'parent time':[4]

$$n_2^p = \left[\left[n_2^f\right]^{1-1/\xi} + \left[n_2^m\right]^{1-1/\xi}\right]^{\frac{1}{1-1/\xi}}, \quad \xi > 1. \tag{9}$$

From (9) it follows that parents are imperfect substitutes for each other as long as the substitution elasticity ξ is finite. Nanny time, on the other hand, can be perfectly replaced by parental time according to (8). The opposite is *not* true: as long as $\psi > 0$ the time input of parents is necessary in producing child care. Some basic care might be outsourced, but it cannot completely replace the attention of a parent.

[3] In a comment on Becker (1960), James S. Duesenberry argues that: "[...] there is no area in which the sociological limitations of freedom of choice apply more strongly than to behavior in regard to bringing up children [...] in many respects the standard of living of the children is mechanically linked to that of the parents". Similarly, according to Bernard Okun: "It is almost impossible to conceive of a child who is raised at a much lower level of living than that of his parents."

[4] For an overview of the properties of the two 'production functions' employed here, see Appendix A.

The value function of a married individual can now be written as:

$$\begin{aligned}
\mathcal{M}_2(E^f, E^m, a_1^f, a_1^m) = & \max_{c_2, c_3, b, n_2^f, n_2^m, n_2^n} \left\{ u(c_2, b) + \frac{u(c_3, b)}{1+\rho} \right\} \\
\text{s.t.} \quad 0 = & (1+r)\big[a_1^f + a_1^m\big] + (1-\tau)\big[w(E^f) + w(E^m)\big]\left[1 + \frac{1-R}{1+r}\right] - \frac{2+r}{1+r}2\bar{\tau} + \bar{s}b \\
& - [Q_a + Q_b b]c_2 - \frac{Q_a c_3}{1+r} - (1-\tau)\Big[w(E^f)\big[n_2^f + T_b b\big] + w(E^m)n_2^m\Big] - (1-s)pn_2^n \\
& \Omega(n_2^f, n_2^m, n_2^n) = N_b b, \quad b \geq 0, \quad 0 \leq n_2^f \leq 1 - T_b b, \quad 0 \leq n_2^m \leq 1, \quad n_2^n \geq 0 \qquad (10)
\end{aligned}$$

The first three terms in the budget constraint capture financial assets and after-tax wage income. Consumption expenditures are proportional to the number of adult equivalents in the household, where $1 < Q_a \leq 2$ is the equivalence scale for two adults and $0 < Q_b \leq 1$ that of a single child. With $Q_a < 2$ and $Q_b < 1$ there are economies of scale for a multi-person household (think of sharing a house, washing clothes, cooking dinner, etcetera). The costs of child care consist of foregone wages of the parents and the nanny bill, with p the relative price of child care services and s the ad valorem subsidy rate. There is a specific subsidy of $\bar{s}$ per child while it is living in the parental household.

For a given number of children the optimal allocation of child care over parents and nannies is the one which minimizes the total associated costs. Since the child care production function features constant returns to scale this is equal to the minimum cost per unit of child care times the total amount of child care required (which is $N_b b$). The unit cost function can be derived in two steps. First, let w^p denote the minimum before-tax cost of a unit of parent time. That is:

$$w^p \equiv \left\{ \min_{n_2^f, n_2^m} \Big[w(E^f)n_2^f + w(E^m)n_2^m\Big] \text{ s.t. } n_2^p = 1 \right\} = \Big[w(E^f)^{1-\xi} + w(E^m)^{1-\xi}\Big]^{\frac{1}{1-\xi}}. \qquad (11)$$

Because the Constant Elasticity of Substitution (CES) production function is self-dual, the price of parent time is a CES aggregate of parental wage levels with substitution elasticity $1/\xi$. For a given total production of parent time n_2^p the optimal input quantities of father and mother time are:

$$n_2^j = n_2^p \left[\frac{w(E^j)}{w^p}\right]^{-\xi}, \quad j \in \{f, m\}. \qquad (12)$$

As long as parents are imperfect substitutes both will contribute a positive amount of time, but the parent with the lower wage does most. In the next step I define ω to be the minimum cost of a unit of child care:

$$\omega \equiv \left\{ \min_{n_2^p, n_2^n} \Big[(1-\tau)w^p n_2^p + (1-s)pn_2^n\Big] \text{ s.t. } \Omega(n_2^f, n_2^m, n_2^n) = 1 \right\}. \qquad (13)$$

There is a trade-off between the (after-tax) value of parental time and the (after-subsidy) price of nanny time. Two cases can be distinguished, depending on whether there is an interior solution to the problem expressed in (13) or not. First, if nannies are relatively cheap in the sense that $(1-s)p \leq (1-\psi)(1-\tau)w^p$ then the care burden is shared between parents and nannies. The optimal allocation is given by:

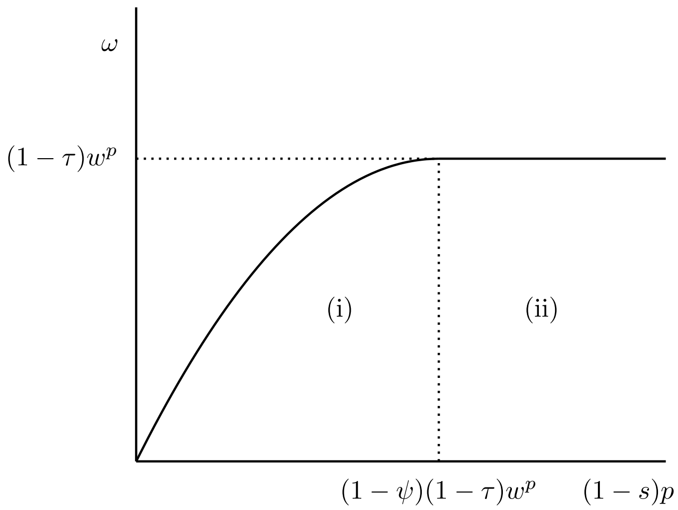
$$n_2^p = N_b b \frac{\psi\omega}{(1-\tau)w^p - (1-s)p}; \quad n_2^n = N_b b \frac{(1-\psi)\omega}{(1-s)p} - n_2^p > 0,$$

with to the following minimum cost function:

$$\omega = \frac{(1-s)p}{1-\psi} \left\{ \frac{1-\psi}{\psi} \left[\frac{(1-\tau)w^p}{(1-s)p} - 1 \right] \right\}^{\psi}.$$

Note that it is not sufficient that the net price of an hour of nanny time is lower than the after-tax parental cost index, it has to be even lower than that in order to compensate for the fact that nannies are less productive. If not, then all care is performed by the parents ($n_2^n = 0$ and $n_2^p = N_b b$) and the unit cost is $\omega = (1-\tau)w^p$. These two cases are illustrated in Figure 2. The solid line depicts the minimum cost of child care as a function of the price of nannies net of subsidies, keeping the tax rate fixed. It is increasing up to the point where it becomes optimal to leave all care to the parents, after that it stays flat. By Shephard's Lemma the demand for nannies equals the slope of the minimum cost function. It is positive in region (i) but zero in (ii). If the ad valorem subsidy on child care goes up then, ceteris paribus, the demand for nannies weakly increases. However, if this subsidy is paid for by higher taxes on wage income then the point of demarkation between region (i) and (ii) shifts to the left as the opportunity cost of parental time decreases as well.

Figure 2: The minimum unit cost of child care



To save on notation, let M_b denote the total (minimum) time cost of a child:

$$M_b = \omega N_b + (1-\tau)w(E^f)T_b. \tag{14}$$

It follows that M_b is a function of the wages (or education level) of the parents, the price of child care services, the marginal tax rate and the ad valorem child care subsidy. Assuming that b need not be an integer number[5] and that an interior solution exists, the remaining first-order conditions of the household problem can be written as:

$$\frac{Q_a c_3}{[Q_a + Q_b b] c_2} = \left(\frac{1+r}{1+\rho}\right)^{\sigma^*} \left(\frac{Q_a}{Q_a + Q_b b}\right)^{1-\sigma^*}, \tag{15}$$

$$\left[1 + \frac{1}{1+\rho}\left(\frac{c_3}{c_2}\right)^{-\frac{1-\sigma^*}{\sigma^*}}\right] \frac{1-\phi}{1+b} = \phi \frac{M_b - \bar{s} + Q_b c_2}{[Q_a + Q_b b] c_2}, \tag{16}$$

$$W_2 = Q_a c_2 + \frac{Q_a c_3}{1+r} + \Big[M_b - \bar{s} + Q_b c_2\Big] b, \tag{17}$$

where W_2 is household wealth net of taxes:

$$W_2 = (1+r)a_1 + (1-\tau)\big[w(E^f) + w(E^m)\big]\left[1 + \frac{1-R}{1+r}\right] - \frac{2+r}{1+r} 2\bar{\tau}. \tag{18}$$

Equation (15) is the couple's Euler equation for total consumption expenditures. The number of adult equivalents present in the household in a given life-cycle stage can be interpreted as the 'price' of individual consumption. If $\sigma^* < 1$ then parents are reluctant to shift consumption towards the period in which its cost is lower, that is when the children have left the parental household in stage 4. As a consequence the level of total consumption expenditures in each stage depends positively on the number of adult equivalents. The second equation is the optimality condition for the number of children. On the left-hand side is the marginal utility of an additional child, while the right-hand side captures the marginal cost in terms of foregone consumption. Equation (17) restates the household budget constraint with the minimum time cost of child care substituted in. There is no analytical solution to this system of equations, so they have to be solved numerically. Some comparative static effects on the demand for children are discussed in Section 3.

2.1.4 Marriage market equilibrium

Since individuals can only get married at the start of life-cycle stage 2, they necessarily have a spouse from the same cohort. For simplicity I assume that all matching probabilities are exogenously given, the probability of getting married q is independent of education level and there is no divorce.

Write $\pi(E^f, E^m)$ for the probability of observing a match in which the female has education E^f and the male education E^m. Despite the popular saying that 'opposites attract', most people tend to get married to someone with a similar level of education. This type of marital sorting is known as positive assortative matching or homogamy, and it might arise because of complementarities between spouses or simply because individuals who are alike are more prone to meet and fall in love. To allow for this kind of behaviour I define:

$$\pi(1,1) = \pi^f(1)\pi^m(1) + \lambda\Big[\min\big\{\pi^f(1), \pi^m(1)\big\} - \pi^f(1)\pi^m(1)\Big], \tag{19}$$

[5] Instead b can be interpreted as the average birth rate across households that are similar in terms of the education and wealth of the spouses.

where the parameter λ is an index of the degree of marital sorting. If $\lambda = 0$ then matching is random, while with $\lambda = 1$ it is perfectly positive assortative. This is a generalization of the specification used by Fernández and Rogerson (2001) to the case where the frequencies of college-educated men and women might differ. The expression for $\pi(0, 0)$ is similar and the cross probabilities follow. Bayes' Rule implies that the conditional probability that a woman with education E^f is matched to a man with education E^m is given by:

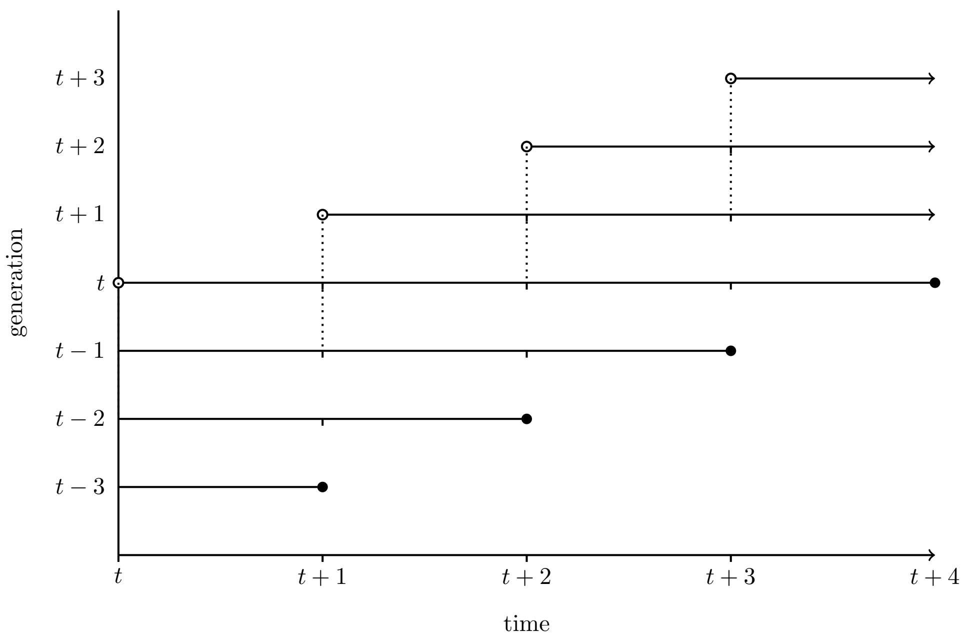
$$\pi_f^m(E^m|E^f) = \frac{\pi(E^f, E^m)}{\pi^f(E^f)}. \tag{20}$$

For a male the definitions are similar.

2.1.5 Demography

The population consists of overlapping generations of individuals. At the start of each period a new generation with equal numbers of males and females is born, see Figure 3. An open dot indicates the arrival of a generation, when the dot is closed all individuals belonging to this cohort pass away. The dotted line represents the parent-child relationship, linking a new generation to one that is currently in life-cycle stage 2. There are no intergenerational spillovers as parents do not leave bequests and the schooling abilities of parents and their children are assumed to be independent.[6]

Figure 3: Overlapping generations



Let G_t denote the size of the cohort born at the start of period t and P_t the size of the total

[6] In the absence of perfect capital markets intergenerational spillovers might be important. If it is not possible to borrow against future human capital then parental income becomes a vital source of education funding. See for example Fernández and Rogerson (2001) who study the effect of increased marital sorting on income inequality.

population. Then in the demographic steady state the relative size of each living generation is constant and depends only on the life-cycle stage:

$$g_s = \frac{G_{t-s}}{P_t}, \quad s \in \{0, 1, 2, 3, 4\}. \tag{21}$$

Because the number of children is a choice variable for married couples, the total fertility rate $\bar{b}$ is endogenous and so is the population growth rate η. The demographic equilibrium condition is given by:[7]

$$\eta = \sqrt{\bar{b}/2} - 1. \tag{22}$$

It follows that the population grows at a positive rate if and only if women get more than 2 children on average. As a proportion $1 - q$ of women remain single and therefore childless, this means that married women should have an average birth rate of at least $2/q$.

2.2 Firms

There are two types of commodities in the economy: a tradeable consumption good (which is the numeraire) and nontradable child care services. These are produced in separate sectors using two production factors. The first is physical capital which can be traded on international financial markets. I assume that there is perfect capital mobility and that the trading volumes of the home country are sufficiently small compared to those of the rest of the world so that the interest rate is exogenously given and constant.[8] The production factor labour is perfectly mobile between the two sectors in the economy but cannot move between countries.

2.2.1 Production sector: consumption good

In the production sector a homogeneous good is produced using capital and labour. The production function is given by:

$$Y_t = \Gamma \big[K_t\big]^{\gamma} \big[L_t^c\big]^{1-\gamma}, \quad \Gamma > 0, \quad 0 < \gamma < 1, \tag{23}$$

where L_t^c is a composite of labour services from educated and uneducated workers:[9]

$$L_t^c = L_t^c(1)^{\nu} \big[L_t^c(0) + L_t^c(1)\big]^{1-\nu}, \quad 0 < \nu < 1. \tag{24}$$

[7]By definition of the birth rate, $G_t = \bar{b}G_{t-2}/2$. By definition of the population growth rate, $G_t = (1+\eta)^2 G_{t-2}$. Combining yields $\bar{b}/2 = (1+\eta)^2$.

[8]Alternatively it can be assumed that the economy is closed such that the interest rate r is endogenous. This makes the model more complicated and does not yield much additional insight (given that relative wages of educated and uneducated workers are still determined domestically). See Appendix D.

[9]This definition of the labour composite is similar to the child care production function which combines time inputs of parents and nannies. See Appendix A for some of its properties.

It follows that educated labour $L_t^c(1)$ is a perfect substitute for uneducated labour $L_t^c(0)$ but not the other way around.[10] For example, both can use their 'brawn' on the workfloor but educated workers also add a 'brain' component in the form of management tasks and research and development. The latter is a necessary input for production. Let w^c denote the minimum cost of the labour composite. Assuming an interior solution:

$$w^c \equiv \left\{ \min_{L_t^c(0),L_t^c(1)} \Big[w(0)L_t^c(0) + w(1)L_t^c(1) \Big] \text{ s.t. } L_t^c = 1 \right\} = \frac{w(0)}{1-\nu} \left\{ \frac{1-\nu}{\nu} \left[\frac{w(1)}{w(0)} - 1 \right] \right\}^{\nu}. \quad (25)$$

A necessary condition for both types of labour to be employed in the production of consumption goods is that uneducated labour is relatively cheap, in that $w(0) \leq (1-\nu)w(1)$.

The stock of capital increases with firm investment I_t and depreciates at rate δ such that:

$$K_{t+1} = (1-\delta)K_t + I_t. \quad (26)$$

The representative profit-maximizing firm chooses capital and labour services in such a way that the following marginal productivity conditions are satisfied:

$$r + \delta = \gamma \Gamma \left(\frac{K_t}{L_t^c} \right)^{-(1-\gamma)}; \quad w^c = (1-\gamma)\Gamma \left(\frac{K_t}{L_t^c} \right)^{\gamma}. \quad (27)$$

Note that given an exogenous world interest rate the capital-labour ratio in the production sector is fixed. This implies that the minimum unit cost of labour is also equalized across borders. However, the equilibrium wages for uneducated and educated workers do depend on the domestic demand for and supply of the two types of labour:

$$w(0) = w^c(1-\nu)\mu^{\nu}; \quad w(1) = w^c \Big[(1-\nu)\mu^{\nu} + \nu\mu^{\nu-1} \Big], \quad (28)$$

where $\mu \equiv L_t^c(1)/[L_t^c(0) + L_t^c(1)]$ is the number of educated workers as a share of total employment in the production sector.

2.2.2 Service sector: nanny time

Professional child care services ('nanny time') are created using labour only:

$$Z_t = \Psi L_t^n, \quad \Psi \geq 1, \quad (29)$$

where L_t^n is a labour composite:

$$L_t^n = L_t^n(0) + L_t^n(1). \quad (30)$$

If $\Psi > 1$ then there are economies of scale for nannies compared to parents as each hour of labour results in more than one unit of 'nanny time'. This could be the case, for example, if nannies can

[10] Alternatively I could have used the more standard CES function to aggregate the two types of labour. However, this has the undesirable consequences that (i) uneducated labour is as good a substitute for educated labour as the other way around and (ii) the marginal product of uneducated labour becomes infinite as $L_t^c(0) \to 0$.

work more efficiently by combining care for children of the same age. In contrast to the production sector, educated and uneducated workers are assumed to be perfect substitutes in creating child care.[11] As a consequence only uneducated labour will be hired since it is less expensive. Perfect labour mobility between sectors implies that the wage rate is equal to that earned in the production sector so that the minimum cost is $w^n = w(0)$. The competitive price of nanny services relative to the consumption good is $p = w^n/\Psi$.

2.3 Government

The government levies taxes and distributes subsidies. There is no other form of government spending. In every period it has to maintain a balanced budget:

$$T_t \equiv \tau\big[w(0)L_t(0) + w(1)L_t(1)\big] + \bar{\tau}\big[P_t - G_0\big] = spN_t + \bar{s}G_0 \equiv S_t, \tag{31}$$

where N_t is total nanny time demanded by households. The left-hand side is the revenue from the proportional labour income tax plus the proceeds from lump-sum taxation of the adult population. The right-hand side consists of ad valorem subsidies paid out for every hour of nanny time and specific subsidies for each child.

2.4 Rest of the world

There is international trade in the consumption good with countries in the rest of the world. Net exports in period t are denoted by NX_t. A surplus on the current account of the balance of payments has to be matched by a capital account deficit, such that:

$$NFA_{t+1} = (1+r)NFA_t + NX_t, \tag{32}$$

where NFA_t is the stock of net foreign assets (domestic holdings of foreign assets minus domestic assets owned by foreigners).

2.5 Equilibrium

Given the demographic structure of the population and the marriage market probabilities I can aggregate all household choices to find total financial asset holdings A_t, labour supply by education type $L_t(0)$ and $L_t(1)$, consumption C_t and demand for nannies N_t. The optimal fertility rates of each couple determine the average birth rate $\bar{b}$. The model admits a balanced growth path along which all macro aggregates (such as K_t) grow at the same rate as the population while per capita measures (such as K_t/P_t) are constant.

[11]Think of this as basic care, not education.

Definition 1 (Steady state)**.** *A macroeconomic steady state or balanced growth path is a sequence of prices and allocations such that in every period:*

(i) Each single individual and every couple maximize utility subject to a budget constraint taking prices and the behaviour of everyone else as given.[12]

(ii) Firms maximize profits taking prices as given.

(iii) The government budget is balanced.

(iv) All markets clear.

- *Capital market:*

$$A_t = K_{t+1} + NFA_{t+1}$$

- *Labour market:*

$$L_t(1) = L_t^c(1) + L_t^n(1); \quad L_t(0) = L_t^c(0) + L_t^n(0)$$

- *Goods and services market:*

$$Y_t = C_t + I_t + NX_t; \quad Z_t = N_t$$

(v) All variables grow at a constant rate, possibly zero.

The circular flow diagram in Figure 4 provides a graphic visualization of the macroeconomic equilibrium. It shows how the four actors in the economy (households, firms, government and the rest of the world) interact on three markets (capital, labour and goods and services). The solid lines capture the flow of goods, the dashed lines represent money. The gross domestic product (GDP) of this economy is equal to the total value of goods and services in terms of the numeraire commodity, that is $GDP_t = Y_t + pZ_t$.

Under the assumption that uneducated labour is employed in both sectors the relative wage rate for educated versus uneducated workers (the 'college wage premium') is given by:

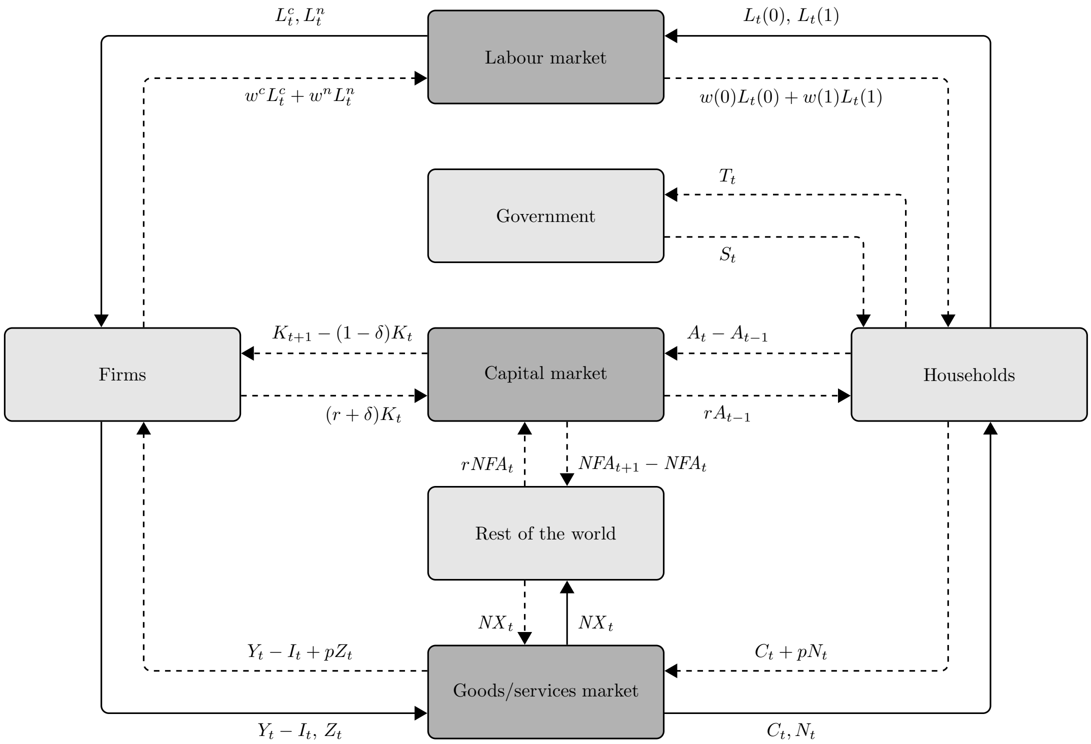
$$\frac{w(1)}{w(0)} = 1 + \frac{\nu}{(1-\nu)\mu} > 1. \tag{33}$$

It depends negatively on the share of educated workers in the production sector (recall that $\mu = L_t^c(1)/[L_t^c(0) + L_t^c(1)]$). Although labour supply decisions are exogenous at the individual level there are still two margins along which μ can change. First, the choice of education affects the time left for work in life-cycle stage 1 and the skill composition of the labour force. Second, the number of children and the allocation of child care determine the fraction of time that parents can supply in life-cycle stage 2 and the demand for uneducated workers from the service sector.

As the definition of the labour composite in (24) and the corresponding college wage premium

[12] See Reijnders (2014) for a more detailed description of the marriage market equilibrium.

Figure 4: Circular flow diagram



(33) are non-standard it is useful to contrast them to two more common cases. First, if the elasticity of substitution between educated and uneducated labour would be constant at $\alpha > 0$ then $w(1)/w(0) = [L_t^c(0)/L_t^c(1)]^{1/\alpha}$. This implies that the college wage premium could be less than unity when educated workers are relatively abundant (however, this would never be an equilibrium with an endogenous choice of education). In contrast, according to (33) the more productive workers always earn more. Second, if educated and uneducated labour are perfect substitutes with relative productivity $\beta > 1$ then $w(1)/w(0) = \beta$. In that case the college wage premium does not depend on the supply of labour.

3 Child care subsidies in general equilibrium

What happens to education and fertility if child care is subsidized? How does this alter the sectoral distribution of labour and the college wage premium? To answer these questions I compare the long-run equilibrium that arises when $s = \bar{s} = 0$ to a scenario in which either one is positive. The discussion proceeds as follows. First I explore the predictions of the model regarding the cross-sectional fertility pattern in Section 3.1. Then I parameterize the model and show the results of the numerical simulations.

3.1 The demand for children

Three assumptions in the model form the key for understanding the implied optimal fertility choices. First, parents derive utility from the quantity of children only. There is no quantity-quality trade-off à la Becker (1960). Second, the consumption costs of children are proportional to parental consumption. This prevents these costs from becoming negligible as the wages of parents increase and automatically ensures that parents with more income provide their offspring with a higher standard of living. Third, consumption and children enter into the utility function in a non-separable way (provided $\sigma \neq 1$).

Recall from Section 2.1 that the model does not yield a closed-form solution for the optimal fertility choice. Still it is possible to derive some comparative static effects.

Proposition 1. *Let b^* denote the optimal choice of the number of children. It is increasing in household wealth and the specific child subsidy and decreasing in the time cost:*

$$\frac{\partial b^*}{\partial W_2} > 0; \quad \frac{\partial b^*}{\partial \bar{s}} > 0; \quad \frac{\partial b^*}{\partial M_b} < 0$$

Proof. See Appendix B. □

It immediately follows from Proposition 1 that, ceteris paribus, a higher ad valorem subsidy on nanny time will increase fertility rates by lowering the time cost of a child. If the wage of one of the parents goes up then this increases both household wealth (income effect) and the opportunity cost of time (substitution effect), which means that the overall effect on fertility is ambiguous in general. Only under very specific assumptions is it possible to derive how fertility choices vary with parental wages in the context of the model.

Proposition 2. *Assume there are no savings in the life-cycle stage 1, no nannies, no time costs of child birth and no lump-sum taxes or specific subsidies. Define w^j to be the wage rate of spouse $j \in \{f, m\}$. Let b^* denote the optimal choice of the number of children. Then b^* depends on the relative wages of husband and wife and attains a minimum when wages are equal:*

$$\frac{\partial b^*}{\partial [w^m/w^f]} \lesseqqgtr 0 \quad \textit{for} \quad \frac{w^m}{w^f} \lesseqqgtr 1$$

Proof. See Appendix B. □

In the proof it is shown that the validity of Proposition 2 hinges crucially on the existence of time costs for which parents are substitutes. It only holds if $N_b > 0$ and $\xi > 0$. Intuitively, couples for which the wife and husband have the same wage rate miss out on the gains from specialization that can be reaped when a low-wage parent takes on most of the child care while the high-wage spouse can spend more time on market work.

As alluded to in the introduction, the main 'stylized fact' about fertility is the negative relationship between the number of children and income. It is however not straightforward to translate this into a litmus test for the model. First of all, it is not clear which measure of income is the relevant one. For example, this could be the wage *rate* of the husband $w(E^m)$ and/or wife $w(E^f)$ or the wage *income* of the husband $w(E^m)[1 - n_2^m]$ and/or wife $w(E^f)[1 - T_b b - n_2^f]$. Second, there are doubts about the statistical validity of this result because of missing control variables and the endogeneity of income, see Jones et al. (2010). For example, the second measure of income suggested above is clearly endogenous as time available for work depends negatively on the number of children.

To circumvent these issues I focus here on the number of children in relation to the (predetermined) level of education of the parents. Write $b^*(E^f, E^m)$ for the optimal fertility choice of a couple where the wife has education E^f and the husband E^m. Proposition 2 then implies that in the absence of savings in stage 1, nannies, time costs of child birth and lump-sum taxes or specific subsidies:

$$b^*(0,0) = b^*(1,1) < b^*(1,0) = b^*(0,1). \tag{34}$$

The first equality sign is a consequence of the specification of the preferences in (1). If all wages grow at the same rate (in this case an increase from $w(0)$ to $w(1)$ for both parents) then income and substitution effects exactly cancel out so that the optimal number of children remains constant. The second equality sign in (34) follows because only relative parental wages matter and not whether the wife is more educated than her husband or vice versa. This stark prediction about cross-sectional fertility choices will no longer hold if one of the premises of Proposition 2 is changed. I will discuss the relaxation of each assumption in turn. First, if there is a time cost of child birth for women then the symmetry between the sexes is broken and $b^*(1,0) < b^*(0,1)$. Second, the introduction of nannies reduces the relative time cost of children more for educated than uneducated parents such that $b^*(0,0) < b^*(1,1)$ by Proposition 1. Lump-sum taxes, on the other hand, have a greater impact on the wealth of low-wage individuals. If these are negative (a transfer) then $b^*(0,0) > b^*(1,1)$. A similar argument can be made for specific subsidies. Finally, the effect on fertility of optimal savings choices in life-cycle stage 1 will depend on the amount that individuals save relative to their wages. For example, educated men and women might save less or borrow more in comparison to their wage level because (i) they forego wages by going to school, (ii) they have to pay a tuition fee and (iii) they face a better prospect of marrying a high-wage spouse. If so then $b^*(0,0) > b^*(1,1)$.

3.2 Parameterization

The aim is to parameterize the model in order to solve for the equilibrium numerically. This is *not* intended to be a calibration exercise for a specific economy, as the model is by construction much too stylized for that purpose.

The length of each period is 18 years. Obtaining a college degree requires a fraction $\epsilon = 0.25$ of the time available in life-cycle stage 1, while the retirement phase is a share $R = 0.4$ of the final stage. The impatience discount factor is set at 1% per annum which translates into $\rho = (1.01)^{18} - 1$. The curvature parameter of the felicity function is $\sigma = 0.7$. I assume that child care requires $N_b = 0.2$ and that the time cost of child birth for the mother is $T_b = 0.02$. The equivalence scale of two adults is $Q_a = 1.7$ while each additional child requires $Q_b = 0.5$. The probability of getting married in life-cycle stage 2 is $q = 0.85$ with a positive degree of marital sorting $\lambda = 0.55$.

I start without taxes or subsidies ($\tau = \bar{\tau} = s = \bar{s} = 0$). The parameterization targets at the macro level are (i) a normalized wage $w(0) = 1$ for uneducated workers with a college wage premium of $w(1) = 1.5$, (ii) an interest rate of 5% per annum or $r = (1.05)^{18} - 1$ per period, (iii) neither a surplus nor a deficit on the balance of payments ($NX_t = NFA_t = 0$) and (iv) a fraction $\pi^f(1) = 0.25$ of educated women and a fraction $\pi^m(1) = 0.26$ of educated men in each cohort. The targeted proportion of college educated women is a bit less than that of men because, everything else equal between the sexes, the positive time cost of child birth implies that they have less incentive to become educated. This is contrary to the current situation in most developed countries, where women tend to graduate in larger numbers. The model can potentially account for this fact by introducing more asymmetries between the sexes (in particular a gender wage gap or differences in the distribution of utility costs, see Reijnders (2014)) but I will abstract from this here. The child care parameter $\psi = 0.160$ is set in such a way that the couple with the highest unit cost of parental time is just indifferent between hiring a nanny or not ($p = (1 - \psi)w^p$) given that nannies cannot exploit economies of scale ($\Psi = 1$). This means that there will be no demand for child care services in the benchmark.

For the micro choices I aim at a birth rate of 2.5 for couples without education to ensure that the population growth rate is positive (albeit small). Under the assumption that there are no tuition fees $\upsilon = 0$ and the elasticity of substitution between father and mother time is $\xi = 4$ this can be achieved by choice of $\phi = 0.632$ (the relative preference for consumption). The macro targets (i)-(iii) hold with $\nu = 0.107$ (the comparative advantage of educated labour in production), $\gamma = 0.283$ (the share of capital in production) and $\Gamma = 2.779$ (the production constant). The corresponding educational thresholds are $\bar{\theta}^f = 0.285$ and $\bar{\theta}^m = 0.287$. These can generate the desired proportions of college educated individuals in (iv) by assuming that the utility cost of education follows a lognormal distribution with location parameter -1.115 and scale parameter 0.207 for both sexes.

The chosen parameter values imply that almost 66% of marriages are between two uneducated individuals. In only 8% of the cases is an educated woman matched to an uneducated man, the probability of observing the opposite match is 0.09. In absence of taxes the minimum cost of parent time ranges between 0.79 for uneducated and 1.19 for educated couples, for mixed households it is 0.92. In all cases it is less than the lowest wage rate among husband and wife because they are assumed to be imperfect substitutes in the production of child care.

3.3 Simulation results

Table 1 reports the results of the numerical simulation.[13] Column (i) is the benchmark case without subsidies. There is no demand for nannies as the price of professional child care services is higher than the productivity-adjusted parental wage index for all couples. The only differences relative to the premises of Proposition 2 above are the positive time cost of child birth and the possibility to borrow or save in life-cycle stage 1. The equilibrium is such that a couple with an

[13] See Appendix C for details on how the macroeconomic equilibrium can be calculated.

uneducated wife and an educated husband has the most children, while parents who are both educated have the least. The average birth rate is just above 2, thereby preventing the population from shrinking.[14]

Consider now the introduction of an ad valorem subsidy of $s = 0.5$ or 50% of the price of a nanny. In order to highlight the seperate mechanisms present in the model Table 2 splits up the move from the old steady state to the new one in several steps. Column (a) corresponds to the benchmark case. It captures the most relevant information from column (i) of Table 1 and in addition shows the optimal savings choices in the first life-cycle stage by gender and education. Educated men and women save less relative to their wage compared with uneducated individuals, which explains why $b^*(1,1) < b^*(0,0)$ (see Section 3.1). The grey cells in the subsequent columns indicate which variables are allowed to change from their value in the benchmark. In column (b) the subsidy is introduced, together with a proportional tax of 3.6% on labour income to ensure a balanced government budget. The marriage market equilibrium is kept fixed, which means that the education frequencies and the savings choices remain the same. It is clear that the lower price of child care increases the demand for children, in particular for educated (high-wage) parents. The birth rate for couples that are both educated goes up from 2.193 to 2.830. The next step is to allow individuals to optimally adjust their first-stage education and savings decision, keeping the college wage premium at its benchmark level of 1.5. In the new marriage market equilibrium the fraction of individuals that decides to obtain an education increases strongly for both sexes. The subsidization of child care has made having children much cheaper for them, thereby raising the return to education. Optimal fertility is a little lower than in column (b) for all couples because they consume more in the first stage (as evidenced by lower savings) which reduces household wealth. Finally, in moving to the last column the wage rates adjust in response to the relative supply of educated and uneducated labour in the production sector. The demand for nannies has drawn uneducated workers into the service sector. As a consequence the college wage premium drops from 1.500 to 1.478 and the after-subsidy price of a nanny increases increases from 0.500 to 0.502. The final equilibrium features a proportion of college-educated individuals below that in the benchmark. Compared to column (c) fertility rates have increased slightly for uneducated couples but decreased for all others. As can be seen from column (ii) in Table 1 (which is the same equilibrium), domestic savings fall short of the capital stock which implies that net foreign assets are negative. The interest payments on this external debt are paid by maintaining a surplus on the current account.

The next column reports the long-run equilibrium given that the tax system is progressive with a fixed transfer of 0.2 (a negative lump-sum tax). The fraction of college educated individuals is lower under this regime than in case (ii) as the progressive tax discourages investment in education, even though the college wage premium is higher at 1.557. The fertility rate of uneducated couples is boosted relative to all others because they profit most from the transfer.

Finally, in column (iv) I consider an alternative subsidization scheme. The tax rate is held fixed at the same level as in scenario (ii) (which is 3.6%), but the ad valorem subsidy on child care is replaced by a specific subsidy per child. This type of scheme is for example used in the Netherlands,

[14] In most developed countries there is a positive population growth rate despite having average birth rates below 2 for the native population. This is because of migration, which is ignored in the model.

Table 1: Long-run equilibrium under different subsidization and taxation regimes

	(i)	(ii)	(iii)	(iv)
Taxation				
s	0.000	0.500	0.500	0.000
$\bar{s}$	0.000	0.000	0.000	0.065
τ	0.000	0.036	0.240	0.036
$\bar{\tau}$	0.000	0.000	-0.200	0.000
Prices				
$w(0)$	1.000	1.005	0.988	0.998
$w(1)/w(0)$	1.500	1.478	1.557	1.511
$(1-s)p$	1.000	0.502	0.494	0.998
Education				
$\pi^f(1)$	0.250	0.243	0.215	0.242
$\pi^m(1)$	0.260	0.253	0.223	0.256
Fertility				
$b^*(0,0)$	2.500	2.659	3.025	3.561
$b^*(1,0)$	2.410	2.697	2.961	3.232
$b^*(0,1)$	2.509	2.814	3.087	3.407
$b^*(1,1)$	2.193	2.786	2.970	2.773
$\bar{b}$	2.076	2.293	2.565	2.884
Goods				
Y_t/P_t	0.916	0.866	0.845	0.828
C_t/P_t	0.815	0.758	0.716	0.696
I_t/P_t	0.101	0.101	0.105	0.111
NX_t/P_t	0.000	0.007	0.024	0.021
Services				
Z_t/P_t	0.000	0.047	0.017	0.000
Income				
GDP_t/P_t	0.916	0.913	0.862	0.828
Labour				
L_t/P_t	0.583	0.596	0.561	0.528
L_t^n/P_t	0.000	0.047	0.017	0.000
μ	0.240	0.251	0.215	0.235
Capital				
K_t/P_t	0.116	0.110	0.107	0.105
NFA_t/P_t	0.000	-0.005	-0.019	-0.018

Notes: Column (i) is the benchmark without taxes or subsidies. In column (ii) there is an ad valorem subsidy of $s = 0.5$, the tax rate τ is such that the government budget is balanced. The left part is the partial equilibrium (keeping prices constant), the right part is the general equilibrium. In column (iii) there is an ad valorem subsidy of $s = 0.5$ and a lump-sum transfer of $\bar{\tau} = -0.2$, the proportional tax rate τ is such that the government budget is balanced. In column (iv) the proportional tax rate τ is the same as in column (ii), the specific subsidy $\bar{s}$ is such that the government budget is balanced.

Table 2: Partial equilibrium effects

	(a)	(b)	(c)	(d)
Taxation				
s	0.000	0.500	0.500	0.500
τ	0.000	0.036	0.037	0.036
Prices				
$w(0)$	1.000	1.000	1.000	1.005
$w(1)/w(0)$	1.500	1.500	1.500	1.478
$(1-s)p$	1.000	0.500	0.500	0.502
Education				
$\pi^f(1)$	0.250	0.250	0.352	0.243
$\pi^m(1)$	0.260	0.260	0.366	0.253
Savings				
$a_1^f(0)/w(0)$	0.160	0.160	0.151	0.153
$a_1^f(1)/w(1)$	0.063	0.063	0.056	0.057
$a_1^m(0)/w(0)$	0.161	0.161	0.152	0.154
$a_1^m(1)/w(1)$	0.064	0.064	0.057	0.058
Fertility				
$b^*(0,0)$	2.500	2.681	2.652	2.659
$b^*(1,0)$	2.410	2.729	2.702	2.697
$b^*(0,1)$	2.509	2.852	2.823	2.814
$b^*(1,1)$	2.193	2.830	2.801	2.786
$\bar{b}$	2.076	2.316	2.307	2.293

Notes: Column (a) is the benchmark without taxes or subsidies (see column (i) in Table 1). In column (b) there is an ad valorem subsidy of $s = 0.5$, the tax rate τ is such that the government budget is balanced. In column (c) there is a new marriage market equilibrium. In column (d) the college wage premium adjusts (see column (ii) in Table 1). The grey cells indicate which variables are allowed to change relative to the benchmark.

under the name of “kinderbijslag”.[15] The effect on fertility choices is substantial as the average birth rate increases from 2.076 in the benchmark to 2.884. Because parents choose not to outsource child care the supply of labour goes down. Especially married women work less as the time burden of child birth goes up and they perform more hours of child care (since they are more likely to be the low-wage spouse in a couple). The college wage premium rises a little, which ensures that the decrease in college education frequencies is limited.

3.3.1 Robustness checks

To the best of my knowledge there are no estimates of the degree of substitution between fathers, mothers and nannies in the production of child care which makes it difficult to obtain reasonable parameter values. However, the results are robust to changes in ψ, Ψ and ξ. An increase in ψ, the weight of non-substitutable parent time in total care (8), will reduce the extent to which parents can substitute their own time for nanny services. This will dampen the effect that a subsidy has on the macroeconomic outcome, but does not alter the qualitative predictions. If nannies are able to exploit economies of scale that parents can not ($\Psi > 1$) then the optimal fertility choice of all couples increases but the effect of a subsidy on education frequencies and labour allocations are similar. Finally, a change in the substitution elasticity ξ mainly affects the optimal fertility choice of unequal-education couples relative to those with equal wages as explained in Section 3.1 above.

A more crucial assumption is the one implicit in the child care subsidization scheme. Thus far I have assumed that every household is eligible for government support, while in reality there might be a ‘means test’. As a short-cut to this, suppose that only couples where both parents are uneducated (and thus get low wages) receive subsidies for child care. Then even in a partial equilibrium context this is detrimental to the returns to education and the proportion of college educated individuals decreases relative to the benchmark. Including general equilibrium effects now works in the opposite direction: the college wage premium goes up such that education frequencies partly recover. The number of children born to uneducated parents rises relative to that of other couples.

Finally, I have assumed that the home country can trade financial assets on the world market at a constant interest rate. If instead the economy would be closed then changes in the interest rate are an additional mechanism whereby policy shocks are transmitted into the economy. Appendix D reports the counterpart of Table 1 under the closed economy assumption, the results hardly change. Hence, the difference between partial and general equilibrium outcomes as illustrated in Table 2 is mainly driven by changes in relative wages.

4 Conclusion

In this paper I have studied the long-run effects of child care subsidies on education, fertility and the sectoral allocation of the labour force. In absence of taxes and subsidies the optimal

[15] The “kinderbijslag” is a subsidy per live-in child under the age of 18 which is independent of the income of the parents. It does increase with the age of the child, but that is of no importance here because of the time aggregation.

choice of financial assets early in life (taking marriage market conditions into account) is such that individuals who decide to attend college save relatively little. As a consequence, a couple with an uneducated wife and an educated husband has the most children, while parents who are both educated have the least. Introducing an ad valorem subsidy on child care financed by a proportional tax on income leads to an increase in fertility for all households. As more uneducated workers are employed in the service sector the college wage premium goes down and college graduation rates drop. This latter consequence is even more pronounced if the tax system is progressive. If the aim of the subsidy is to stimulate fertility, then this can be more effectively done by providing a specific subsidy per child. However, this reduces the supply of labour, especially by uneducated married women.

In future work I would like to compute the transitional path between equilibria. This will enable me to study the welfare effects of each subsidization scheme and the implied intergenerational redistribution.

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A Properties of production functions

The table below lists some properties of the two production functions used in the model. It is assumed that the factor prices $w = (w_x, w_z)$ are positive and finite.

	Constant Elasticity of Substitution	One-directional substitution
Definition	$y = \left[x^{1-1/\alpha} + z^{1-1/\alpha}\right]^{\frac{1}{1-1/\alpha}}$, $\alpha > 1$	$y = x^{\beta}\left[x + z\right]^{1-\beta}$, $0 < \beta < 1$
Returns to scale	Constant	Constant
Marginal products	$\frac{\partial y}{\partial x} = \left[1 + \left(\frac{z}{x}\right)^{1-1/\alpha}\right]^{\frac{1/\alpha}{1-1/\alpha}}$ $\frac{\partial y}{\partial z} = \left[1 + \left(\frac{z}{x}\right)^{-(1-1/\alpha)}\right]^{\frac{1/\alpha}{1-1/\alpha}}$	$\frac{\partial y}{\partial x} = \left[1 - \beta + \beta\frac{x+z}{x}\right]\left(\frac{x}{x+z}\right)^{\beta}$ $\frac{\partial y}{\partial z} = (1-\beta)\left(\frac{x}{x+z}\right)^{\beta}$
Interior solution	$\alpha \ll \infty$	$w_z \leq (1-\beta)w_x$
Minimum cost	$C(w,y) = y\left[w_x^{-(\alpha-1)} + w_z^{-(\alpha-1)}\right]^{-\frac{1}{\alpha-1}}$	$C(w,y) = y\frac{w_z}{1-\beta}\left\{\frac{1-\beta}{\beta}\left[\frac{w_x}{w_z} - 1\right]\right\}^{\beta}$
Conditional demands	$x(w,y) = y\left[\frac{w_x}{C(w,y)}\right]^{-\alpha}$ $z(w,y) = y\left[\frac{w_z}{C(w,y)}\right]^{-\alpha}$	$x(w,y) = y\frac{\beta C(w,y)}{w_x - w_z}$ $z(w,y) = y\frac{(1-\beta)C(w,y)}{w_z} - x(w,y)$
Corner solution	$\alpha \to \infty$	$w_z > (1-\beta)w_x$
Minimum cost	$C(w,y) = \min\{w_x, w_z\}$	$C(w,y) = w_x$
Conditional factor	$x(w,y) = \begin{cases} y & \text{if } w_x < w_z \\ \in [0,y] & \text{if } w_x = w_z \\ 0 & \text{if } w_x > w_z \end{cases}$ $z(w,y) = \begin{cases} 0 & \text{if } w_x < w_z \\ y - x & \text{if } w_x = w_z \\ y & \text{if } w_x > w_z \end{cases}$	$x(w,y) = y$ $z(w,y) = 0$

For the purpose of this paper, the most important difference between the two production functions concerns the degree of substitutability between the inputs. In case of the CES production function the substitution elasticity is constant and symmetric: input x is 'as good' a substitute for z as the other way around. Under one-directional substitution, on the other hand, x is a perfect substitute for z but z can only partly replace x. In two of the scenario's considere above, parents versus nannies and uneducated versus educated labour, the latter seems like a desirable property. In addition, whereas the marginal product of each production factor becomes infinite at zero for the CES this will not happen for the 'inferior' input z under one-directional substitution. Corner solutions are therefore more likely to occur.

B Proofs

The system of first-order conditions for the couple as given in (15)-(17) can be reduced to a single equation in the number of children b only by substituting out for c_2 and c_3:

$$W_2 - (M_b - \bar{s})\frac{b+\phi}{1-\phi} - \frac{\phi}{1-\phi}\frac{Q_b(1+b)}{Q_a+Q_b b}\Gamma_2(b)\Big[W_2 - (M_b - \bar{s})b\Big] = 0, \tag{B.1}$$

where $\Gamma_2(b)$ is the couple's marginal propensity to consume out of wealth in stage 2:

$$\Gamma_2(b) = \left[1 + \frac{1}{1+r}\left(\frac{1+r}{1+\rho}\right)^{\sigma^*}\left(\frac{Q_a}{Q_a+Q_b b}\right)^{1-\sigma^*}\right]^{-1}. \tag{B.2}$$

It follows that for any b that satisfies this condition the following inequality holds:

$$\frac{\phi}{1-\phi}\frac{Q_b(1+b)}{Q_a+Q_b b}\Gamma_2(b) = \frac{W_2 - (M_b - \bar{s})\frac{b+\phi}{1-\phi}}{W_2 - (M_b - \bar{s})b} < 1. \tag{B.3}$$

Proposition 1. *Let b^* denote the optimal choice of the number of children. It is increasing in household wealth and the specific child subsidy and decreasing in the time cost:*

$$\frac{\partial b^*}{\partial W_2} > 0; \quad \frac{\partial b^*}{\partial \bar{s}} > 0; \quad \frac{\partial b^*}{\partial M_b} < 0$$

Proof. Define:

$$F(b, W_2, M_b, \bar{s}) = W_2 - (M_b - \bar{s})\frac{b+\phi}{1-\phi} - \frac{\phi}{1-\phi}\frac{Q_b(1+b)}{Q_a+Q_b b}\Gamma_2(b)\Big[W_2 - (M_b - \bar{s})b\Big]$$

The optimal choice b^* is such that $F(b^*, W_2, M_b, \bar{s}) = 0$. This implicitly defines b^* as a function of $(W_2, M_b, \bar{s})$. The partial derivatives of F satisfy:

$$\begin{aligned}
\frac{\partial F(b^*, W_2, M_b, \bar{s})}{\partial b} &< 0 \\
\frac{\partial F(b^*, W_2, M_b, \bar{s})}{\partial W_2} &= 1 - \frac{\phi}{1-\phi}\frac{Q_b(1+b^*)}{Q_a+Q_b b^*}\Gamma_2(b^*) > 0 \\
\frac{\partial F(b^*, W_2, M_b, \bar{s})}{\partial M_b} &= -\frac{b^*+\phi}{1-\phi} + \frac{\phi}{1-\phi}\frac{Q_b(1+b^*)}{Q_a+Q_b b^*}\Gamma_2(b^*)b^* < 0 \\
\frac{\partial F(b^*, W_2, M_b, \bar{s})}{\partial \bar{s}} &= \frac{b^*+\phi}{1-\phi} - \frac{\phi}{1-\phi}\frac{Q_b(1+b^*)}{Q_a+Q_b b^*}\Gamma_2(b^*)b^* > 0
\end{aligned}$$

where the sign of the first follows from the second-order condition for a maximum while the second, third and fourth expression make use of (B.3). The Implicit Function Theorem then implies:

$$\begin{aligned}
\frac{\partial b^*}{\partial W_2} &= -\frac{\partial F(b^*, W_2, M_b, \bar{s})/\partial W_2}{\partial F(b^*, W_2, M_b, \bar{s})/\partial b} > 0 \\
\frac{\partial b^*}{\partial M_b} &= -\frac{\partial F(b^*, W_2, M_b, \bar{s})/\partial M_2}{\partial F(b^*, W_2, M_b, \bar{s})/\partial b} < 0 \\
\frac{\partial b^*}{\partial \bar{s}} &= -\frac{\partial F(b^*, W_2, M_b, \bar{s})/\partial \bar{s}}{\partial F(b^*, W_2, M_b, \bar{s})/\partial b} > 0
\end{aligned}$$

□

Proposition 2. *Assume there are no savings in the life-cycle stage* 1*, no nannies, no time costs of child birth and no lump-sum taxes or specific subsidies. Define* w^j *to be the wage rate of spouse* $j \in \{f, m\}$*. Let* b^* *denote the optimal choice of the number of children. Then* b^* *depends on the relative wages of husband and wife and attains a minimum when wages are equal:*

$$\frac{\partial b^*}{\partial [w^m/w^f]} \lesseqqgtr 0 \quad \textit{for} \quad \frac{w^m}{w^f} \lesseqqgtr 1$$

Proof. Let $a_1 = 0$, $\psi = 1$, $T_b = 0$, $\bar{\tau} = 0$ and $\bar{s} = 0$. Write $X = w^m/w^f$. Define:

$$\tilde{F}(b, X) = \tilde{W}_2(X) - \tilde{M}_b(X)\frac{b+\phi}{1-\phi} - \frac{\phi}{1-\phi}\frac{Q_b(1+b)}{Q_a+Q_b b}\Gamma_2(b)\left[\tilde{W}_2(X) - \tilde{M}_b(X)b\right]$$

where:

$$\begin{aligned}
\tilde{W}_2(X) &\equiv \frac{W_2}{w^f} = (1-\tau)\left[1+X\right]\left[1+\frac{1-R}{1+r}\right] \\
\tilde{M}_b(X) &\equiv \frac{M_b}{w^f} = \left[1+X^{1-\xi}\right]^{\frac{1}{1-\xi}}
\end{aligned}$$

The optimal choice b^* is such that $\tilde{F}(b^*, X) = 0$. This implicitly defines b^* as a function of X. The partial derivatives of F satisfy:

$$\begin{aligned}
&\frac{\partial \tilde{F}(b^*, X)}{\partial b} < 0 \\
&\frac{\partial \tilde{F}(b^*, X)}{\partial X} = \frac{\tilde{W}_2(X)}{1+X} - \frac{X^{-\xi}\tilde{M}_b(X)}{1+X^{1-\xi}}\frac{b^*+\phi}{1-\phi} - \frac{\phi}{1-\phi}\frac{Q_b(1+b^*)}{Q_a+Q_b b^*}\Gamma_2(b^*)\left[\frac{\tilde{W}_2(X)}{1+X} - \frac{X^{-\xi}\tilde{M}_b(X)}{1+X^{1-\xi}}b^*\right] \\
&\frac{\partial^2 \tilde{F}(b^*, X)}{\partial X^2} = \frac{\xi X^{-(1+\xi)}\tilde{M}_b(X)}{[1+X^{1-\xi}]^2}\left[\frac{b^*+\phi}{1-\phi} - \frac{\phi}{1-\phi}\frac{Q_b(1+b^*)}{Q_a+Q_b b^*}\Gamma_2(b^*)\right] > 0
\end{aligned}$$

where the sign of the first follows from the second-order condition for a maximum while the second and third expression make use of (B.3) and:

$$\begin{aligned}
\frac{\partial \tilde{W}_2(X)}{\partial X} &= \frac{\tilde{W}_2(X)}{1+X}; \qquad & \frac{\partial^2 \tilde{W}_2(X)}{\partial X^2} &= 0 \\
\frac{\partial \tilde{M}_b(X)}{\partial X} &= \frac{X^{-\xi}\tilde{M}_b(X)}{1+X^{1-\xi}}; \qquad & \frac{\partial^2 \tilde{M}_b(X)}{\partial X^2} &= -\frac{\xi X^{-(1+\xi)}\tilde{M}_b(X)}{[1+X^{1-\xi}]^2}
\end{aligned}$$

In particular, when evaluated at $X = 1$ (equal wages for husband and wife):

$$\begin{aligned}
\frac{\partial \tilde{F}(b^*, 1)}{\partial X} &= \frac{1}{2}\tilde{F}(b^*, 1) = 0 \\
\frac{\partial^2 \tilde{F}(b^*, 1)}{\partial X^2} &= \frac{\xi \tilde{M}_b(1)}{4}\left[\frac{b^*+\phi}{1-\phi} - \frac{\phi}{1-\phi}\frac{Q_b(1+b^*)}{Q_a+Q_b b^*}\Gamma_2(b^*)\right] > 0
\end{aligned}$$

The Implicit Function Theorem then implies:

$$\left.\frac{\partial b^*}{\partial X}\right|_{X=1} = -\frac{\partial \tilde{F}(b^*(1),1)/\partial X}{\partial \tilde{F}(b^*(1),1)/\partial b} = 0$$

$$\left.\frac{\partial^2 b^*}{\partial X^2}\right|_{X=1} = -\frac{\partial^2 \tilde{F}(b^*(1),1)/\partial X^2}{\partial \tilde{F}(b^*(1),1)/\partial b} > 0$$

Hence, the function $b^*(X)$ attains a (local) minimum at $X = 1$. □

C Algorithm to find the macro equilibrium

For a given interest rate r, subsidies $(s, \bar{s})$ and taxes $(\tau, \bar{\tau})$ the steady-state macro equilibrium can be found numerically in the following steps.

(1) Given r, the capital-labour ratio in the production sector is known and thereby the return to effective labour:

$$\frac{K_t}{L_t^c} = \left(\frac{r+\delta}{\gamma\Gamma}\right)^{-\frac{1}{1-\gamma}}; \quad w^c = (1-\gamma)\Phi\left(\frac{r+\delta}{\gamma\Gamma}\right)^{-\frac{\gamma}{1-\gamma}} \tag{C.1}$$

(2) Find a fixed point for the steady-state value of μ.

- Given μ, the wage rates are known and thereby the relative price of nannies:

$$w(0) = w^c(1-\nu)\mu^\nu; \quad w(1) = \left[1 + \frac{\nu}{(1-\nu)\mu}\right]w(0); \quad p = \frac{w(0)}{\Psi} \tag{C.2}$$

- Solve the micro model given the factor prices and aggregate over households.[16]

- The demand for nannies determines employment in the service sector. The remaining uneducated workers and all educated workers are employed in the production sector:

$$\frac{L_t^n}{P_t} = \frac{1}{\Psi}\frac{N_t}{P_t}; \quad \frac{L_t^c(0)}{P_t} = \frac{L_t(0)}{P_t} - \frac{L_t^n}{P_t}; \quad \frac{L_t^c(1)}{P_t} = \frac{L_t(1)}{P_t} \tag{C.3}$$

- From these results the value of μ can be calculated.

(3) There are now two possibilities, depending on whether the economy is open or closed.

(i) If the economy is open then the capital stock can be determined from the capital labour ratio and employment:

$$\frac{K_t}{P_t} = \frac{K_t}{L_t^c}\frac{L_t^c}{P_t} \tag{C.4a}$$

[16] For a given set of factor prices the marriage market equilibrium and corresponding micro allocations are found by the algorithm described in Reijnders (2014). The optimal asset choice in stage 1 has to be derived numerically as there is no analytical solution to the couple's problem in stage 2.

Net foreign assets are the difference between domestic assets and domestic capital:

$$\frac{NFA_t}{P_t} = \frac{1}{1+\eta}\frac{A_{t-1}}{P_{t-1}} - \frac{K_t}{P_t} \tag{C.4b}$$

Net exports are equal to the change in net foreign assets:

$$\frac{NX_t}{P_t} = (1+\eta)\frac{NFA_{t+1}}{P_{t+1}} - (1+r)\frac{NFA_t}{P_t} \tag{C.4c}$$

(ii) If the economy is closed then the capital stock is determined by asset holdings:

$$\frac{K_t}{P_t} = \frac{1}{1+\eta}\frac{A_{t-1}}{P_{t-1}} \tag{C.5a}$$

Net foreign assets and next exports are zero:

$$\frac{NFA_t}{P_t} = \frac{NX_t}{P_t} = 0 \tag{C.5b}$$

(4) Investment follows from the capital accumulation identity:

$$\frac{I_t}{P_t} = (1+\eta)\frac{K_{t+1}}{P_{t+1}} - (1-\delta)\frac{K_t}{P_t} \tag{C.6}$$

If the economy is closed then I have to find a fixed point for the interest rate r. I loop over the macro allocation until the government budget (31) is balanced.

D The closed economy

The results of the different subsidization and taxation scenario's are given in Table D.1, see Section 3.3 for an explanation.

Table D.1: Long-run equilibrium in the closed economy

	(i)	(ii)	(iii)	(iv)
Taxation				
s	0.000	0.500	0.500	0.000
$\bar{s}$	0.000	0.000	0.000	0.063
τ	0.000	0.036	0.247	0.036
$\bar{\tau}$	0.000	0.000	-0.200	0.000
Education				
$\pi^f(1)$	0.250	0.242	0.211	0.239
$\pi^m(1)$	0.260	0.252	0.219	0.253
Fertility				
$b^*(0,0)$	2.500	2.672	3.093	3.599
$b^*(1,0)$	2.410	2.709	3.018	3.267
$b^*(0,1)$	2.509	2.826	3.146	3.443
$b^*(1,1)$	2.193	2.797	3.020	2.801
$\bar{b}$	2.076	2.303	2.620	2.917
Prices				
$w(0)$	1.000	0.996	0.955	0.965
$w(1)/w(0)$	1.500	1.480	1.568	1.518
$(1-s)p$	1.000	0.498	0.477	0.965
$(1+r)^{1/18}-1$	0.050	0.051	0.054	0.054
Goods				
Y_t/P_t	0.916	0.857	0.813	0.798
C_t/P_t	0.815	0.759	0.718	0.699
I_t/P_t	0.101	0.098	0.095	0.099
Services				
Z_t/P_t	0.000	0.047	0.015	0.000
Income				
GDP_t/P_t	0.916	0.904	0.827	0.798
Labour				
L_t/P_t	0.583	0.595	0.557	0.527
L_t^n/P_t	0.000	0.047	0.015	0.000
μ	0.240	0.250	0.212	0.231
Capital				
K_t/P_t	0.116	0.106	0.095	0.094

Notes: Column (i) is the benchmark without taxes or subsidies. In column (ii) there is an ad valorem subsidy of $s = 0.5$, the tax rate τ is such that the government budget is balanced. The left part is the partial equilibrium (keeping prices constant), the right part is the general equilibrium. In column (iii) there is an ad valorem subsidy of $s = 0.5$ and a lump-sum transfer of $\bar{\tau} = -0.2$, the proportional tax rate τ is such that the government budget is balanced. In column (iv) the proportional tax rate τ is the same as in column (ii), the specific subsidy $\bar{s}$ is such that the government budget is balanced.

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