Productivity Growth: Theory and Empirics

Labour Supply and Wage Taxation in Endogenous Growth Models

Jacob Øland Jensen
Department of Economics, University of Copenhagen

Supervisor : Carl–Johan Dalgaard

October 30, 2005
1 Introduction

1.1 Background and Motivation

Most models of endogenous growth assume that the households inelastically supply their labour, i.e. there is no labour supply decision. This in turn means that no parameters is able to affect the supply of labour. A change in real wealth, initial capital or levels of taxation will therefore have no effect what so ever on the labour supply. This is a rather strong assumption that most economists will find dubious. Here in Denmark many economists argue that a reduction of taxes on wage income will increase labour supply. If these models of endogenous growth are representative of the “real” world then it is easy to say that these economists are way off. Another issue that arises when labour is supplied inelasticly is that a wage income taxation will function as a lump sum tax. The idea of being able to extract, to some extend, unlimited tax revenue from a tax on the households labour supply just does not sound right. Why should the household chose to work at all, if the government just captures everything earned?

This paper tries to remedy both issues. Below three models are presented where the labour supply decision is endogenous and where there is some role for the government sector, i.e. there is a need for taxation. The first model, and the one given far most attention, is of the endogenous growth through productive government expenditure variety. In the models of this type without endogenous labour supply, the financing of the government productive expenditure is rather obvious, just levy a tax on labour supply. As the labour supply is supplied inelasticly no distortionary effects will arise, and the government is able to restore the first best equilibrium. When the labour supply is elastic, other means of taxation must be used as well in order to obtain the first best solution. The last two models are two sector endogenous growth models with endogenous labour supply. Also here several issues arise regarding the taxation structure of the economy.
1.2 Structure of this Paper

This paper consists of four sections. This first section is the introduction. The second section presents the main model discussed in this paper. The model is solved, both for the competitive equilibrium and for the planned equilibrium. The optimal taxation problem is solved, and last some simulation results are presented. When applicable the equation numbers of the papers discussed is used. The third section presents two other models of endogenous growth. The welfare effects of a change in tax policy are analysed and some results of simulations are presented. The fourth and final section presents some concluding remarks.

2 The Main Model


The first subsection presents the model and solves for the growth rate both in the centralised and decentralised economy. The second section solves the government problem of choosing the optimal fiscal policy consisting of government production/spending and taxation. The third and last subsection discusses simulations of the US economy.

2.1 The Model and it’s Solution...

The model consists of three sectors: the firms, the public sector and the households. The public sector influences both of the other two sectors. The link (from the public sector) to the firms is through productive government investments, such as infrastructure, education and other productivity enhancing measures, i.e. productive government investments enter the production function of the firms. The public sector also claims a fraction of total output and uses it for production of public consumption goods for the households to consume. To make things more tractable it is assumed that the government can issue no
debt, i.e. government spending must equal tax revenue at every instant of time\footnote{To make things even more tractable, the government is only allowed to use linear taxation schedules.}

The production function of the firms is of the Cobb–Douglas variety incorporating the productive government investments.

\[ y = \alpha' G_p^\beta (1 - l)^\phi k^{1-\beta} \]  

(2.1)

An explanation of the different components is required: \( y \) is output of the individual firm. \( \alpha' \) is the exogenous given technological factor. \( G_p \) is the productive government investments. \( l \) is labour supply and \( k \) is (per capita\footnote{Here and in the rest of this section we assume, following Turnovsky, that the size of the population is constant.}) capital stock. At the aggregate level the production function looks like the following:

\[ Y = (\alpha g_p^\beta)^{\frac{1}{1-\beta}} (1 - l)^{\frac{\phi}{1-\beta}} K \]  

(2.2)

Three new variables are introduced here; \( Y \) is aggregated output, \( K \) is aggregated capital stock and \( g_p \) is the fraction of aggregated output devoted to productive government investments. As (2.2) shows the aggregate production is an AK production function. Thus we should expect the model to exhibit endogenous growth if the labour supply is constant at least asymptotically\footnote{If the model did not include an endogenous labour supply decision (i.e. labour is supplied inelastic), we could immediately write the aggregate production function as follow: \( Y = AK, A \equiv (\alpha g_p^\beta)^{\frac{1}{1-\beta}} (1 - l)^{\frac{\phi}{1-\beta}} \)}.

The households enjoy utility from private produced goods as well as public produced goods. Furthermore households derive utility from leisure as well. An infinite living, perfect foreseeing representative agent (Ramsey agent) represents the household sector of this economy. The utility function of the representative agent is given by the following:

\[ U_0 = \int_{t=0}^{\infty} \frac{1}{\gamma} (ct^\beta G_c^\gamma) e^{-\rho t} dt \]  

(2.3)

Two more variables introduced here: \( c \) is per capita consumption and \( G_c \) is public consumption goods.
2 The Main Model

2.1.1 The Competitive Equilibrium

The growth rate of the economy, is the result of firms maximising profits ((2.1) minus costs for capital and labour) and households maximising utility (i.e. maximising (2.3) wrt. $c$ and $l$ subject to the individual capital accumulation equation given the level of public expenditure and taxes). The outcome of this is four equations as given at p 196. The two equations of most interest are the following:

\[
\frac{1 - \beta}{\Omega(l)} \Upsilon = \frac{1 - \tau_c}{1 + \tau_c}
\]

\[
\psi = \left[ \frac{1}{1 - \tau_k (1 - \beta)} \right] \left( 1 - \frac{\Upsilon K}{Y} \right)
\]

\[
\Omega(l) = \frac{1}{\phi(1 - \beta)} \frac{l}{1 - l}
\]

where $\tau_c$, $\tau_k$, $\tau_w$ is a consumption tax, capital income tax and a labour income tax respectively.

Equation \(7a')\) is the condition for intratemporal optimality to prevail. This equation has an intuitive interpretation; the marginal rate of substitution must equal the relative price between the two goods\(^4\). This equation must hold at every instant of time. Note that as $\frac{1 - \beta}{\Omega(l)} > 0$ for $l \in (0, 1)$ (7a’) can be used to analyse the effects of a change in either the consumption tax ($\tau_c$) or the labour income tax ($\tau_w$).

Even though equation \(7c')\) looks rather complicated it is “just” the consumption-Euler equation, as in the standard Ramsey model\(^5\). Thus $\psi$ is the growth rate of consumption, and due to the specification of the model, capital and output as well. The term $\frac{1}{1 - \tau_k (1 - \beta)}$ is the inverse of the intertemporal substitution elasticity. The term $\left( 1 - \frac{\Upsilon K}{Y} \right)$ is the net return to capital and $\rho$ is the rate of time preference. Using (2.2) in (2.4) and it is easily seen that \(7c')\) is constant only if $l$ is constant, implying that $\frac{\Upsilon K}{Y}$ and $\frac{C}{Y}$ are constant as well. Thus the model exhibits endogenous (and balanced growth) if the labour supply is asymptotic inelastic.

\(^4\)To see this point, use the definition of $\Omega(l)$ and the $w$ (the real wage in this economy, given by eq. (13) in Turnovsky’s paper). Calculate the MRS and rearrange.

\(^5\)In the standard Ramsey model, with a CES utility function, eq \(7c')\) would look the following way: $\psi = \frac{1}{\phi} \left[ r - \rho \right]$, where $r$ is the net return on capital.
2 The Main Model

2.1.2 The Planned Equilibrium

In the planned equilibrium utility is maximised subject to the resource constraint of the economy given by:

$$\dot{K} = (1 - g_c - g_p) Y - C$$

A standard capital accumulation equation. The solution to this program is given in Turnovsky’s paper p 190. Again only the intratemporal optimality condition and the consumption-Euler equation receives attention here:

$$\frac{1}{\Omega(l)} \frac{C}{Y} = \frac{\mu}{\lambda} \quad (7a)$$

$$\psi = \frac{1}{1 - \gamma(1 + \eta)} \left[ \frac{\mu}{\lambda} \frac{Y}{K} - \rho \right] \quad (7c)$$

The two equations have the same interpretation as above, just bearing in mind that now we are dealing with the social “prices” in eq (7a) and the social net return to capital in eq (7c).

Allowing for Endogenous Government Expenditure  Allowing the social planner to choose the level of \((g_c, g_p)\) as well as \((l, c, Y, K)\) leads to the following characterisation of the optimal level of government expenditure:

$$\hat{g}_c = \eta \frac{C}{Y}$$

$$\hat{g}_p = \beta \frac{\mu}{\lambda}$$

Using these two equations along with the other first order conditions yield the following two relationships.

$$\frac{\mu}{\lambda} = 1 - \beta$$

$$\frac{C}{Y} = (1 - \beta) \Omega(l)$$

Combined the above four equations yield the following levels of optimal government expenditure.

$$\hat{g}_c = \eta (1 - \beta) \Omega(l) = \eta \frac{C^*}{Y} \quad (2.4)$$

$$\hat{g}_p = \beta \quad (2.5)$$
These results will be useful later, when the optimal taxation schedule is derived.

2.2 Optimal Policy and Taxation

As this model incorporates externalities, in form of a production externality and a consumption externality, the competitive equilibrium will not be socially desirable. Hence the government should use the taxation schedule to restore social (Pareto) efficiency. There is a couple of ways to approach this problem. First of all solving the model, given in section 2.1.2 for \((l, \frac{C}{Y}, \psi, g_c, g_p, \tau_c, \tau_w, \tau_k)\) will yield the socially optimal levels of taxation. But as we already have the first best solutions, given by eq (7a) and (7b) and the competitive outcome, given by eq \((7a')\) and \((7b')\) it will be more time efficient just to compare these two set of equations. Comparing eq (7a) and \((7a')\) yields:

\[
1 - \tau_k = \frac{1 - g_c - g_p + \psi Y C}{1 - g_p} \tag{19a}
\]

By setting the government taxation/expenditure schedule as given by eq (19b) the externalities will be internalised and the competitive equilibrium will be first best. As we shall see in a moment, when the government expenditure is set optimally eq (19b) reveals a well-known result of optimal taxation.

Comparing at the growth rates in the two equilibria yields:

\[
1 - \tau_k = \frac{1 - g_c - g_p + \psi Y C}{1 - g_p} \tag{19b}
\]

As before mentioned the growth rate depends on the net return to capital. It is therefore intuitive that to have equal growth rates, ceteris paribus, the net return on capital must be equal. This is exactly what equation \((19a)\) secures.

2.2.1 Optimal Government Policy

When the government behaves according to eq \((2.4)\) and \((2.5)\) the solution to the optimal taxation problem above become rather simple. Note that when \(g_c = \hat{g}_c\) and \(g_p = \hat{g}_p\) then

\[^6\text{To arrive at the two results presented below use eq } (2.5) \text{ eq } (7b) \text{ in the paper by Turnovsky.}\]
\[ \frac{1-g_p-g_p+\eta Y}{1-\beta} = 1 \] and therefore eq (19a) and (19b) collapse to:

\[ -\tau_w = \tau_c \]

\[ \tau_k = 0 \]

As the above shows, setting government expenditure optimally will equal private and public net return on capital. No distortitory taxation is needed!

The second of the above equations states that the taxation on consumption should equal a negative tax (subsidy) on labour supply. This is the Ramsey result regarding uniform taxation\(^7\). Note that a subsidy of labour supply is nothing but a tax on leisure.

2.3 Simulations

Turnovsky makes simulations based on data for the american economy. It is not neccessary to restate all the parameter values\(^8\), but a few comments are needed. First of all, as \( \phi = \beta \) the government production becomes labour augmenting, i.e. the aggregate production function becomes: \( Y = \alpha^{\frac{1}{1-\gamma}} [g_p (1-l)]^{\frac{\gamma}{1-\gamma}} K \). Quite symmetrically with the assumption of \( \theta = \eta \) government consumption becomes leisure augmenting, and the instantaneous utility function becomes. \( U = \frac{1}{\gamma} [c (G_c l)^{\eta}]^{\gamma} \). These two assumptions make simulation results much more tractable, as cross effects between government spending and labour supply are avoided. Also worth noting is that \( g_p = \beta \) implies that government productivity expenditure is set optimally.

In the Appendix is presented table 1 from the paper by Turnovsky:

As the above table shows, the benchmark economy has a net return on capital of 7.25 percent, a growth rate of 1.41 percent and a public deficit of more than 11 percent of the initial capital stock (the \( V \) parameter). Increasing capital taxation from 0.28 to 0.40 turns the deficit into a surplus of more than ten percent. This increase in capital income income taxation cuts down growth by a third and the overall wellfare loss is 4.44 percent. As section A of table 1 shows, the only welfare improving edict is to lower both capital and

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\(^7\)If \( u(x_1, x_2) \) is weakly separable in \((x_1, x_2)\) then \( x_1 \) and \( x_2 \) should be taxed uniformly.

\(^8\)For all parameter values and a thoroughly discussion please consult [Turnovsky, 2000] pp 203–204.
wage taxation, improving growth and welfare but leaving the government with a deficit of almost a quarter of the initial capital stock.

Section B considers compensated changes in government spending and taxation, i.e. changes that leaves the government deficit around 11 percent of the initial capital stock. The most welfare improving edict is to set $\tau_k = \tau_w = 0$ and let all government spending be financed by consumption taxation. In this regime growth is almost double and welfare is improved by more than four percent. Pre-tax return on capital is the same.

Section C considers optimal taxation. It is worth noting that the only welfare improving scheme is the “Global Optimum” setting, where $\tau_k = 0$ and $-\tau_w = \tau_c (= 0.54)$ as section 2.2 proved. The growth rate in this regime is double as high compared with the benchmark economy, the net return on capital is also high, as is the gross return on capital, i.e. in the benchmark model household accumulates more capital than socially desirable. The welfare improvement is 5.48 percent, and, by definition, the largest possible. Note that other optimal taxation schemes lead to higher growth rates, but due to the impatience of the consumer this is not welfare improving.

3 Other Models

This section describes two other models which also consider endogenous labour supply and wage taxation in an endogenous growth setup. The main difference between these two models and the model presented above is that in these two models endogenous growth is generated in a two sector setup (the Uzawa-Lucas approach) where as the above model exhibits endogenous growth through productive government expenditure.

3.1 The Paper by Novales and Ruiz

Novales and Ruiz [Novales & Ruiz, 2002] analyse the possiblity to generate higher growth (and welfare) by cutting capital- and wage income taxation, without violating the inter-temporal budget constraint of the government. The next section presents briefly the model and the second section presents simulation results for the US economy.
3 Other Models

3.1.1 The Model

As mentioned above Novales and Ruiz utilise the Uzawa-Lucas approach to endogenous growth. This involves both consumption goods and human capital to be “produced” by a Cobb-Douglas technology. In the production of consumption goods, human capital, physical capital and labour are used.

The government sector operates more autonomously in this model, than in the model of [Turnovsky, 2000]. The government captures an - exogenously given - fraction of total production. This fraction of production is then given back to the consumers. To finance the government expenditure, taxation is imposed on capital- and wage income. As opposed to the model by Turnovsky, the government is here allowed to run budget deficits as long as the intertemporal budget constraint is not violated.

3.1.2 Taxation

To understand how the intertemporal budget balancing works consider a wage income tax cut. Under plausible assumptions this will decrease leisure and thus increase labour supply. This will in turn make capital more productive, which will increase production and growth. This will increase the tax base in the future, and thereby the government is able to cover the budget deficit generated today, by having larger tax revenues in the future.

In the benchmark model of Novales and Ruiz the parameters are similar to the ones used by Turnovsky. Here leisure is ~60 percent of total time (77 percent in [Turnovsky, 2000])11. Annual growth is 1.5 percent and tax rates are \( \tau_w = 0.23 \) and \( \tau_k = 0.50 \). Note that the tax rate on capital income is considerably larger than the 0.28 used by Turnovsky.

Novales and Ruiz considers feasible tax cuts. For wage income taxation it is possible to reduce this rate to 0.18 without violation the intertemporal budget constraint. This

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9Leisure being a normal, among others.
10For unchanged taxation levels.
11The lower amount of time allocated to leisure, is partially due to, the fact that in a Uzawa-Lucas model time must also be allocated to produce human capital.
cut will increase annual growth to 1.8 percent and increase welfare by 5.1 percent. It is worth noting, that the model predicts overshooting of production efforts etc. For instance the labour supply will increase with around six percent immediately after the tax cut, then gradually reduce to an increase of only 0.9 percent in equilibrium. This illustrates rather well the main point of the paper; transition matters for the level of available tax cuts! For capital income taxation a tax cut of 0.12 is feasible, leaving $\tau_k = 0.38$. This cut will increase growth to 1.7 percent per annum and increase welfare by 4.9 percent.

### 3.2 The Paper by Jones, Manuelli and Rossi

Jones et. al. [Jones, Manuelli & Rossi, 1993] considers optimal taxation in a setup very similar to the one presented above\textsuperscript{12}. In contrast to Novales and Ruiz who use a single tax rate for all time periods Jones et. al. searches for the sequence of linear taxes that maximises welfare. This naturally complicates matters a lot and only a numerical solution is possible.

Their benchmark model uses the following parameter values: $l = 0.71$, $\tau_w = 0.31$, $\tau_k = 0.21$, $\tau_c = 0.083$ and $\psi = 0.02$. When taxes are set optimally growth increases to 4 percent per annum, leisure decreases by seven percentage points and labour supply increases by seven percentage points. Time spent on education is unchanged, though other set of parameter values give rise to change in time spent on education as well. The welfare gain of the optimal taxation regime is 1.2 percent.

The tax rates – which now are functions of time – all evolve similarly. The capital income tax and the consumption tax both start out very high, and then rapidly approach zero in the limit. The tax on labour supply is initially negative, then it becomes slightly positive and eventually it becomes negative again and then it approaches zero from above in the limit\textsuperscript{13}.

Even though this model has strong similarities (including parameter values) with the

\textsuperscript{12}See section III of the mentioned paper.

\textsuperscript{13}See Fig. 3 p 501 in [Jones, Manuelli & Rossi, 1993] for a graphically exposition of the transition of tax rates.
model presented by Novales and Ruiz, the implications are very different. According to Jones et. al. a tax rate different from zero must imply that an economy must be in the early fase of a transition to a Ramsey optimum.

The result of zero tax rates in the limit should raise some questions regarding the model as well as the applicability of the Ramsey method to these kind of taxation problems.

4 Conclusion

Implementing an endogenous labour supply decision in an endogenous growth model does complicate matters quite a lot, but most result can be maintained. The model of Turnovsky shows that even with out a lump sum tax on labour supply it is still possible to obtain the first best equilibrium.

Simulation studies from all three models presented above show that welfare can be improved by up to five percent by choosing the right tax structure and growth will increase during the proces as well.

Even though the three models show similar results regarding the welfare improving posibilities of choosing the right tax structure, they disagrees on how the optimal tax structure should look.

- Turnovsky suggests a zero taxation of capital income and a large subsidy on wage income combined with a consumption tax of an identical magnitude.

- Novales and Ruiz do not consider a consumption tax but suggests positive tax rates on both capital and wage income.

- Jones et. al. considers time dependent taxation, and concludes that capital income and consumption taxes should be very high in the begining the converging to zero from above. The wage income tax should be negative in the begining then become positive and in the limit approach zero.

Even though the three models make a useable presentation of the real world economy, (at least) three issues must be considered:
i. The utility function is designed such that the labour supply is asymptotical inelastic. This assumption is not very strong, but it somewhat gives a sense of a model with only “pseudo–endogenous” labour supply. Though, in application this should have no influence.

ii. To make a taxation schedule that should persist in all future is perhaps a bit ambitious. Even in the most benevolent dictatorships the temptation to change taxation in the future exists, after households have made their decision on labour supply, consumption and savings. In modern democracies this temptation is even bigger as other political parties may come to power over time. To incorporate this time inconsistency problem in a similar setup seems like a unsurmountable task. Some guidelines from the political economy literature might come in handy.

iii. When the model as presented by Jones et. al. can predict all tax rates to become zero in the limit, the whole setup can be untrustworthy. In real world application it just does not seem realistic that tax rates different from zero are a transitional dynamic phenomena only. When such a model reveals such a controversial result it can be hard to believe in models with similar characteristica, such as the model of Novales and Ruiz and, to a lesser extent, the model of Turnovsky.

Although real life taxation is much more complicated than the linear three dimensional tax structure suggested by the three models, the models all three suggest that close attention is paid to the way the tax system is put together. Minor alterations can lead to substantial welfare improvements, with out hampering the government sector finances.
References

Primary Literature


Secondary Literature


Table 1: Fiscal shocks

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<th>$r_{w}$</th>
<th>$r_{e}$</th>
<th>$g_{p}$</th>
<th>$g_{c}$</th>
<th>$l$</th>
<th>$c/y$</th>
<th>$r_{d}(1-r_{k})$</th>
<th>$\phi$</th>
<th>V</th>
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<td>0.08</td>
<td>0.08</td>
<td>0.65</td>
<td>0.56</td>
<td>11.7%</td>
<td>3.23%</td>
<td></td>
<td>-4.67%</td>
</tr>
<tr>
<td>$g_{p}$ + $g_{c}$</td>
<td>0</td>
<td>-0.54</td>
<td>0.54</td>
<td>0.16</td>
<td>0.08</td>
<td>0.65</td>
<td>0.51</td>
<td>11.1%</td>
<td>3.06%</td>
<td></td>
<td>-7.60%</td>
</tr>
</tbody>
</table>

*The percentage welfare gains or losses in Parts A and B of this table are relative to the Benchmark economy.

The percentage welfare gain in the Row 1 in Part C of this table is relative to the Benchmark economy. The percentage welfare losses in Rows 2-7 are measured relative to the Global optimum reported in Row 1. Benchmark parameters: $\gamma = -1, \beta = 0.08, \theta = 0.3, \eta = 0.3, \rho = 0.04, \pi = 0.18, \tau = 1.12$