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April 2014

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Sveriges Riksbank Working Paper Series

No. 284

April 2014

Abstract

Optimal taxes for Europe and the U.S. are derived in a realistically calibrated model in which agents buy consumption goods and services and use home capital and labor to produce household services. The optimal tax rate on services is substantially lower than the tax rate on goods. Specifically, the planner cannot tax home production directly and instead lowers the tax rate on market services to increase the relative price of home production. The optimal tax rate on the return to home capital is strictly positive and the welfare gains from switching to optimal taxes are large.

JEL classification: D13; H21; J22

Keywords: Optimal Taxation, Household Production, Time Allocation, Labor Supply

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1 Introduction

By now, it is quite well established that the amount of market work differs substantially across countries. For instance, people in the U.S. work between 30 to 50 percent more per person than people in European countries, such as France, Germany and Belgium.[1] One explanation that has been offered for these differences is that taxes distort the margin between labor and other activities.[2] Specifically, taxes not only distort the margin between market work and leisure, but also distort households' margin between buying market-produced services and home production. Several recent papers argue further that the high tax rates in Europe could be one reason for the failure of the European service sector to develop in the same way as in the U.S.[3] When faced with high taxes on labor, goods and services, Europeans work relatively fewer hours in the market and instead satisfy a larger share of their demand for services through home production.

Against this background, the objective of this paper is to analyze optimal tax policy in a fully dynamic setting in which a representative agent takes decisions on how to allocate her income between consumption goods, market services and savings, and how to allocate her time between market work, home production and leisure. Home-produced services are imperfect substitutes for market services and they are produced by combining labor and home capital (which comprises consumer durables and housing). This setup captures the fact that households can choose between going to restaurants or cooking at home, between painting their own house or paying someone else to do it, etc.[4]

[1] The numbers are computed for people aged 15-64. The source is EU KLEMS (2009).

[2] See Prescott (2004), Rogerson (2008), Ragan (2005), and Olovsson (2009).

[3] Papers that argue along this dimension include Freeman and Schettkat (2002), Rogerson (2008), Ragan (2005), Ngai and Pissarides (2008) and Olovsson (2009).

[4] The same margin generally does not exist for consumption goods. Most people would not consider producing their own cars, computers or cell phones because they find the cost disproportionate.

The analysis follows Ramsey (1927), in that the social planner chooses an optimal tax structure in an economy with a representative agent when only distortionary taxes are available. For a given tax rate on consumption goods, the tax instruments that the planner has at his/her disposal are taxes on industrial capital, home capital, labor and market-produced services. Tax policy is restricted in that leisure and hours spent in home production cannot be taxed.

The first and theoretical part of the paper derives analytical optimal tax formulas for market-produced services, home capital and industrial capital.[5] For the service tax, the natural starting point is the well-known Atkinson-Stiglitz (A-S) separability theorem which states that commodity taxes should be uniform across goods and services if the utility function is weakly separable between labor and all commodities.[6] This is also true in the model in this paper. However, if home production requires time as an input, a necessary condition for weak separability between labor and all commodities is weak separability between home production and all commodities. In particular, non-separability between the two types of services causes the A-S theorem to fail. The optimal service tax should then adjust the relative price between home and market services such that it also takes the distortions on market production from untaxed home production into account. With standard preferences and production functions, the optimal tax on market-produced services should be lower (higher) than the tax on goods when home and market services are substitutes (complements).

Intuitively, the first best outcome requires uniform taxation of all commodities, including leisure and home production. Since these two activities cannot be taxed directly, however, the optimal tax formula instead features relatively higher tax rates on commodities that are complementary

[5] The tax rate on consumption goods is given and the labor tax rate is basically a residual that has to be set to the value that exactly balances the government's budget constraint.

[6] See Atkinson and Stiglitz (1972, 1976).

to leisure and home production. Specifically, when home and market services are substitutes, a reduction in the tax rate on market services is equivalent to a tax on home production, since it increases the relative price of home production. When the two types of services are instead complements, a tax on market services is equivalent to a tax on home production because the two types of services are then consumed together.[7]

Consider now the optimal tax on home capital. The representative agent can save in two types of capital: home and industrial capital. In equilibrium, these two assets must have the same return but because home capital is used in home production, its accumulation can potentially distort the future demand for market-produced goods and services. From the perspective of the representative agent, market production is exogenous and she therefore does not internalize the effects that home capital may have on market production. As a result, an inefficient amount of home capital is generally accumulated. In fact, it is only when preferences are weakly separable in home capital and all commodities that there are no distortions from home capital. In this case, the implied tax on the total return to home capital is zero. Otherwise, a non-zero tax on the return to home capital is necessary to make the agent internalize the effects on market production. Specifically, when home and market services are substitutes, a marginal unit of home capital will reduce the future demand for market services. This requires a strictly positive tax on the return to home capital. The opposite is true when the two types of services are instead complements.

As in Chamely (1986) and Judd (1985), the optimal steady-state tax rate on industrial capital is zero. Therefore, untaxable home production does not change this result. Since almost all empirical studies find home and market services to be substitutes, the results from the theoretical analysis

[7] The result for the tax rate on market services is thus an extension of the results in Atkinson and Stiglitz (1976), Corlett and Hague (1953), Sandmo (1990), Kleven et al. (2000) and Kleven (2004).

show that services should be taxed at a lower rate than goods and that the return to home capital should be taxed at a strictly positive rate.

In the second and quantitative part of the paper, the model is calibrated to the U.S. and optimal tax rates are computed on capital, home capital, labor and market-produced services. Moreover, since the model provides good predictions of market and home hours for Europe when furnished with European tax rates, optimal tax rates are also computed for Europe. The results confirm that the optimal tax rates on market services are substantially lower than tax rates on goods. For the U.S., the optimal service tax is close to zero, whereas it is around five percentage points lower than the tax rate on goods for Europe. In addition, the optimal tax rates on home capital are higher than current tax rates.

There are large welfare gains from implementing optimal taxes. In contrast to the findings in Chari et al. (1994), the welfare gains do not rely on a very large initial tax rate on capital. In fact, even under the restriction that the tax rate on industrial capital is not allowed to increase, the welfare gain is 1.63 percent of lifetime consumption for the U.S. and as large as seven percent for Europe. The key assumptions are discussed at the end of the paper.

2 The model

2.1 The representative household

Consider a representative agent with the following well-behaved instantaneous utility function:

$$u_t = u\left(c_t, s_t, l_t, k_{n,t}\right), \tag{1}$$

where c_t is consumption goods, s_t is services, l_t is leisure, and $k_{n,t}$ is home capital, which can be thought of as housing and consumer durables. Services are an aggregate of market-produced services $s_{m,t}$ and home-produced (non-market) services $s_{n,t}$:

$$s_t = s\left(s_{m,t}, s_{n,t}\right). \tag{2}$$

s is assumed to be strictly increasing in both its arguments. The production function for home services is a Cobb-Douglas function in home capital k_n and hours worked in home production (in efficiency units) $z_n h_n$, where z_n is the constant productivity in home production. The amount of home-produced services s_n, is thus given by

$$s_{n,t} \equiv f^S\left(k_{n,t}, z_n h_{n,t}\right) = k_{n,t}^{\alpha}\left(z_n h_{n,t}\right)^{1-\alpha}. \tag{3}$$

Between any two consecutive periods, home capital depreciates at the rate δ_n. The agent supplies labor to the labor market consisting of the goods market and the service sector. She has one unit of productive time per period which must be divided between market work, home production and leisure

$$h_{m,t} + h_{n,t} + l_t = 1. \tag{4}$$

Denoting taxes on consumption, market-produced services, labor, home capital and the return to industrial capital respectively by τ^c, τ^s, τ^h, τ^{k_n}, and τ^{k_m}, the agent's consolidated budget constraint is

$$\sum_{t=0}^{\infty} q_t \left[c_t \left(1+\tau^c\right) + \left(1+\tau_t^s\right) p_t s_{m,t} + a_{t+1} + k_{n,t+1}\right] = \tag{5}$$
$$\sum_{t=0}^{\infty} q_t \left[w_t \left(1-\tau_t^h\right) h_{m,t} + R_t a_t + \left(1-\tau_t^{k_n}\right)\left(1-\delta_n\right) k_{n,t} + \Psi_t\right],$$

where β denotes the subjective discount factor, q_t is the price of consumption in period t, w the wage rate, a is assets, p is the market price of services, $R_t = 1 + \left(1-\tau_t^{k_m}\right)\left[r_t - \delta\right]$ the gross after-tax interest rate and δ is the depreciation rate on industrial capital. Ψ is a transfer from the government that contains the tax revenues which are given back to the consumer, assuming that this part of government consumption is a perfect substitute for private consumption. Consumption goods, industrial and home capital all have a relative price of one.

Note that only a part of the return to home capital can be taxed. Specifically, the tax on home capital is levied on the stock of undepreciated home capital, whereas the home-produced services that home capital generate are not explicitly taxed. Note also that τ^c does not depend on time. In the Ramsey problem below, τ^c is held fixed at the initial level throughout the analysis because there is a continuum of tax rates that can implement the optimal allocation if taxes on consumption, labor and capital are all used.

In the model, capital of one type can, in each period, be converted into the other type without any frictions or time lags. This is not necessarily realistic and it matters for the transition and for the size of the welfare effects, but not for the properties of the Ramsey steady state. The case without frictions is a natural starting point but it is straightforward to introduce frictions into the model.[8]

2.2 Firms

There is no aggregate uncertainty in the economy. Firms rent capital and labor from the representative household. Consumption goods and market services are both produced by combining capital and labor in a Cobb-Douglas technology:

$$F^i\left(k_i, h_i\right) = k_i^{\alpha} h_i^{1-\alpha}, \quad i = \{g, s\}, \tag{6}$$

where k_i and h_i, respectively, denote the amounts of capital and labor used in sector i. Identical production functions imply that capital's share of income is the same in the production of goods and services, which seems to be empirically true.[9]

2.3 The government

The government sets tax rates to finance the exogenous sequence of constant government consumption g. The period-t government budget constraint is given by

$$g + \Psi_t = d_t\left(1 - R_t\right) + \tau^c c_t + \tau_t^s p_t s_{m,t} + \tau_t^h w_t h_{m,t} + \tau_t^{k_m} r_t k_{m,t} + \tau_t^{k_n}\left(1 - \delta_n\right) k_{n,t}, \tag{7}$$

where d is the level of government debt and k_m industrial capital.

[8] In addition, on the individual level, investments in housing may be lumpy. Since the model captures the aggregate level and home capital consists of housing and durables, it is feasible to abstract from this type of lumpiness.

[9] Uppenberg and Strauss (2010) show that on average, services have as much fixed capital per employee as manufacturing.

2.4 The competitive equilibrium

The utility-maximization problem for the representative agent is to maximize (1) subject to (5). Defining the marginal disutility of work as $u_{h_{m,t}} \equiv -u_{l_t}$, the first-order conditions with respect to c_t, $h_{m,t}$, $s_{m,t}$, $h_{n,t}$, a_{t+1} and $k_{n,t+1}$ are, respectively, given by

(8) $$\beta^t u_{c_t} - \lambda q_t (1 + \tau^c) = 0;$$

(9) $$w_t \left(1 - \tau_t^h\right) + \frac{u_{h_{m,t}}}{u_{c_t}} (1 + \tau^c) = 0;$$

(10) $$p_t (1 + \tau_t^s) - \frac{u_{s_{m,t}}}{u_{c_t}} (1 + \tau^c) = 0;$$

(11) $$W_t \equiv u_{h_{n,t}} + u_{h_{m,t}} = 0;$$

(12) $$-u_{c_t} + \beta u_{c_{t+1}} R_{t+1} = 0;$$

and

$$-\frac{u_{c_t}}{1+\tau^c}+\beta\left(u_{\widetilde{k}_{n,t+1}}+u_{c_{t+1}}\frac{\left(1-\tau_{t+1}^{k_n}\right)(1-\delta_n)}{1+\tau^c}\right)=0, \tag{13}$$

where $u_{h_{n,t}} \equiv u_{s_{n,t}} f_{h_n,t}^S$ and $u_{\widetilde{k}_{n,t+1}} \equiv u_{s_{n,t+1}} f_{k_n,t+1}^S + u_{k_{n,t+1}}$.

Total market hours are divided between the goods and the service sectors, i.e., $h_{m,t} = h_{g,t} + h_{s,t}$, $\forall t$. Similarly, the total amount of industrial capital is divided between the goods and the service sectors, i.e., $k_{m,t} = k_{g,t} + k_{s,t}$, $\forall t$. In addition, market clearing in the asset markets requires $k_{m,t} = a_t - d_t$, $\forall t$.

Competitive pricing ensures that, in each period, the returns to capital and labor in sector i are respectively given by:

$$r_{i,t} = F_{k_{i,t}}^i\left(k_{i,t}, h_{i,t}\right) - \delta, \quad \text{and} \quad w_{i,t} = F_{h_{i,t}}^i\left(k_{i,t}, h_{i,t}\right), \quad i = \{g, s\}. \tag{14}$$

For employment to be positive in both sectors, wages have to be the same, i.e., $w_t \equiv w_{s,t} = w_{g,t}$, $\forall t$. For investments to be positive in both sectors, the return also has to be the same in both sectors, i.e., we must have $r_t \equiv r_{g,t} = r_{s,t}$, $\forall t$. This implies that

$$h_{s,t} = h_{g,t} k_{s,t} / k_{g,t}, \quad \forall t. \tag{15}$$

The price of market-produced services in each period is given by $p_t \equiv F_{h_g,t}^g / F_{h_s,t}^s = 1$. Intuitively, with identical production functions for goods and services, the price of services is equal to one. The aggregate resource constraint in the economy is:

$$c_t + k_{m,t+1} + k_{n,t+1} + g_t = F^g(k_{g,t}, h_{g,t}) + (1-\delta) k_{m,t} + (1-\delta_n) k_{n,t}. \tag{16}$$

Finally, in equilibrium, the demand for market services has to equal the supply of market services. The market-clearing condition for services is given by

$$s_{m,t} = F^s(k_{s,t}, h_{s,t}). \tag{17}$$

2.5 The Ramsey equilibrium

The objective of the social planner is to find a sequence of tax rates that fulfills the budget constraint and a transversality condition. This analysis follows Ramsey (1927), who considered the problem of choosing an optimal tax structure in an economy with a representative agent when only distortionary taxes are available. As is standard in this literature, I assume that the planner has access to a commitment technology, so that time-inconsistency problems can be ignored. Tax policy is restricted in that leisure and hours spent in home production cannot be taxed. In addition, tax rates on market and home capital in the first period cannot be changed. This assumption is used to rule out lump-sum taxation. The level of government consumption g and the level of transfers Ψ are both held fixed throughout the transition. Relaxing the restriction that transfers are constant makes it possible for the planner to reduce taxes, which leads to higher welfare gains.

I make use of the primal approach to find the optimal policy. This implies choosing paths for capital stocks, consumption, hours in the goods market, in the service sector as well as in home production, subject to the constraint that these sequences are consistent with household optimization. The principal idea is to use the first-order conditions to define prices, given an allocation. Prices and tax rates can then be substituted away and need not be explicitly included in the planner's problem. Equation (8) defines q_t, (9) determines τ_t^h, (10) can be used to compute τ_t^s, (12) gives $\tau_t^{k_m}$ and (13) determines $\tau_t^{k_n}$.[10] Since (11) does not contain any taxes that the government can set directly, this constraint has to be included in the planner's problem. Substituting (8)-(10) and (12)-(13) into the household's present-value constraint (5) gives

$$\sum_{t=0}^{\infty}\beta^t\left[u_{c_t}\left(c_t-\tfrac{\Psi}{1+\tau^c}\right)+u_{s_{m,t}}s_{m,t}+u_{h_{m,t}}h_{m,t}+\beta u_{\widetilde{k}_{n,t+1}}k_{n,t+1}\right] -V_0=0, \tag{18}$$

where $V^0=u_{c_0}\left[\left(1+\left(1-\tau_0^k\right)\left(F_{k_m,0}-\delta\right)\right)\left(k_{m,0}+d_0\right)+\left(1-\tau_0^{k_n}\right)\left(1-\delta_n\right)k_{n,0}\right]$.

Equation (18) is generally referred to as the implementability constraint, since it is a constraint on the set of allocations that can be implemented as a competitive equilibrium with distorting taxes. Let Φ be a Lagrange multiplier on (18) and define

$$V=u\left(c_t,s_t,1-h_{m,t}-h_{n,t},k_{n,t}\right)+ \Phi\left[u_{c_t}\left(c_t-\tfrac{\Psi}{1+\tau^c}\right)+u_{s_{m,t}}s_{m,t}+u_{h_{m,t}}h_{m,t}+\beta u_{\widetilde{k}_{n,t+1}}k_{n,t+1}\right]. \tag{19}$$

To formulate the planning problem, we can substitute away s_m and s_n and instead directly use

[10] q_0 is normalized to unity.

production functions (3) and (6). Taking (15) into account, services in period t can be written as

$$s_t \equiv s\left(F^s\left(k_{s,t},\left(h_{g,t}k_{s,t}\right)/k_{g,t}\right), f^S\left(k_{n,t}, z_n h_{n,t}\right)\right). \tag{20}$$

The Ramsey problem can then be formulated as

$$\begin{aligned} \max_{\{c_t,k_{g,t+1},k_{s,t+1},k_{n,t+1},h_{g,t},h_{n,t}\}_{t=0}^{\infty}} & \sum_{t=0}^{\infty}\left\{\beta^t V\left(c_t, s_t, 1-h_{m,t}-h_{n,t}, k_{n,t}\right)\right. \\ & -\lambda_t\left[c_t+k_{g,t+1}+k_{s,t+1}+k_{n,t+1}+g_t-F^g\left(k_{g,t},h_{g,t}\right)\right. \\ & \left.-\left(1-\delta\right)\left(k_{g,t}+k_{s,t}\right)-\left(1-\delta_n\right)k_{n,t}\right]-\chi_t W_t-\Phi V^0. \end{aligned} \tag{21}$$

The equations that characterize the Ramsey equilibrium are the optimality condition for home production (11), the resource constraint (16), the market-clearing condition for services (17), the household's present-value constraint (18) and the first-order conditions to (21).

3 Optimal tax formulas

By allowing transfers to be zero in the Ramsey allocation, it is possible to derive optimal tax formulas. For $t > 1$, they are given by:[11]

$$\tau_t^{k_m} = 0, \tag{22}$$

[11] See Appendix A.1. The optimal tax rates in period $t = 1$ only differ from those in (22)-(24) in that (22) and (24) then both contain an extra term that captures the usual spike in the tax rate for capital in the first period of the transition.

$$
\begin{aligned}
1+\tau_t^s &= (1+\tau^c) \\
&\cdot \left[1-\left(\Phi\frac{\partial}{\partial h_{g,t}}\left(u_{c_t}c_t+u_{s_{m,t}}s_{m,t}+u_{\widetilde{k}_{n,t}}k_{n,t}\right)-\chi_t\frac{\partial}{\partial h_{g,t}}u_{h_{n,t}}\right)\frac{h_{g,t}}{u_{c_t}s_{m,t}(1-\alpha)}\right],
\end{aligned}
\tag{23}
$$

$$
\begin{aligned}
\tau_t^{k_n} &= \left(\frac{R_t}{1-\delta_n}-1\right)\tau^c \\
&-\left[\Phi\frac{\partial}{\partial k_{n,t}}\left(u_{c_t}c_t+u_{s_{m,t}}s_{m,t}+u_{\widetilde{k}_{n,t}}k_{n,t}\right)-\chi_t\frac{\partial}{\partial k_{n,t}}\left(u_{h_{n,t}}-u_{l,t}\right)\right]\frac{1+\tau^c}{(1-\delta_n)u_{c_t}}.
\end{aligned}
\tag{24}
$$

As in Chamley (1986) and Judd (1985), the optimal tax rate on industrial capital is zero. Hence, untaxable home production does not change this result. The optimal tax formula for services (23) shows that, as in Atkinson and Stiglitz (1976), commodity taxes should be uniform across goods and market services when the utility function is weakly separable between labor and all commodities. In that case, all the derivatives with respect to $h_{g,t}$ are zero and $\tau_t^s = \tau^c$. Otherwise, commodities that are substitutable with labor increase the optimal service tax whereas commodities that are complementary to labor decrease the tax. This result resembles Corlett and Hague (1953).[12]

Note then that from the agent's first order condition for home hours (11), the marginal utility from an additional home hour is directly linked to the marginal disutility from work. This implies that if preferences are not weakly separable in home production and all traded commodities then they will not be weakly separable in labor and all traded commodities either. In particular, non-separability between the two types of services implies that the A-S theorem does not apply. The optimal service tax should then adjust the relative price between home and market services such

[12] It follows from (1) and (4) that if a commodity is substitutable with labor, then it is complementary to leisure and/or home hours. Corlett and Hague (1953) consider a setting without home production and show that the optimal tax system implies relatively high taxes on commodities that are complementary to leisure.

that it also takes the distortions on market production from untaxed home production into account. To make progress, it is useful to introduce more structure. For the quantitative part of the paper, the representative agent is assumed to have the following preferences:[13]

$$u\left(c_t, s_t, l_t, k_{n,t}\right) = \log\left(c_t^{\eta} s_t^{1-\eta}\right) + \varphi_1 \frac{l_t^{1-\mu}}{1-\mu} + \varphi_k \log k_{n,t}, \tag{25}$$

and

$$s\left(s_{m,t}, s_{n,t}\right) = \left[\theta\left(s_{m,t}\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\theta)\left(s_{n,t}\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}. \tag{26}$$

With these preferences, it is straightforward to verify that when home services are substitutes with market services (i.e., when $\varepsilon > 1$), the derivatives $\partial\left(u_{c_t} c_t\right)/\partial h_{g,t}$, $\partial\left(u_{s_{m,t}} s_{m,t}\right)/\partial h_{g,t}$ and $-\partial u_{h_{n,t}}/\partial h_{g,t}$ in (23) are all weakly positive, whereas the derivative $\partial\left(u_{\widetilde{k}_{n,t}} k_{n,t}\right)/\partial h_{g,t}$ is negative.[14] In addition, the three positive derivatives then strictly dominate the negative derivative, thus implying that the optimal tax on services should be lower than the tax on goods. This result is reversed when home services are instead complements to market goods and services (i.e., when $\varepsilon < 1$).

[13] For simplicity, the utility function is additively separable between goods and services on the one hand, and leisure and the direct utility from home capital on the other hand. This significantly reduces the number of cross derivatives that must be computed in the numerical section. It is possible to argue that many durable goods are instead more realistically characterized as complements to leisure rather than inputs into home production. However, allowing for two types of home capital that can be taxed at different rates would complicate the model without adding much theoretical insight. We already know from Corlett and Hague (1953), Kleven (2004) as well as from equation (24) that goods that are complementary to leisure should be taxed at a relatively higher rate. Since it would also be difficult to assess which durables that are used for home production and which that are used for leisure, home capital that is complementary to leisure is abstracted from. It is, however, straightforward to consider this margin in future work.

[14] See Appendix A.1.

Intuitively, the first best outcome requires uniform taxation of all commodities, including leisure and home production. With preferences given by (25)-(26), all traded goods and services are equally substitutable for leisure. It is therefore not possible to use non-uniform taxation to tax leisure. However, when home and market services are substitutes, a reduction in the tax rate on market services is equivalent to a tax on home production since it increases the relative price of home production. When the two types of services are instead complements, a tax on market services is equivalent to a tax on home production because the two types of services are then consumed together.[15]

The optimal tax formula for home capital (24) is somewhat involved, partly because only a fraction of the return to home capital can be taxed. The term $\left(\frac{R_t}{1-\delta_n} - 1\right)\tau^c$ neutralizes the distortion generated by τ^c in the investment decision for home capital. Too see this, note from the agent's first-order condition (13), that the return to home capital consists of two parts. First, the agent derives utility from the home-produced and direct services that home capital produce. Second, she can also derive utility from consuming what is left of the investment after depreciation and the tax on home capital has been paid. Because only the latter part is taxed at a rate of τ^c, the consumption tax drives a wedge between the two parts of the return to home capital. The multiplication of τ^c in the first term and $1 + \tau^c$ in the second term of (24) removes this wedge.

Substituting the optimal tax rate on home capital (24) into the agent's first order condition for home capital (13) delivers

[15] These results are consistent with several previous studies. Kleven et al. (2000) set up a model that is similar to the one in this paper. They abstract from (both home and industrial) capital and they assume home and market services to be perfect substitutes. In that setting, they show that market services should carry a lower tax rate than goods. Kleven (2004) analyzes optimal taxes in a setting where agents combine market goods and time in a Leontief production function to derive utility. The optimal tax system then features relatively low taxes on market goods that requires little household time. Market services save time so they should therefore have a low or negative tax rate. The conclusion is thus the same as in this paper, but the argument is different. See also Sandmo (1990).

$$(27) \quad \frac{u_{\widetilde{k}_{n,t}}}{u_{c_t}} + 1 - \delta_n + \frac{1}{u_{c_t}} \left[\Phi \frac{\partial}{\partial k_{n,t}} \left(u_{c_t} c_t + u_{s_{m,t}} s_{m,t} + u_{\widetilde{k}_{n,t}} k_{n,t} \right) - \chi_t \frac{\partial}{\partial k_{n,t}} \left(u_{h_{n,t}} - u_{l,t} \right) \right] = R_t.$$

When preferences are weakly separable between home capital and all commodities, the term in square brackets on the left hand side of (27) is zero (because all the derivatives with respect to $k_{n,t}$ are then zero). The private return to home capital ($u_{\widetilde{k}_{n,t}}/u_{c_t} + 1 - \delta_n$) is then equal to the return to industrial capital (R_t). Since industrial capital is untaxed according to (22), equation (27) is identical to the first order condition that would result in an economy without any taxes. The positive optimal tax rate on *the stock* of home capital thus effectively implies a zero tax rate on *the total return* to home capital.

The term in square brackets in (24) takes into account that the accumulation of home capital can also potentially distort the demand for market-produced goods and services. The representative agent views market production as exogenous, but the Ramsey planner acknowledges that the level of home capital generally affects the level of market production. The agent will therefore also generally invest an inefficient amount of home capital. In fact, only when preferences are weakly separable in home capital and all commodities will there be no distortions from home capital. Otherwise, the tax rate depends on how home capital affects the demand for market produced goods and services as well as home hours and leisure.

With preferences given by (25)-(26), it is again possible to show that when home services are substitutes with market services, the derivatives $\partial \left(u_{c_t} c_t \right) / \partial k_{n,t}$, $\partial \left(u_{s_{m,t}} s_{m,t} \right) / \partial k_{n,t}$ and $-\partial u_{h_{n,t}} / \partial k_{n,t}$ in (24) are all weakly negative, whereas the derivative $\partial \left(u_{\widetilde{k}_{n,t}} k_{n,t} \right) / \partial k_{n,t}$ is positive.[16] In addition,

[16] Note that if home capital and leisure are complements (i.e., $\partial u_{l,t} / \partial k_{n,t} < 0$), then this also increases the optimal

the three negative derivatives strictly dominate the positive derivative such that the optimal tax on home capital should be strictly positive to offset the distortions from home capital on market activity. This result is then reversed when the two types of services are complements. In this case, home capital should be subsidized. Since basically all empirical studies find home and market services to be substitutes, the tax rate on services should be lower than the tax rate on goods and the tax rate on the return to home capital should be strictly positive.

Finally, the labor tax rate is essentially a residual that must be set to the value that exactly balances the government's budget constraint.

4 Calibration

Let us now calibrate the model to match the U.S. In addition, since the model successfully predicts European market and home hours when furnished with European policy instruments, optimal tax rates on capital, home capital, labor and services are computed for both the U.S. and Europe. European values for policy and hours are computed as averages of values in Belgium, Denmark, France, Germany, Italy, the Netherlands, Sweden and the U.K.

The preference parameters are β, μ, η, φ_1, φ_2, θ and ε. One period is assumed to be one year and the parameter β is set to 0.96 in order to generate a steady-state interest rate around four percent. The parameter μ is set to 5, which implies that the intertemporal (Frisch) elasticity of substitution for labor is 0.50.[17] The parameter η in the utility function is set to 0.20, so that roughly fifty percent of private consumption comes from services as in the U.S.[18] The weight parameter

tax rate on home capital. This is, again, the result in Corlett and Hague (1953).

[17] Estimates of the Frisch elasticity of labor supply elasticity for men in the labor force are found in the interval 0-0.3. See Browning et al. (1999) for a survey. Estimates for women are generally higher.

[18] The average share of market services in GDP is around 50 percent in the raw data for the period 1980-2007 (EU KLEMS, 2009).

on leisure, φ_1, is chosen to match the fact that Americans work 26.50 hours per week on average, which implies $\varphi_1 = 0.151$.[19] The weight on market services θ, is set to 0.3595 to match the fact that Americans devote 39 percent of their total working time to home production.[20]

A key parameter governing a household's choice between market-produced and home-produced services is the elasticity of substitution between these goods, i.e., ε. Estimates of the elasticity ε are found to have a wide range in the literature. McGrattan, Rogerson and Wright (1997) use aggregate time series for a business-cycle model with home production to assess the elasticity. They find an elasticity in the range 1.7-1.8. Using micro data that include information on time spent in home production, Rupert, Rogerson and Wright (1995) find similar values. Chang and Schorfheide (2003) find higher values: 2.2-2.5. These values all correspond to the elasticity of substitution between all market and non-market consumption, whereas the model refers to the elasticity between market and non-market services. For this reason, Ragan (2005) calibrates the elasticity to be 10. Against this background, ε is set to 2.5 in the benchmark calibration, but a lower value is considered in the sensitivity analysis.

The parameter φ_k is the weight on home capital in the utility function. I set $\varphi_k = 0.36$, which implies that industrial capital constitutes roughly 50 percent of the total capital. This is consistent with the estimate in Feldstein (1980). In the sensitivity analysis, an alternative value is considered.

Turning now to production parameters, Bridgman (2013) estimates that productivity in home production in the U.S. has been between 0.4-0.6 of the productivity in market work since 2000.

[19] To compute hours worked per person and week, total hours worked per year are first divided by the number of persons aged 15-64. This number is then divided by 52 (weeks per year). If we assume 100 productive hours per week, the numbers express both hours in percent of total productive time and hours per week. Data on total hours worked are taken from EU KLEMS (2009) and data on the population aged 15-64 are taken from the OECD database on Employment and Labor Market Statistics.

[20] The estimate for time spent in home production in the U.S. is 17.15 hours per person and week, which is taken from Olovsson (2009).

Based on this estimate, z_n is set to 0.55, thus implying that home productivity is roughly half the value of market productivity (which is normalized to one). This value is also varied in the sensitivity analysis. Parameter α governs capital's share of income and is set to its standard value of 0.30.

The depreciation rate for home capital is set to 0.2, which is based on the estimate in Baxter (1996).[21] The depreciation rate for productive capital is set to 0.12. This is slightly higher than the standard value (around 0.08), and it is needed to prevent the ratio of the residential stock relative to the total capital from becoming too high. As in almost all macroeconomic models, however, the level of the depreciation rate is quantitatively unimportant for the results.

Data on initial debt are taken from the National Accounts and set to 0.80 for Europe and 0.65 for the United States.[22] Government consumption is set to 25 and 20 percent of GDP for Europe and the U.S, respectively.

Average effective tax rates (AETRs) on labor, consumption, services and industrial capital are estimated from National Accounts data and Revenue Statistics. Due to a lack of data, however, the tax rates on home capital are calibrated instead of estimated. Specifically, τ^{k_n} is computed as a weighted average of the tax on durables and the property tax. Tax rates on property are estimated in OECD (2014), durable goods are assumed to be taxed at the rate of τ^c and the weight on residential housing is 35 percent (as in Baxter, 1996).[23] Details about the estimation procedure

[21] Baxter defines the bundle of durable consumption goods as an aggregate which includes the National Income and Product Accounts (NIPA) definition combined with the stock of residential housing. Using an annual depreciation for the NIPA goods of 22%, an annual rate just below 4% for housing and a weight on residential housing of 0.35, Baxter computes the weighted average depreciation rate for aggregate consumption durables to be about 0.16. Since then, however, a number of goods with much higher depreciation rates (such as computers, software, cell phones, electronic tablets etc.) have become increasingly more important. The depreciation rate for computers, for example, is about 0.55. For this reason, I set the depreciation rate for durable goods to be slightly higher than the estimate by Baxter.

[22] Values for 2010.

[23] Note that the tax on home capital has to be paid in every period that undepreciated home capital remains. The NPV of the steady-state tax rate on one unit of home capital is 6 and 12 percent for the U.S. and Europe respectively.

are found in Appendix A.3 and the estimated tax rates are shown in Table 1.

Table 1: AETRs in Europe and the U.S.

τ^{s}_{EU}	τ^{c}_{EU}	τ^{h}_{EU}	$\tau^{k_m}_{EU}$	$\tau^{k_n}_{EU}$	τ^{s}_{US}	τ^{c}_{US}	τ^{h}_{US}	$\tau^{k_m}_{US}$	$\tau^{k_n}_{US}$
17.00	17.00	40.00	25.00	3.53	0.00	8.00	26.79	28.00	1.79

AETRs in percent in the initial steady states.

Ragan (2005) shows that the amount of time spent in home production in Europe is 8-16 percent higher than in the U.S.[24] Since Europe in this study is an average across several countries, I set European home hours to be 13 percent higher than in the U.S., which is close to the mean of the interval.[25] Data and model predictions on market and home hours in steady states are shown in Table 2.

Table 2: Hours worked per person in the data and the steady state of the model

	Data		Model	
	U.S.	Europe	U.S.	Europe
Market work	26.50	22.00	26.50	22.77
Home production	17.15	19.40	17.15	19.98

Hours worked in percent of total productive time. Source for market hours: EU KLEMS, November 2009.

5 Results

The results for the benchmark calibration are reported in this section. Results with alternative calibrations are reported in Section 6.

5.1 Optimal taxation

Actual and optimal tax rates for the U.S. and Europe are displayed in Table 3.

[24] Home hours in Italy and the Netherlands are missing from the data.

[25] The estimate for hours spent in home production in Sweden is significantly lower in Ragan (2005) than in Olovsson (2009). In the former study, there is no difference between Sweden and the U.S., whereas in the latter study home hours are 11 percent higher in Sweden than in the U.S. Time-use surveys are generally hard to compare, but Olovsson made use of a time-use survey that is claimed to be comparable for Sweden and the U.S. For this reason, European home hours are set to a value slightly higher than the mean of the interval.

Table 3: Actual and optimal steady-state tax rates

	τ^{k_m}	τ^{k_n}	τ^{h}	τ^{s}	τ^{c}
AETRs in the U.S.	28.00	1.79	26.79	0.00	8.00
Optimal steady-state tax rates for the U.S.	0.00	3.32	12.99	0.61	8.00
AETRs in Europe	25.00	3.53	40.00	17.00	17.00
Optimal steady-state tax rates for Europe	0.00	9.96	7.46	12.35	17.00

All tax rates are in percent. τ^c is exogenous for the Ramsey planner.

The main qualitative intuition behind these tax rates has already been provided in Section 3. The optimal steady-state tax rate on capital is zero as shown in (22). The optimal tax rate on services is close to zero for the U.S. and is significantly lower than the tax rate on goods for Europe. The optimal tax rates on home capital are higher than current tax rates. Labor taxes are significantly lower in the Ramsey equilibrium. Intuitively, with higher tax rates on home capital, more efficient production and with the government holding negative quantities of debt, the labor tax can be reduced.[26]

5.2 Initial steady states versus Ramsey equilibria

Initial steady states are compared with steady states in the Ramsey equilibria for the U.S. and Europe, respectively, in Table 4. Figures 1 and 2 in Appendix A.4 plot the full transition. The welfare measure used is the constant percentage amount by which the consumption of goods, market services and home capital must be increased in all periods in the benchmark economy so as to yield the same utility as under the policy experiment.

The results show that except for home hours, all variables are higher in the Ramsey than in the initial allocations. The reduction in home hours leads to a reduction in home production.[27] For

[26] The initial debt level is 80 and 65 percent of GDP, respectively, for Europe and the United States. In the Ramsey equilibria, the debt levels are around -40 percent of GDP for both regions.

[27] Figure 1 in the Appendix shows that the steady-state level of home production is lower in the Ramsey allocation than in the initial allocation.

the U.S., market hours are about ten percent higher and home hours are roughly thirteen percent lower.

Table 4: Steady-state allocations and total welfare gains

	c	s_m	k_m	k_n	h_m	h_n	Welfare gain
U.S. - Initial allocation	4.66	4.40	55.92	53.77	26.50	17.15	0.00
U.S. - Ramsey allocation	5.38	5.98	70.74	58.23	29.25	15.18	2.60
Europe - Initial allocation	3.83	2.44	48.95	46.68	22.77	19.98	0.00
Europe - Ramsey allocation	5.30	5.50	67.76	52.11	28.01	15.98	9.10

Steady-state values for c, s_m, k_m, k_n, h_m and h_n. The welfare gains take the full transitions into account.

The stock of industrial capital is significantly higher in the Ramsey allocation than in the initial economies. As in the standard model without home production, capital accumulation is stimulated by the zero tax rate on industrial capital. In the model with home production, an additional effect emanates from the reallocation of labor from the home sector to the market sector. The increase in labor supply also stimulates savings since the interest rate is high when the capital/labor ratio is low.

The stock of home capital is higher in the Ramsey allocation. This might be surprising given that the tax rate on home capital is higher in the Ramsey allocations than in the initial economies. The intuition for this is that the switch to the Ramsey economy creates income and substitution effects. The income effect is due to the removal of distortions. Fewer distortions enable a higher income, and a higher income increases the consumption level of all normal goods. For home capital, the higher tax rate also creates a substitution effect and this has a negative effect on the stock of home capital. The stock of home capital will then increase if the income effect dominates the substitution effect even though the Ramsey tax rate on home capital is larger than the initial tax rate.

For market services, a lower tax rate in combination with a higher average income contribute to a higher consumption level of market services. The increase in market services is larger for Europe than for the U.S., because the tax rate on services is reduced by more in Europe. The effects are larger for Europe in general. In particular, labor supply increases by 23 percent and the size of the service sector more than doubles after implementation of the optimal policy. In contrast, home hours decrease by 25 percent. Even though these effects are large, the difference in labor supply is smaller than the real-world difference in labor supply between France and the U.S., which is 30 percent.

5.3 Welfare

The welfare gains associated with the transitions are large and equal to 2.60 and 9.10 percent, respectively, for the U.S. and Europe. As a comparison, the largest welfare gain found by Chari, Christiano and Kehoe (1994) in a stochastic setting is just above six percent. In a standard model without home production, a large part of the welfare gain is due to the high tax rate on capital in the first period of the transition.[28] The high initial tax rate forces the agent to consume a large part of her capital to safeguard it from taxation. This creates a spike in first-period consumption. In contrast, with home production, the high initial tax rates on capital only cause a drop in the stock of home capital whereas the stock of industrial capital is basically unaffected (as can be seen in Figure 1). As in the standard model, however, the reduction in (home) capital also generates a spike in first-period consumption.

The transitional properties of the optimal tax scheme can easily be criticized as lacking realism. In practice, it could be difficult to implement capital tax rates around 1 000 percent (see Figure 2 in the Appendix). To analyze the extent to which welfare gains depend on the initial tax rates

[28] See Chari et al. (1994).

in the model with home production, capital taxes are now restricted to below a threshold level. Specifically, it is assumed that capital tax rates are not permitted to increase. The following restrictions are thus added to the Ramsey problem as stated in (21): $\tau^{k_m}_{EU,t} \leq \tau^{k_m}_{EU}$, $\forall t$ and $\tau^{k_m}_{US,t} \leq \tau^{k_m}_{US}$, $\forall t$, where $\tau^{k_m}_{EU}$ and $\tau^{k_m}_{US}$ are the initial steady-state tax rates that are reported in Table 1. The welfare effects and the optimal steady-state tax rates associated with this exercise are shown in Table 5, and the full transitions are plotted in Figures 1 and 2 in the Appendix.

Table 5: Optimal steady-state tax rates and total welfare gains with restrictions on capital taxes

	τ^{k_m}	τ^{k_n}	τ^h	τ^s	Welfare
U.S.	0.00	3.88	20.74	-2.67	1.63
Europe	0.00	12.14	16.15	11.81	7.39

Steady-state values for τ^{k_m}, τ^{k_n}, τ^h, and τ^s. All tax rates are in percent. The welfare gains take the full transitions into account.

The results show that restrictions on capital taxes lead to higher steady-state tax rates on labor and home capital, and to a lower steady state tax rate on services. Even though welfare gains are lower, they are still significant. In particular, Europe would benefit substantially from a tax reform. As can be seen in Figure 1, the spike in first-period consumption disappears when the capital tax is not allowed to increase and this is what reduces the welfare effects. Capital is instead reallocated from the home sector to the goods sector in the first period of the transition.

6 Sensitivity analysis

In this section, alternative values for three potentially important parameters, z_n, φ_k and ε, are considered in order to evaluate their quantitative effects on tax rates and welfare effects. In the benchmark calibration, the representative agent's labor productivity in home production is equal to roughly half of her labor productivity in market work. Here, the labor productivities in these two activities are assumed to be the same. The benchmark calibration of the taste parameter for home capital involves matching the ratio of market capital to the total capital stock. In this section, the extreme value of $\varphi_k = 0$ is considered. This means that the agent does not receive any direct utility from holding home capital. The elasticity of substitution between market and home services is set to a more conservative estimate of 1.8. Optimal U.S. steady-state tax rates and welfare effects for all three cases are displayed in Table 6.[29]

Table 6: Optimal steady-state tax rates and total welfare gains with alternative parameter values

	$\tau_{US}^{k_n}$	τ_{US}^{h}	τ_{US}^{s}	Welfare
$z_n = 1$	3.24	12.39	0.32	2.67
$\varphi_k = 0$	4.77	17.40	-0.94	2.76
$\varepsilon = 1.8$	3.21	13.30	3.12	2.23

Steady-state values for $\tau_{US}^{k_n}$, τ_{US}^{h}, and τ_{US}^{s}. All tax rates are in percent. The welfare gains take the full transitions into account.

The table shows that the magnitudes of the welfare gains do not seem to be sensitive to large changes in the parameters. It is possible to use the optimal tax formulas in section 3 to understand the effects of the parameters on the optimal tax rates. Hours and consumption levels are not reported in the table, but a higher z_n is associated with higher levels of both home hours and home capital. Intuitively, higher labor-productivity in home production makes home production a more attractive alternative. It is straightforward to verify that, with preferences given by (25)-(26), all the derivatives with respect to k_n in (24) decrease and that the multiplier χ_t increases relative to in the benchmark economy.[30] As a result, the optimal tax on services is lower and the optimal tax rate on home capital is higher than in the benchmark economy.

Similarly, a lower utility weight on home capital makes the agent hold less home capital. With the considered preferences, all the derivatives with respect to k_n in (24) then increase, which implies

[29] Each row reports the tax rates and welfare effects associated with the change of one parameter. This implies that the initial economy no longer exactly matches all calibration targets for the United States. Steady-state taxes on industrial capital are not reported because they are zero in all cases.

[30] All derivatives with respect to k_n in (24) are inversely proportional to k_n. The multiplier χ_t is given by (29).

a higher tax rate on home capital. Finally, a lower elasticity directly implies a higher tax rate on services and a lower tax rate on home capital relative to the benchmark calibration.

The labor tax rate is residually determined and must be increased (decreased) when the tax revenues from consumption goods, market services and home capital are decreased (increased). The sensitivity analysis shows that the welfare effects are not that sensitive to the considered parameters and that the main results are fairly robust to relatively large changes in the parameters.

7 Discussion

As all economic models, the model here is a stylized version of the real world and it incorporates several simplifying assumptions. This discussion focuses on some of the key assumptions and the potential implications of relaxing them. Consider first the fact that the utility function in the model features a constant elasticity of substitution (CES) between home and market services. This assumption is standard in the macroeconomic literature, but a relevant question is how the results would change with a non-constant elasticity of substitution.[31] The preceding analysis shows that this elasticity determines the extent to which the planner can use other tax rates to influence the relative price of home production. This should be true independent of whether the elasticity is constant or not. Hence, even though overall effects could be smaller with a decreasing elasticity of substitution, a decreasing elasticity is unlikely to overturn the result of a lower tax rate on services. The properties of the elasticity of substitution are important, however, for the exact values of the optimal tax rates and the welfare effects.

One way to achieve a connection between the micro and the macro literature would be to make

[31] A non-constant elasticity is often assumed in the theoretical literature. See for instance Ermisch (2003).

home capital a lumpy investment. Small reform changes would then only produce small changes in home hours, because the stock of home capital is left unaffected. The implication is a decreasing elasticity of substitution between home and market services for small reforms. Large reforms, however, also generate investments in home capital and therefore also lead to a larger response in home hours. Lumpy home capital is a realistic assumption, but it mainly affects the transition and the size of the welfare effects, and not the optimal steady-state tax rates.

Second, the model abstracts from technological progress. In contrast, Greenwood et al. (2005) argue that technological progress in the home sector is important for explaining the reduction in housework and the increase in market work during the 20th century. Their model differs from the one in this paper in two important respects: (i) they assume the production function for home services to be Leontief in hours and capital (whereas it is Cobb-Douglas in this paper); and (ii) they assume that technical change is investment specific (whereas it would be Hicks neutral here). These specific assumptions are important for the results. If the substitution elasticity between home capital and home hours is higher than one, the tax rate on home capital is potentially a more efficient instrument for reducing home hours. Similarly, if technical change in home production is embodied in home capital, the planner might want to stimulate R&D in that sector and also encourage its adoption.

Third, our model abstracts from heterogeneity and a relevant question is if the main results in this paper would change if heterogeneity were incorporated into the model. However, heterogeneity does not alter the fact that non-separability between the two types of services makes the A-S theorem break down. It therefore seems likely that also with heterogeneity, the planner will implement lower tax rates on market services and then use differentiated labor tax rates to achieve the desired level of redistribution. A formal analysis of heterogeneity has to be left for future research.

The optimal policy could, however, have implications for redistribution. Specifically, in a setting where low-skilled agents work in the service sector, and high-skilled agents work in the goods sector, the relative wage between the two sectors could be affected. Since the service sector expands more than the goods sector under the optimal policy, the wage rate and the labor supply are both expected to increase relatively more in the service sector. An increase in the supply of market-produced services is then likely to benefit the low skilled more than the high skilled.[32,33]

Fourth and finally, the quantitative part abstracts from the fact that goods and services may be more or less complimentary to leisure and that this may be important for the optimal tax rates. It would, however, be straightforward to consider this dimension, since the optimal tax formula for services (23) captures this margin. The results in Kleven (2004) also suggest that such an extension only should strengthen the results in this paper.[34] A formal analysis of this aspect also has to be left for future research.

8 Conclusions

In this paper, optimal tax policy is analyzed in a fully dynamic setting in which a representative agent takes decisions on how to allocate her income between consumption goods, market services and savings. The agent also chooses how to allocate her time between market work, home production and leisure. The first and theoretical part of the paper derives analytical optimal tax formulas for market-produced services, home capital and industrial capital. It shows that as in Atkinson-

[32] More work in the service sector can be due to longer work weeks. If skill formation is endogenous, it can also arise because more people choose to remain unskilled. This requires that the return to unskilled work (i.e., the wage rate) increases in relative terms.

[33] Another concern could emerge from the suspicion that only high-income agents consume market services, and that they may therefore gain more than the poor. Olovsson (2009), however, documents that low-income households also spend a large fraction of their income on market services.

[34] See footnote 15.

Stiglitz (1976), commodity taxes should be uniform across goods and services if the utility function is weakly separable between labor and all commodities. However, if home production requires time as an input, a necessary condition for weak separability between labor and all commodities is weak separability between home production and all commodities. It also shows that the accumulation of home capital can distort the demand for market-produced goods and services. As a result, if home and market services are substitutes (complements) then services should be taxed at a lower (higher) rate than goods and the tax on the return to home capital is strictly positive (negative). The optimal steady-state tax rate on industrial capital is still zero. Therefore, untaxable home production does not change this result.

In the second and quantitative part of the paper, the model is calibrated and optimal tax rates on capital, home capital, labor and services are computed for Europe and the United States. The results from this exercise show that the optimal tax rates on services are substantially lower than tax rates on goods and that the return to home capital should be taxed at a strictly positive rate. In addition, there are large welfare gains from implementing optimal taxes. These welfare gains do not rely on a very large initial tax rate on capital.

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A Appendix

A.1 First order conditions in the Ramsey problem

For $t \geq 1$ the first order conditions in the Ramsey problem in (21) with respect to $h_{g,t}$, $h_{n,t}$, $k_{g,t+1}$, $k_{s,t+1}$ and $k_{n,t+1}$ are given by

(28)
$$0 = \frac{(1-\alpha)u_{s_{m,t}}}{h_{g,t}} - \frac{\partial u_{l_t}}{\partial h_{g,t}}\frac{h_{m,t}}{h_{g,t}} + u_{c_t}(1-\alpha)k_{g,t}^{\alpha}h_{g,t}^{-\alpha} - \chi_t \frac{\partial}{\partial h_{g,t}}\left(u_{s_{n,t}} f_{h_{n,t}}^{s} - u_{l,t}\right)$$
$$+\Phi\frac{\partial}{\partial h_{g,t}}\left[u_{c_t}c_t + u_{s_{m,t}}s_{m,t} + u_{k_{n,t}}k_{n,t} - u_{l,t}h_{m,t}\right];$$

(29)
$$\chi_t = \Phi\frac{\frac{\partial}{\partial h_{n,t}}\left(u_{c_t}c_t + u_{s_{m,t}}s_{m,t} + \left(u_{k_{n,t}} + u_{s_{n,t}} f_{k_{n,t}}^{s}\right)k_{n,t} - u_{l_t}h_{m,t}\right)}{\frac{\partial}{\partial h_{n,t}}\left(u_{s_{n,t}} f_{h_{n,t}}^{s} - u_{l,t}\right)};$$

(30)
$$(1-\alpha)\frac{u_{s_{m,t+1}}}{k_{g,t+1}} = u_{h_{m,t+1}}\left(h_{g,t+1}k_{s,t+1}/k_{g,t+1}^{2}\right) + u_{c_{t+1}}\alpha k_{g,t+1}^{\alpha-1}h_{g,t+1}^{1-\alpha} + u_{c_{t+1}}(1-\delta)$$
$$-u_{c_t}/\beta - \chi_{t+1}\frac{\partial}{\partial k_{g,t+1}}\left(u_{s_{n,t+1}} f_{h_{n,t+1}}^{s} - u_{l,t+1}\right)$$
$$+\Phi\frac{\partial}{\partial k_{g,t+1}}\left[u_{c_{t+1}}c_{t+1} + u_{s_{m,t+1}}s_{m,t+1} + u_{k_{n,t+1}}k_{n,t+1} - u_{l,t+1}h_{m,t+1}\right];$$

(31)
$$0 = \frac{u_{s_{m,t+1}}}{k_{s,t+1}} - u_{h_{m,t+1}}\left(h_{g,t+1}/k_{g,t+1}\right) - u_{c_t}/\beta + u_{c_{t+1}}(1-\delta) - \chi_{t+1}\frac{\partial}{\partial k_{s,t+1}}\left(u_{s_{n,t+1}} f_{h_{n,t+1}}^{s} - u_{l,t+1}\right)$$
$$+\Phi\frac{\partial}{\partial k_{s,t+1}}\left[u_{c_{t+1}}c_{t+1} + u_{s_{m,t+1}}s_{m,t+1} + u_{k_{n,t+1}}k_{n,t+1} - u_{l,t+1}h_{m,t+1}\right];$$

$$
(32) \qquad u_{\tilde{k}_{n,t+1}} = u_{c_t}/\beta - u_{c_{t+1}}(1-\delta_n) + \chi_{t+1}\frac{\partial}{\partial k_{n,t+1}}\left(u_{s_{n,t+1}} f^s_{h_{n,t+1}} - u_{l,t+1}\right)
$$
$$
-\Phi\frac{\partial}{\partial k_{n,t+1}}\left[u_{c_{t+1}}c_{t+1} + u_{s_{m,t+1}}s_{m,t+1} + u_{k_{n,t+1}}k_{n,t+1}\right],
$$

To obtain the first-order conditions for period 0, add $-\Phi V^0_c/\beta$ to the r.h.s. of equations (30)-(31), add $\Phi V^0_c/\beta$ to the r.h.s of (32) and subtract $\Phi V^0_{h_g}$ from the r.h.s. of equation (28).[35]

The optimal tax formula (22) can be derived by combining (12), (28) and (30). The optimal tax formula (23) can be derived by combining (28), (30) and (31). Finally, the optimal tax formula (24) can be derived by combining (13) with (32).

With preferences given by (25)-(26), the derivatives in Section 3 are given by $\frac{\partial u_{c_t}c_t}{\partial h_{g,t}} = 0$; $\frac{\partial u_{s_{m,t}}s_{m,t}}{\partial h_{g,t}} = \frac{\varepsilon-1}{\varepsilon}(1-\alpha)(1-\eta)(1-\theta)\theta\frac{\Delta}{h_{g,t}}$; $\frac{\partial u_{\tilde{k}_{n,t}}k_{n,t}}{\partial h_{g,t}} = -\alpha\frac{\partial u_{s_{m,t}}s_{m,t}}{\partial h_{g,t}}$; $\frac{\partial u_{h_{n,t}}}{\partial h_{g,t}} = -\frac{\varphi_1(1+k_{s,t}/k_{g,t})}{(1-h_{m,t}-h_{n,t})^2} -\frac{\varepsilon-1}{\varepsilon}(1-\alpha)^2(1-\eta)(1-\theta)\theta\frac{\Delta}{h_{n,t}h_{g,t}}$; $\frac{\partial u_{c_t}c_t}{\partial k_{n,t}} = 0$; $\frac{\partial u_{s_{m,t}}s_{m,t}}{\partial k_{n,t}} = -\frac{\varepsilon-1}{\varepsilon}(1-\eta)\theta(1-\theta)\alpha\frac{\Delta}{k_{n,t}}$; $\frac{\partial u_{\tilde{k}_{n,t}}k_{n,t}}{\partial k_{n,t}} = -\alpha\frac{\partial u_{s_{m,t}}s_{m,t}}{\partial k_{n,t}}$, and $\frac{\partial u_{h_{n,t}}}{\partial k_{n,t}} = \frac{\varepsilon-1}{\varepsilon}(1-\alpha)(1-\eta)(1-\theta)\alpha\theta\frac{\Delta}{k_{n,t}h_{n,t}}$, and where $\Delta \equiv \frac{(s_{n,t})^{\frac{\varepsilon-1}{\varepsilon}}(s_{m,t})^{\frac{\varepsilon-1}{\varepsilon}}}{\left(\theta(s_{m,t})^{\frac{\varepsilon-1}{\varepsilon}}+(1-\theta)(s_{n,t})^{\frac{\varepsilon-1}{\varepsilon}}\right)^2}$.

A.2 Numerical Computation

The algorithm that is used to find the equilibrium starts by fixing the initial tax rates on market and home capital, $\tau_0^{k_m}$ and $\tau_0^{k_n}$. The next step is to make a guess on a multiplier Φ and solve for the transition using the equations specified in Section 2.5. The third step is to check whether the adjusted budget constraint holds with equality; otherwise the multiplier has to be updated. When the allocation has been found, the interest rate and tax rates are computed from the agent's first-order conditions.

[35] V^0_X then referrs to the derivative of V^0 with respect to X.

A.3 Estimating average effective tax rates

The approach developed by Mendoza et al. (1994) is used to estimate current tax rates on labor, consumption, services and capital. The idea is to relate realized tax rates directly to the relevant macroeconomic variables in the National Accounts. Resulting estimates are known as average effective tax rates (AETR), and are consistent with the concept of aggregate tax rates at the national level and with the representative agent framework. The tax revenue data are taken from the OECD Revenue Statistics database, which contains information on tax revenues as reported by member countries. Estimates of the value of the associated tax bases are from the OECD National Accounts database.

Table 7: Variable names and symbols used

Revenue Statistics:
1100 = Taxes on income, profit and capital gains of individuals or households
2000 = Total social security contributions
2200 = Social security contributions paid by employers
3000 = Taxes on payroll and workforce
4000 = Taxes on property
4100 = Recurrent taxes on immovable property
4400 = Taxes on financial and capital transactions
5110 = General taxes on goods and services
5121 = Excise taxes
National Accounts:
CP = Household final consumption expenditure
CG = Government final consumption expenditure
OS = Net operating surplus of the overall economy
OSPUE = Households' unincorporated operating surplus
PEI = Households' property income
S = Household consumption expenditures on services
W = Wages and salaries

In the U.S., tax rates on services are basically zero.[36] Using this as an assumption, the tax rate

[36] Isaacson and Bertoni (2000).

on consumption goods in the U.S. can then be calculated by deducting the amount households and the government spend on services from the tax base. In Europe in contrast, supplies of goods and services are both subject to a standard tax rate of at least 15 percent. I thus assume European tax rates on goods and services to be equal when calculating these tax rates. The AETRs on consumption goods and services are then given by

$$\tau^c_{US} = \frac{5110 + 5121}{CP + CG - S - 5110 - 5121} \quad \text{and} \quad \tau^c_{EU} = \tau^s_{EU} = \frac{5110 + 5121}{CP + CG - 5110 - 5121}$$

The approach to calculating AETRs on labor and on capital is to begin by calculating the AETR on total household income, τ^i, and then use this measure to compute the labor tax rate, τ^h:

$$\tau^i = \frac{1100}{OSPUE + PEI + W} \quad \text{and} \quad \tau^h = \frac{\tau^i W + 2000 + 3000}{W + 2200}.$$

Capital taxes are then finally given by

$$\tau^{k_m} = \frac{\tau^i (OSPUE + PEI) + 1200 + 4100 + 4400}{OS}.$$

A.4 Graphs

The transition in the benchmark calibration is displayed in Figure 1, and associated optimal tax rates are displayed in Figure 2.

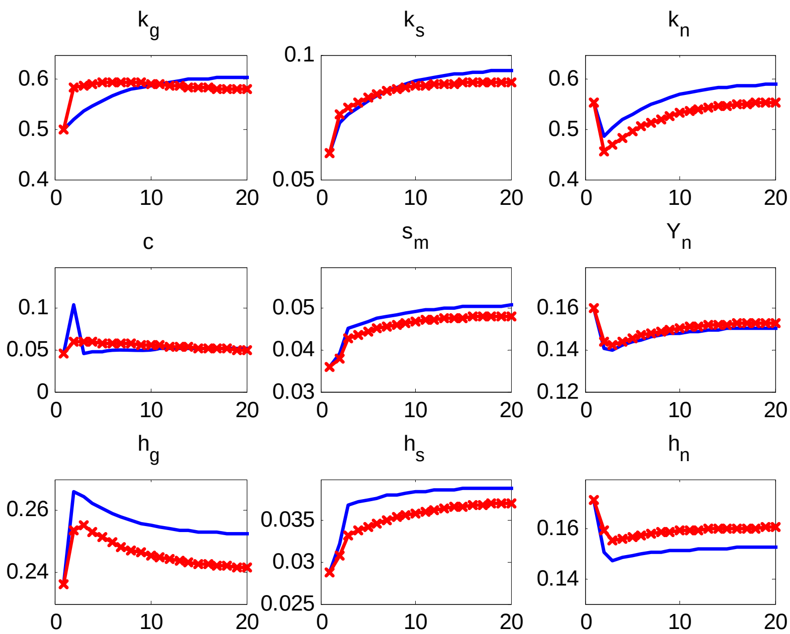

Figure 1: Inputs and outputs in the three sectors in the transitions. The solid lines denote the benchmark case and the dashed lines denote the case where the capital tax is not allowed to be increased.

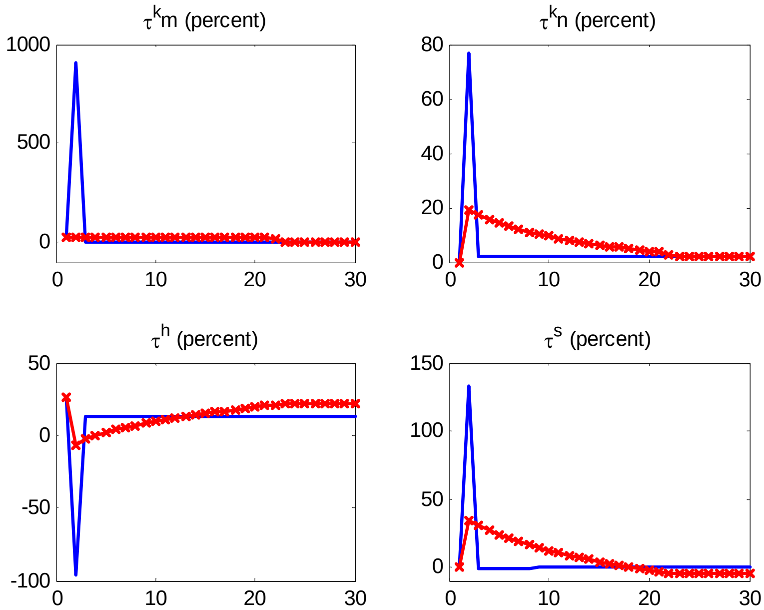

Figure 2: The optimal path for tax rates on capital, home capital, labor and services in the U.S. The solid lines denote the benchmark case and the dashed lines denote the case where the capital tax is not allowed to be increased.

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