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Behavioral optimal taxation: Aspirations

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Abstract
I show the results of a novel simple two-period model comparing lump-sum taxes with proportional labor taxes. The difference to the classical optimal taxation literature is that people's aspirations change from one period to another, as suggested by empirical evidence. It turns out that the policy implication from this model differs considerably from the one assuming full rationality. In the behavioral model, a lump-sum tax is much less attractive. The model does not aim to be a full-fledged quantitative model, it should rather be seen as a cautionary tale about the robustness of classical optimal taxation results when deviating from full rationality.

JEL Classification: H21; D90; D60

Keywords
Easterlin paradox — behavioral public finance — behavioral optimal taxation — aspirations

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Introduction

Optimal taxation theory has, as most of economics, almost exclusively assumed fully rational economic agents over many decades.[1] However, by now, evidence that human behavior systematically deviates from rational choice is abundant. Non-rational behavior can be found in all domains of economic and financial decision making. This includes findings that people often use simple heuristics instead of maximizing utility (e.g., Gigerenzer and Todd, 1999), that people react differently to the same things depending on how they are framed (e.g., Tversky and Kahneman, 1986), that people dislike losses irrationally much (e.g., Kahneman et al., 1991), or that people discount future outcomes too much (e.g., Burks et al., 2012). Boundedly rational behavior has been found in basically all areas of economics and finance, including savings and consumption decisions (e.g., Thaler and Benartzi, 2004), pricing of financial assets (e.g., Weber et al., 2018; Kopányi-Peuker and Weber, 2021), decisions related to health (e.g., Richman, 2005; Rice, 2013), and behavior in the labor market (e.g., Babcock et al., 2012).

There are in particular several papers documenting non-rational behavior in the context of taxation. Much of this literature revolves around the misperception of taxes that are less salient (e.g., Sausgruber and Tyran, 2005; Chetty et al., 2009). Such missing salience can have effects on who bears the burden of a tax (e.g., Kerschbamer and Kirchsteiger, 2000), on labor supply and work effort (e.g., Blumkin et al., 2012; Fochmann et al., 2013), and on political preferences (e.g., Sausgruber and Tyran, 2011; Weber and Schram, 2017). There is less literature that analyzes the reactions to different schedules of tax rates with behavioral economics; an exception is Carpenter et al. (2016), who analyze whether workers in a contest react differently to schedules of tax rates than workers paid with a piece rate.

This abundance of evidence has lead scholars to call for the development of behavioral models for welfare evaluations (Bernheim and Rangel, 2005; McCaffery and Baron, 2006; Kőszegi and Rabin, 2008; Riedl, 2010; Mullainathan et al., 2011; Chetty, 2015). However, such models are still extremely rare in the field of optimal taxation (some notable exceptions are O'Donoghue and Rabin, 2006; Chetty et al., 2009; Gerritsen, 2016; Farhi and Gabaix, 2020). The question whether the results obtained in a rich literature of classical optimal taxation theory, based on full rationality, carry over to a world populated by actual humans is clearly important. How robust are the classical results to assuming non-rational behavior?

In this short piece, I formulate a simple two-period model introducing changing aspirations. The model is based on the following empirical evidence. While happiness (a term that I use interchangeably with utility) and wealth are positively correlated (e.g., Hagerty and Veenhoven, 2003), there is also evidence that utility received from wealth or income changes over time. How this utility changes depends on how much money someone had (and spent) in the past. A poor person who receives a certain amount of money will afterward be much happier than a rich person who loses money (assuming that their total wealth after these changes is equal). Easterlin (2001) explains this with changing aspirations. He provides evidence that the aspirations a person has rise with income, so

[1] Proponents of rational choice go a long way to defend it, coming up with arguments such as "rational choice may not be perfect, but it avoids getting lost in the wilderness of bounded rationality." This is wrong: what is the value of a clearly defined benchmark if it is not good? Proponents of rational choice may also admit that individuals are not rational but claim that, on average, the individual mistakes cancel out (so that the rational benchmark would still be the best there is). However, this claim would only be true if mistakes across individuals were uncorrelated, which they are usually not.

that over the span of a life happiness remains similar, although income rises substantially. These changes in aspirations are not foreseen by people, meaning that they think their happiness will be higher in the future (anticipating higher earnings) than it will actually be. When making decisions, people thus do not take into account that their aspirations will change in the future, leading them to suboptimal decisions. Empirical evidence for changing aspirations can also be found by Stutzer (2004) who shows that aspirations increase with income and that higher aspirations lead to lower utility as measured by reported satisfaction with life. Note that the definition of aspirations that I use only concerns income/consumption (this is not the only possible definition, aspirations could also extend to social or moral matters; e.g., Veenhoven, 1991; Dockery, 2003).

In the model, a representative agent maximizes what he believes to be his life-time utility (I use the masculine form for the representative agent – who considers this inappropriate may be appeased by the fact that the agent is boundedly rational, that is "stupid"). The model assumes that the government needs to raise a certain amount of tax revenue in each period. It can raise the revenue either with a lump-sum tax or with a proportional tax on labor income. The model can be used to analyze how the representative agent's experienced life-time utility, which is the social welfare measure used, can be different under the two tax regimes.[2]

The evaluation of the two tax regimes can be remarkably different from the normative evaluation in a fully rational model, where a lump-sum tax is generally preferable. The reason for the result in a rational world is that a proportional labor tax leads to a disincentive to work, reducing labor supply. However, as less labor is supplied in the economy, the government needs to set a relatively high tax rate to obtain a given level of revenue. Overall, social welfare is then lower than under a lump-sum tax without disincentives to work. In the behavioral model, the introduction of aspirations adds a dimension. When deciding how much to work in the first period, the agent ignores that higher consumption in the first period will translate into higher aspirations in the second period (higher aspirations in the second period reduce the agent's utility in that same period). Therefore, without any taxes in place, the agent supplies too much labor. Ex post, in or after the second period, the agent regrets his excessive labor supply in the first period (this model thus corresponds to the anecdotal evidence that people on their deathbed often regret having worked too much, while hardly anyone regrets not having spent enough time working). As a proportional labor tax provides a disincentive to work it can be welfare enhancing by reducing excessive labor supply.[3]

Lump-sum taxes and proportional labor taxes are often used in the public finance literature. Lump-sum taxes are fixed amounts that have to be paid per individual or per household, independent of income or wealth (very similar taxes are also referred to as poll taxes or head taxes). In practice, such taxes have been used in various forms throughout history. Today, taxes that are explicitly labeled as lump-sum taxes are rare (possibly, because they are unpopular and considered unfair by many), but taxes and fees with the same or similar properties still exist. Several countries, for instance, still have broadcast license fees, which have to be paid once per household (or per household owning a TV, radio, or computer, which extends to basically all households in middle- and high-income countries). In the cases of Germany and Switzerland, for example, these fees add up to about 200 and 300 euros per year. Another example are fees for renewing identity cards (in some countries having a valid identity card is compulsory, so that the fee cannot be avoided). There are also many excise taxes that are theoretically different from lump-sum taxes, as they depend on the consumption of products, but that have similar effects, because the involved elasticities are very low. Taking for instance the coffee tax in Germany, the tax is similar to a lump-sum tax if the consumption of coffee does (at current prices) not change much when the tax changes moderately (this seems to be a realistic assumption; taxes make up for only a very small part of the cost of coffee, especially when the coffee is consumed in a coffee shop). The coffee tax is then similar to a lump-sum tax, where the amount of the lump-sum tax is proportional to a household's coffee consumption. Proportional labor taxes are the simplest form of modeling taxes on labor income. Proportional or quasi-proportional labor or income taxes exist in several countries (in about 30 countries in the world, including the EU countries Bulgaria, Estonia, Hungary, Lithuania, and Romania). Most countries instead rely on progressive labor or income taxes. I stick with a proportional labor tax to keep the model tractable, but note that an optimal tax that does not need to be proportional is never worse than a proportional tax (if optimally designed). In cases in which a proportional labor tax is superior to a lump-sum tax, a more general (optimal) labor tax is thus also superior.

A few disclaimers are in place to put the model into perspective. While there are several drawbacks of lump-sum taxes, the mechanism in this model makes up for at best a minor part of this. All other things that can lead to a superiority of a proportional labor tax over a lump-sum tax are absent (as in many economic models). This includes distributional concerns and social welfare being influenced by decisions of poorer individuals (e.g., decisions on engaging in criminal activities or drug consumption, including their implications on government safety nets and health insurance). Even if

[2]What type of utility should be used for welfare evaluation is not trivial. I consider experienced utility the right concept, in line with Kahneman et al. (1997), Easterlin (2001), and Kahneman (2003). As experienced utility is closely related to subjective well-being, this piece also relates to a strand of literature analyzing effects of policies on subjective well-being (e.g., Jakubow, 2016).

[3]The results are different from the standard results. Note, however, that literature on positional externalities, for example including social comparisons, can lead to similar results as the model with aspirations (e.g., Aronsson and Johansson-Stenman, 2008; Wendner and Goulder, 2008; Aronsson and Johansson-Stenman, 2018).

lump-sum taxes are not optimal to raise tax revenue, this does not mean that proportional labor taxes are necessarily a good way to do so. However, other taxes are absent in the model, including progressive labor taxes, capital income taxes, consumption taxes, excise taxes on unhealthy or environmentally harmful products, wealth and property taxes, inheritance and remittance taxes, financial transaction taxes, etc. This piece should thus not be read as a statement about the benefits of a proportional labor tax. Instead, it may be seen as a simple model analyzing the effect of a single behavioral mechanism (changing aspirations) and as an illustration of how a classical result of optimal taxation theory can break down when this behavioral mechanism is taken into account.

Model

In this section, I first describe the general set-up of the model, giving the specifics of the agent's decision utility, experienced utility, and the decision problem(s), in the absence of any taxes. Thereafter, taxes are briefly introduced with a short comment on what to keep in mind when solving the model with taxes, while the details of how the model can be solved are relegated to the appendix.

The agent's decision problem

A representative agent tries to maximize life-time utility in a two-period model, deriving utility from consumption and leisure. He can choose c_1, c_2, h_1 and h_2 denoting consumption in periods 1 and 2 and work time in periods 1 and 2. The maximal work time is normalized to one, such that $h_1, h_2 \in [0,1]$. The wage rate in period 1, w_1 is exogenous, the wage rate in period 2 is $w_2 = w_1 + \phi h_1$, with $\phi \geq 0$ representing an increase in the wage rate depending on the amount of time worked in the first period (this can be viewed as more work experience leading to a higher salary; this realistic ingredient is often not present in standard models, but it is fully compatible with standard economic modeling and thinking). There is no possibility to save money. When making the decisions for the first period, the agent assumes his (discounted) life-time utility to be

$$\begin{aligned} u^*(c_1,h_1,c_2,h_2) = \log c_1 + b\log(1-h_1) \\ + \beta\left(\log c_2 + b\log(1-h_2)\right), \end{aligned} \tag{1}$$

with $\beta \in (0,1]$ and $b > 0$. In the absence of taxes, the agent thus solves the following constrained optimization problem (where the two constraints are binding).

$$\begin{aligned} \max_{c_1,h_1,c_2,h_2} & u^*(c_1,h_1,c_2,h_2), \\ s.t.\ & c_1 \leq h_1 w_1, \\ & c_2 \leq h_2(w_1 + \phi h_1). \end{aligned} \tag{2}$$

So far, the model is just a regular economic model with a rational agent. The model does not yet account for a change in aspirations depending on consumption. For the agent's decision utility before/in the first period, aspirations also should not be included, because the agent does not know that his aspirations will change. Aspirations enter the model in the following way. While the agent maximizes u^* as given in Equation (1), his experienced (or real) life-time utility is

$$\begin{aligned} u(c_1,h_1,c_2,h_2) = \log c_1 + b\log(1-h_1) \\ + \beta\left(\log c_2 - \delta\log c_1 + b\log(1-h_2)\right), \end{aligned} \tag{3}$$

with $\delta > 0$. The agent's utility in the second period does not only depend on second period values, but also on the consumption in the first period. His aspirations in the second period increase with consumption in the first period, so that utility in the second period decreases with consumption in the first period (for fixed c_2 and h_2). The agent is thus not fully rational: he maximizes what he considers to be his life-time utility, but he does not maximize his real life-time utility (as he does not know that his future aspirations will change with current consumption).

The agent's decision after the first period

The model, as it is given now, looks like the agent is making a plan of how much to consume and work for both periods before period 1 and then sticks to this plan throughout. But what happens after the first period, when the agent can revise his choices for the second period (when he becomes aware of the correct experienced utility function in period 2)? The answer is that the solution of the model remains the same.

There are two points to consider here. The first is that experienced utility in the second period does not only depend on consumption and leisure, but also on past consumption. The second point is that the agent does not know this dependence of future utility on current consumption. This way of modeling is consistent with the evidence that when people have to indicate how happy they were in the past or how happy they think they will be in the future, they make these evaluations using their current level of aspirations (Easterlin, 2001). In the model, this means that the agent in period 1 takes suboptimal decisions concerning period 1 consumption and leisure, because he does so with an incorrect period-2 utility function in mind. After period 1, he perceives his current utility correctly and could thus choose a different combination of consumption and leisure for period 2 than originally planned. However, this does not happen. The agent would in general choose different values for both periods if he knew his experienced period-2 utility before period 1.[4] But if he maximizes u^* as given in Equation (1) in the first period, the second period values that maximize u^* for fixed c_1 and h_1 are the same as the second period values that maximize u as given in Equation (3) for the same fixed values of c_1 and h_1.

[4]One could also model the agent as partially sophisticated, meaning that the agent is to some extent aware of the change in aspirations. This would weaken the effects of changing aspirations but not eliminate them (as long as the sophistication does not lead to a full anticipation of changes in aspirations).

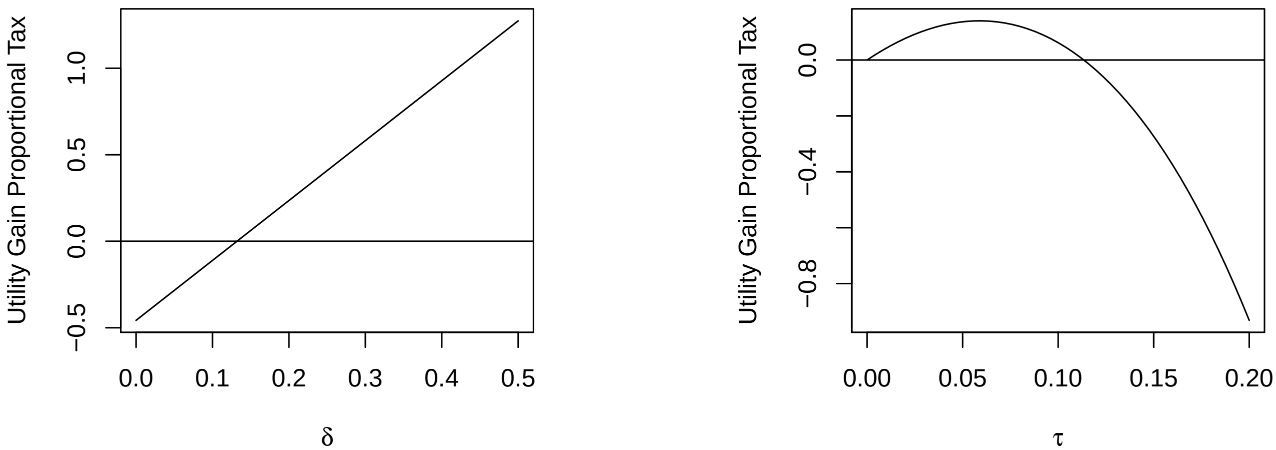

Figure 1. Differences in social welfare as functions of δ and $\tau := \tau_1 = \tau_2$

Notes: $(w_1, b, \beta, \phi, \tau_1, \tau_2) = (1, 0.5, 0.9, 1, 0.1, 0.1)$ (left) and $(w_1, b, \beta, \phi, \delta) = (1, 0.5, 0.9, 1, 0.15)$ (right).

Obtaining solutions of the model with taxes

Details on how the model can be solved numerically are shown in the appendix. Lump-sum taxes are denoted by τ_1 (in period 1) and τ_2 (in period 2). The proportional labor tax rates are denoted by κ_1 (in period 1) and κ_2 (in period 2). When solving the model, the tax revenues in both periods are kept equal under both tax regimes to ensure that they are comparable.[5]

Results

The results are illustrated with simple graphs. The main purpose is to compare the two tax regimes with respect to their social welfare, which is the (discounted) experienced lifetime utility of the representative agent. The graphs below show how the difference in social welfare between a proportional tax and a lump-sum tax depends on the model parameters. The vertical axis shows the gain in social welfare when using a proportional labor tax instead of a lump-sum tax (positive values thus correspond to higher welfare under a proportional tax; the social welfare differences have been multiplied with 100 for convenience). The horizontal axis represents different parameter values.

All parameters except for the parameter under consideration are fixed at a standard calibration, which is

$$(w_1, b, \beta, \phi, \tau_1, \tau_2, \delta) = (1, 0.5, 0.9, 1, 0.1, 0.1, 0.15).$$

The qualitative features of the results are not very sensitive to the choice of this calibration (but, of course, the exact calculated quantities depend on it).

Figure 1 (left panel) shows the effect of introducing aspirations into the model. The case of $\delta = 0$ corresponds to the fully rational model where aspirations play no role. In that case, one obtains the classical result that a lump-sum tax leads to higher social welfare than a proportional labor tax. However, for increasing δ, meaning that aspirations play a more important role, the advantage of a lump-sum tax vanishes and for sufficiently high δ a proportional labor tax leads to greater social welfare than a lump-sum tax.

Figure 1 (right panel) shows the effects of changes in the collected tax revenue. For this graph we assume that τ_1 and τ_2 are kept equal and change simultaneously ($\tau := \tau_1 = \tau_2$; the proportional labor tax is of course always chosen such as to obtain the same tax revenue). For $\tau = 0$, that is, when no taxes are raised, the theoretical tax regime does naturally not matter. In the graph, we observe an inverse U-shape. When τ increases, we first observe an increase of the social welfare advantage of a proportional tax rate. The increasing part of this inverse U can be explained as follows. A proportional tax can be superior to a lump-sum tax, but for very low values of the tax, this hardly matters (we are close to $\tau = 0$ where the social welfare must be equal between the two tax regimes). The higher the tax, the more the difference matters. However, this only holds up to a point. At some level of the tax, the welfare gain under a proportional tax starts to decrease, as the classical effect of the disincentive to work becomes large. For a sufficiently high level of tax revenues raised, labor supply becomes so low that a lump-sum tax is then again superior to a proportional tax.

Figure 2 (left panel) shows the effect of the discount factor β in the model (which is equal in the decision utility and in the experienced utility). One can observe a monotonic increase of the social welfare difference in β. This is not surprising. All the disutility stemming from suboptimal choices due to the agent neglecting the changes in aspirations only enter the utility function of the second period. The less important the second period is for social welfare (i.e., the lower β), the less important is the effect of aspirations. In relative terms, this means that the disutility in the first-period stemming from the

[5] In formulae, this means $\kappa_1 h_1 w1 = \tau_1$ and $\kappa_2 h_2 (w_1 + \phi h_1) = \tau_2$.

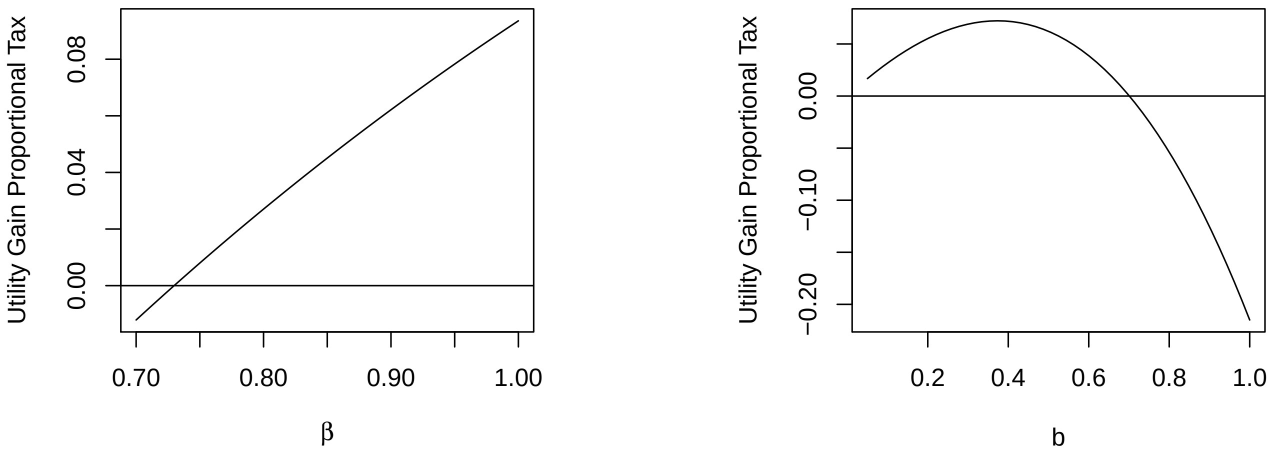

Figure 2. Differences in social welfare as functions of β and b

Notes: $(w_1, b, \phi, \tau_1, \tau_2, \delta) = (1, 0.5, 1, 0.1, 0.1, 0.15)$ (left) and $(w_1, \beta, \phi, \tau_1, \tau_2, \delta) = (1, 0.9, 1, 0.1, 0.1, 0.15)$ (right).

distortion under a proportional tax becomes more important. That is, the higher is β, the better a proportional tax does in terms of social welfare as compared to a lump-sum tax.

Figure 2 (right panel) shows an inverse U-shape for the difference in social welfare as a function of b. For $b = 0$ this difference is zero. This is very intuitive: if the agent does not care at all about leisure time the results of the two tax systems are equal, because in either case the agent works as much as possible. When b increases from a zero level, a proportional tax increases in attractiveness. This is the case because then the effects of aspirations kick in. That leisure matters for the agent means that he reduces work time more under a proportional tax. For low levels of b this is welfare enhancing, because it offsets the excess labor that the agent would otherwise supply (because he does not take into account that second-period experienced utility depends negatively on first-period consumption). However, when leisure is very important for the agent, also the distortionary effects from the proportional tax are very important (the agent reacts in a stronger way to the tax because leisure time is relatively more attractive than working). At some point, the incentive for the agent to reduce labor supply is higher than the optimal level to offset the effects of changing aspirations. Therefore, a lump-sum tax is relatively more attractive again for very high values of b.

The effects of the wage rate in the first period can be seen in Figure 3 (left panel). Again we can observe an inverse U-shape (albeit one that is less symmetrical than the ones before). For very low levels of the wage rate, lump-sum taxes are superior to proportional taxes. This is a region where working is not particularly attractive for the agent. This means that the overall level of consumption in the first period for the agent is low, so that differences in how much the agent consumes have a high impact on his utility. This makes the usual distortion from a proportional tax providing a disincentive to work particularly harmful. However, as w_1 increases, a proportional tax becomes more interesting for a social welfare maximizing government, as this effect becomes weaker (while the typical effect of aspirations becomes more important, meaning that the proportional tax reduces the excessive labor supply). For very high values of w_1, a lump-sum tax slowly increases in attractiveness again.

Figure 3 (right panel) shows the effect of the parameter determining how the period-two wage depends on work experience. The higher this parameter, the more attractive is a proportional tax. This is the case, because a higher value of ϕ makes the agent work more in the first period in order to benefit from a higher wage increase in the second period. However, this leads to a greater excess labor supply, which is mitigated by a proportional labor tax.

Conclusion

This contribution contains a simple two-period optimal taxation model with aspirations that change over the life cycle. It shows that the standard policy implication that lump-sum taxes are superior to proportional taxes can break down when this behavioral mechanism is present. The intuition is that people may actually work too much under a lump-sum tax, because they think that their higher future income will make them happier than it actually will. The disincentives to work under the proportional labor tax decrease labor supply, which can be welfare increasing.

In the remainder of this conclusion, I first discuss some potential criticisms, which I mainly see as possible extensions to get to a larger quantitative behavioral public finance model. Then I discuss which policy implications can be drawn from the model (and seem valid despite the mentioned caveats).

One possible criticism is that savings or accumulation of capital are not possible in this model. This is true, but

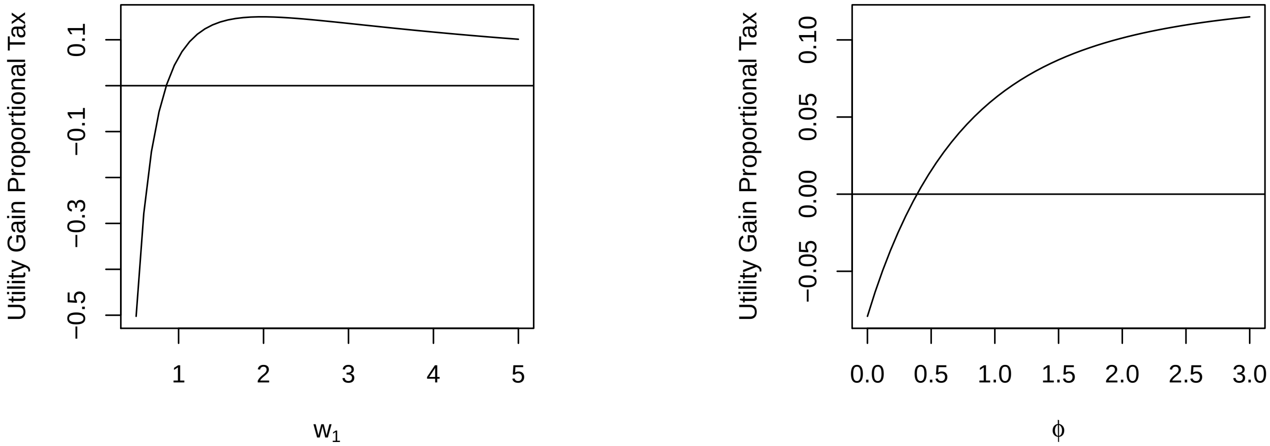

Figure 3. Differences in social welfare as functions of w_1 and ϕ

Notes: $(b,\beta,\phi,\tau_1,\tau_2,\delta) = (0.5, 0.9, 1, 0.1, 0.1, 0.15)$ (left) and $(w_1,b,\beta,\tau_1,\tau_2,\delta) = (1, 0.5, 0.9, 0.1, 0.1, 0.15)$ (right).

it is mainly to keep the model simple. An extension with saving or capital accumulation that yields qualitatively similar results seems possible. Similarly, one may not be happy with a two-period framework. Also here, the model could most likely be extended to a multi-period model or one with an infinitely lived agent without changing the main result (infinitely lived agent models are methodologically also questionable, of course). Such changes would come at the expense of simplicity.

To obtain a large-scale quantitative model, a few more components seem necessary, including the heterogeneity of agents, financial asset markets, and wage bargaining. Furthermore, all tax instruments that are available to a government should be in the model and analyzed jointly, as the availability of one tax instrument may in general influence the trade-offs between others. Such a quantitative model should then come together with sound behavioral assumptions about human behavior (the parameters of which would have to be estimated). This includes assuming present-biasedness and procrastination (e.g., O'Donoghue and Rabin, 2001; Burks et al., 2012), misperception of probabilities (e.g., Tversky and Kahneman, 1992; Abdellaoui et al., 2013; Lampe and Weber, 2021), expectation formation according to a reinforcement learning model (e.g., Heemeijer et al., 2009; Hommes et al., 2019; Bertasiute et al., 2020), and other-regarding behavior in the labor market (e.g., Brandts et al., 2010; Casoria and Riedl, 2013).

Looking at the model together with other economic considerations, this contribution should not be seen as a praise of proportional labor taxes. In the real world, many more taxes exist, which are absent from the model and potentially better than proportional labor taxes (including in particular progressive labor taxes). However, it can well be read as a warning against lump-sum taxes. The model shows one additional mechanism, why lump-sum taxes are not as good as classical economists used to think, even when only proportional labor taxes are otherwise available. This comes in addition to other reasons why one might not favor lump-sum taxes, most notably including inequality.

Therefore, governments may want to decrease or abolish lump-sum taxes and quasi lump-sum taxes where these still exist. This could include the reduction or abolition of broadcast license fees, which are still common in several countries, fees for personal identity cards or passports, but even some excise taxes with very inelastic demand, such as a tax on coffee as in Germany (if coffee consumption were fully price inelastic, a coffee tax would economically be equivalent to a lump-sum tax, with different levels depending on coffee consumption).

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Appendix

This appendix shows the maximization problems and the first-order conditions.

The model with a lump-sum tax

When lump-sum taxes τ_1 (in period 1) and τ_2 (in period 2) are introduced, the agent solves the optimization problem

$$\begin{aligned} \max_{c_1,h_1,c_2,h_2} \; & u^*(c_1,h_1,c_2,h_2), \qquad (4) \\ s.t.\; c_1 \le & h_1 w_1 - \tau_1, \\ c_2 \le & h_2(w_1+\phi h_1) - \tau_2, \end{aligned}$$

where $\tau_1 \geq 0$ and $\tau_2 \geq 0$ are known in advance.

The first order conditions (that lead in the range of admissible values also to the global maximum) are as follows:

$$\begin{aligned} \frac{-b}{1-h_1} + \frac{w_1}{c_1} + \frac{\beta h_2 \phi}{c_2} &= 0, \\ \frac{-b}{1-h_2} + \frac{w_1+\phi h_1}{c_2} &= 0, \\ h_1 w_1 - \tau_1 - c_1 &= 0, \\ h_2(w_1+\phi h_1) - \tau_2 - c_2 &= 0. \end{aligned}$$

The multipliers have already been substituted, thus the equations are in the four unknowns c_1, h_1, c_2 and h_2. Numerical solutions for this system of equations can easily be obtained.

The model with a proportional labor tax

When the government relies instead on a proportional labor tax with tax rates κ_1 (in period 1) and κ_2 (in period 2), the agent solves the optimization problem

$$\begin{aligned} \max_{c_1,h_1,c_2,h_2} \; & u^*(c_1,h_1,c_2,h_2), \qquad (5) \\ s.t.\; c_1 \le & (1-\kappa_1)h_1 w_1, \\ c_2 \le & (1-\kappa_2)h_2(w_1+\phi h_1), \end{aligned}$$

where he takes $\kappa_1 \geq 0$ and $\kappa_2 \geq 0$ as given.

The first order conditions (again after substituting the multipliers, yielding in the range of admissible values again the global maximum) are

$$\begin{aligned} \frac{-b}{1-h_1} + \frac{(1-\kappa_1)w_1}{c_1} + \frac{\beta(1-\kappa_2)h_2\phi}{c_2} &= 0, \\ \frac{-b}{1-h_2} + \frac{(1-\kappa_2)(w_1+\phi h_1)}{c_2} &= 0, \\ (1-\kappa_1)h_1 w_1 - c_1 &= 0, \\ (1-\kappa_2)h_2(w_1+\phi h_1) - c_2 &= 0, \end{aligned}$$

For a meaningful comparison of the two different tax regimes, the revenue raised under both should be equal, so that

$$\kappa_1 h_1 w1 = \tau_1, \qquad (6)$$

$$\kappa_2 h_2(w_1+\phi h_1) = \tau_2. \qquad (7)$$

The first order conditions together with the equations relating κ_1 and κ_2 to τ_1 and τ_2 give the agent's decision for given levels of tax revenue raised, τ_1 and τ_2 (if one prefers four equations in the four unknowns c_1, h_1, c_2 and h_2 corresponding to the system for lump-sum taxes, one can use Equations (6) and (7) to substitute κ_1 and κ_2 in the first order conditions). Also for this system of equations, numerical solutions can easily be obtained.