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Abstract

The existing literature suggests that the concern for economic efficiency calls for individual taxation of married couples with a higher rate on the primary earner. This paper reconsiders the choice of tax unit in the Becker model of household production, which includes previous analyses as special cases. In the general framework, where all utility yielding commodities are produced through a combinatiion of market goods and household time, optimal taxation requires joint taxation of the family. This result assumes that there are no restrictions in the use of commodity taxes. In the presence of such restrictions individual taxation is typically optimal. However, this may call for a lower rate on primary earners, unlike the standard result.

JEL Classification: H21, D13, J22.

Keywords: optimal taxation, household production, time allocation.

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1 Introduction

Whether married couples should be subject to joint or individual filing has been a debating point throughout the existence of the income tax. In recent decades the balance of the argument has been tilting in favor of individual taxation, one of the important reasons being that such a system is supposed to be superior in terms of economic efficiency, see e.g. Rosen (1977) and Boskin and Sheshinski (1983). Indeed, there has been a development in OECD countries towards using the individual as the tax unit and in those countries still operating a system of joint taxation, such as the United States and Germany, many have proposed its abandonment. This paper questions the proposition that the development towards individual taxation is good for efficiency.

The efficiency argument in favor of individual taxation takes as its point of departure that the labor supply of primary earners is less elastic than that of secondary earners. Traditional Ramsey considerations call for higher tax rates on the less elastic tax bases, implying that the income of primary earners should carry a relatively high rate of tax. A simple way of achieving this goal in a system of progressive income taxation, since primary earners by definition have a higher income, is to let the two members of the household file individually. By contrast, in a system of joint taxation the marginal tax rates for the two partners are identical so that the distortionary effects on aggregate labor supply become more severe.

Despite the important role of labor supply for the above result, little attention has been paid to the model of labor supply on which it is based. The literature on optimal income taxation relies on the labor-leisure framework, in which households are assumed to derive utility from the consumption of market goods and time, separately. However, since the work of Becker (1965), Lancaster (1966), and Muth (1966), it has been recognized that goods and time are not themselves carriers of utility but are rather inputs into a process which generates household activities or commodities. In other words, households derive utility from different combinations of goods and time and, particularly important for our results, there is no such thing as *pure* leisure. For example, watching a movie requires not only the moviegoer's time but also the purchase of transportation, tickets, etc. One may think of this as a theory of consumption technology or as a theory of household production, although it does not deal with production activities in the common sense of the term.

Our paper builds upon the Becker (1965) framework, extended to allow for the presence of two members of each household. How does the taxation of labor income distort behavior in this model? Firstly, the reduction of shadow wages within the household leads to a substitution away from goods intensive activities towards time intensive activities, thereby reducing the supply of labor to the market. This effect is analogous to the labor-leisure distortion in standard models. Secondly, differential rates of tax for the husband and wife affect the relative shadow wage within the household, thereby leading to a distortion of the primary-secondary labor input mix in household production. The optimal tax system should aim at minimizing or preferably avoiding these two distortions. We analyze whether this calls for individual or joint income taxation, taking into account that governments also have commodity taxes at their disposal.

Our first result is that in the absence of restrictions in the use of commodity taxes, joint filing is always optimal. The result applies even in the presence of different labor supply elasticities for primary and secondary earners; in fact the optimal tax rule is completely independent of the magnitude of these elasticities. In the Becker framework we may take care of the substitution between different activities through the use of selective commodity taxation, where the rates are set according to the factor shares in each activity. The income tax system on the other hand should avoid distorting the time inputs of the two partners in household activities, which implies joint taxation.

This recommendation is related in spirit to the production efficiency theorem of Diamond and Mirrlees (1971), stating that optimal government behavior entails production efficiency in the market sector when there are no restrictions on the availability of tax instruments. Likewise, we find that the fully optimized tax system involves production efficiency in the household sector. This implies that the case for individual taxation must be sought in the presence of restrictions in the use of commodity taxes, resulting from administrative costs, political inefficiencies, etc.

Our second result deals with the case of such restrictions. Now the income tax should try to compensate for the missing commodity taxes. The ability of individual income taxation to do so relies on the existence of a systematic tendency in the primary-secondary input mix for those activities which are taxed to leniently. Specifically, if the time of primary earners are used predominantly in those activities which are favored by commodity taxes, we should impose a relatively low tax rate on primary earners, and vice versa. On the other hand, if there is no such systematic relationship it is still optimal to employ joint taxation. In any case, the optimal income tax system depends on the nature of administrative costs, not the magnitude of labor supply elasticities, and there is no presumption in favor of a higher tax rate on the income of primary earners, as advocated by the literature.

The paper is related to the study of Piggott and Whalley (1996). In a specialized model of household production, they use numerical simulation techniques to show that a switch from individual to joint taxation may lead to an aggregate welfare gain or loss depending on the value of labor supply elasticities and other parameters to which their model is calibrated. But in their model, cf. the critiques by Apps and Rees (1999a) and Gottfried and Richter (1999), joint taxation is still an unlikely candidate for the *optimal* tax system. However, this conclusion relies on the simplified Gronau (1973, 1977) specifications of household production, which retains the assumption of pure leisure as a utility yielding commodity. In our model, which includes both the Piggott-Whalley and the Boskin-Sheshinski analyses as special cases, we demonstrate that the pure leisure assumption is a necessary condition for the optimality of individual taxation.

The paper is organized in the following way. The next section sets up the model of household production, while Section 3 demonstrates that the fully optimized tax system involves joint taxation. Section 4 analyses optimal income taxation with restrictions in the use of commodity taxes. Section 5 investigates the role of labor supply elasticities for our results and, finally, Section 6 concludes.

2 The Model

Since we are concerned solely with the effects of taxation on efficiency, we adopt the so-called household utility function approach also used in the Boskin-Sheshinski and Piggott-Whalley papers. In this approach the family is considered to be the decision making unit and behavior is determined by the maximization of a family utility function. As pointed out by Apps and Rees (1988), the analysis of taxation in this framework is compatible with the individual-based, collective models on the assumption that the distribution of utility within the household agrees with the preferences of the social planner.[1]

The representative family obtains utility by combining market-produced goods, $X^1, X^2, \ldots, X^n$, and household time, $L^1, L^2, \ldots, L^n$ so as to obtain commodities/activities, $Z^1, Z^2, \ldots, Z^n$. In algebra,

$$U = U\left(Z^1, Z^2, \ldots, Z^n\right), \tag{1}$$

and

$$Z^i = f^i\left(X^i, L^i\right), \qquad i = 1, 2, \ldots, n, \tag{2}$$

where the f-function exhibits constant returns to scale.[2] This basic setting is identical to the original Becker (1965) framework except that L^i, rather than being the input of one individual, is treated as a composite input due to the presence of two members of each household. Thus,

$$L^i = g^i\left(L_P^i, L_S^i\right) \qquad i = 1, 2, \ldots, n, \tag{3}$$

where $g(\cdot)$ features constant returns to scale and where L_P^i and L_S^i are the time inputs of the two household members, whom we will refer to as a primary (P) and a secondary (S) earner, respectively. The formulation includes the case where some activities use the time input of one household member only.

[1] By contrast, in the case of dissonance between the intra-family distributional outcome and the preferences of the social planner, the welfare effects of taxation also depend on distributional effects not accounted for in our analysis, see Apps and Rees (1988, 1999b). For a further discussion of intra-household distribution in models of collective labor supply and household production see Chiappori (1997) and Apps and Rees (1997).

[2] More generally, we may think of X^i as a composite input incorporating many different market-produced goods. It is possible that some of these market-produced goods enter more than one household activity. The only substantive assumption needed for our purpose is the feasibility of selective taxation across different X^i's.

Household decisions must be made in accordance with the budget constraint

$$\sum_{i=1}^{n} P^i X^i - W_P N_P - N_S \leq 0, \tag{4}$$

where N_P and N_S denote labor supply to the market of the primary and the secondary earner, respectively, while P^i is the consumer price of good i and W_P is the consumer wage of the primary worker. The consumer wage of the secondary worker is normalized to one. Taxes are introduced by defining $P^i \equiv p^i + \tau^i P^i$ and $W_P \equiv w_P - \tau_P W_P$, where small letters refer to producer prices and wages, and where tax rates, τ^i and τ_P, are measured in proportion of after-tax prices and wages. Without loss of generality, due to the equivalence of a uniform value-added tax and a general income tax, we disregard taxes on secondary earners and interpret τ_P as the *excess* marginal tax rate on the primary earner. Thus, $\tau_P = 0$ corresponds to joint income taxation, whereas $\tau_P > 0$ corresponds to individual taxation with the highest rate on the primary earner.

Decisions are also subject to the following time constraints of the two individuals

$$\sum_{i=1}^{n} L_S^i + N_S = 1, \tag{5}$$

$$\sum_{i=1}^{n} L_P^i + N_P = 1, \tag{6}$$

where the total time available is normalized to one.

We solve the dual consumer problem by minimizing the LHS of (4) subject to $U \geq \bar{U}$ and equations (1), (2), (3), (5), and (6). The solution is characterized by

$$\tilde{Z}^i = Z^i \left(\mathbf{Q}, \bar{U} \right), \tag{7}$$

$$\tilde{X}^i = x^i \left(P^i, W^i \right) \tilde{Z}^i \quad , \quad \tilde{L}^i = l^i \left(P^i, W^i \right) \tilde{Z}^i, \tag{8}$$

$$\tilde{L}_P^i = l_P^i \left(W_P\right) \tilde{L}^i \quad , \quad \tilde{L}_S^i = l_S^i \left(W_P\right) \tilde{L}^i, \tag{9}$$

where a tilde refers to compensated demand or supply, x^i and l^i are the inputs of goods and labor, respectively, per unit of commodity i, while l_P^i and l_S^i are the time uses of primary and secondary earners per unit of labor in activity i. The solution depends on unit costs in household activities, $\mathbf{Q} = (Q^1, ..., Q^n)$, as well as wage indices, W^i, which are given by

$$Q^i = Q^i \left(P^i, W^i\right) \equiv P^i x^i \left(P^i, W^i\right) + W^i l^i \left(P^i, W^i\right), \tag{10}$$

$$W^i = W^i \left(W_P\right) \equiv W_P l_P^i \left(W_P\right) + l_S^i \left(W_P\right). \tag{11}$$

For later use, note that the expenditure function may be derived by inserting equations (5) - (11) in equation (4), which gives

$$e\left(\mathbf{Q}, W_P, \bar{U}\right) = \sum_{i=1}^{n} Q^i \tilde{Z}^i - W_P - 1. \tag{12}$$

Like Becker we focus on the case where the amount of time required for the consumption of a certain good, i, is fixed, such that $x^i \left(P^i, W^i\right) \equiv x^i$ and $l^i \left(P^i, W^i\right) \equiv l^i$. In this case, the effects of taxation on behavior become directly comparable to the effects discussed in the literature. Taxes affect behavior in two ways. Firstly, commodity and labor taxes induce a substitution away from goods intensive activities towards time intensive activities, thereby reducing the supply of labor to the market. This is analogous to the labor-leisure distortion of the Boskin-Sheshinski approach. Secondly, different marginal tax rates on the two household members affect the primary-secondary labor input mix in each household activity, corresponding to the effect introduced by the Piggott-Whalley contribution. Thus, the assumption of fixed proportions retains the tax effects emphasized in the previous papers and, indeed, our framework is sufficiently general to encompass these studies as special cases. This is easily seen by considering the following examples:

- For $n = 3$ and $l^1 = x^2 = l_S^2 = x^3 = l_P^3 = 0$, the utility function becomes $U(X^1, L_P^2, L_S^3)$, such that the framework corresponds to Boskin and Sheshinski (1983).

- For $n = 4$ and $l^1 = x^2 = x^3 = l_S^3 = x^4 = l_P^4 = 0$, the utility function becomes $U(X^1, g^2(L_P^2, L_S^2), L_P^3, L_S^4)$, such that the framework corresponds to Piggott and Whalley (1996).

3 Optimal Taxation

To derive the optimal tax system, we define the dead-weight burden of taxation as the equivalent variation minus the tax revenue, that is

$$D = e\left(\mathbf{Q}, W_P, \bar{U}\right) - e\left(\mathbf{q}, w_P, \bar{U}\right) - T\left(\mathbf{P}, W_P, \bar{U}\right), \tag{13}$$

where $\mathbf{q} = (q^1, ..., q^n)$ denotes the vector of unit costs in the absence of taxation, $\mathbf{P} = (P^1, ..., P^n)$ is the vector of consumer prices, $\bar{U}$ is the after tax utility level, while $T(\cdot)$ is the total tax revenue defined as

$$T\left(\mathbf{P}, W_P, \bar{U}\right) = \sum_{i=1}^{n} \tau^i P^i \tilde{X}^i + \tau_P W_P \tilde{N}_P.$$

By inserting equations (5) - (11) as well as the definitions $\tau^i = (P^i - p^i)/P^i$ and $\tau_P = (w_P - W_P)/W_P$, the tax revenue becomes

$$T\left(\mathbf{P}, W_P, \bar{U}\right) = \sum_{i=1}^{n} \left(P^i - p^i\right) x^i \tilde{Z}^i + (w_P - W_P)\left(1 - \sum_{i=1}^{n} l_P^i l^i \tilde{Z}^i\right). \tag{14}$$

Given the usual assumption of linear production technology in the market sector, the optimal tax system may be found by minimizing D with respect to consumer prices and wages subject to an exogenous revenue requirement, $\bar{T}$. That is,

$$\min_{\mathbf{P},W_P} D\left(\mathbf{P}, W_P, \bar{U}\right) \quad \text{st.} \quad T\left(\mathbf{P}, W_P, \bar{U}\right) \geq \bar{T}. \tag{15}$$

Let $\alpha_X^i \equiv x^i P^i / Q^i$ denote the cost share for market-produced goods in the production of commodity i. Then, solving the above problem, we obtain

Proposition 1 *Positive goods shares in all activities, $\alpha_X^i > 0 \ \forall i$, is a sufficient condition for the optimal tax system to be characterized by joint taxation, $\tau_P = 0$. In this case the optimal commodity tax structure is given by $\tau^i/\tau^j = \alpha_X^j/\alpha_X^i \ \forall i, j$.*

Proof. See Appendix A.

Thus, when all utility yielding commodities require the input of market goods it is more efficient to have joint than individual filing. To grasp the intuition for this result, consider the adverse effects of a general income tax or, equivalently, a uniform value-added tax. Since household time is untaxable, uniform commodity taxation leads to a substitution away from goods intensive activities towards time intensive activities, thereby reducing the supply of labor to the market. Now, rather than using individual income taxation to deal with this distortion, it is better to employ selective commodity taxation. In particular, by imposing higher tax rates on goods that are used in time intensive activities, as reflected by the rule in Proposition 1, relative unit costs, Q^i/Q^j, are left unchanged, whereby distortions between household activities are avoided altogether. In this situation, the use of individual income taxation, by changing relative shadow wages, merely creates a household production inefficiency, which could be avoided by the use of joint taxation.

In conclusion, when all market goods are taxable (while household time is not) it is possible to combine selective commodity taxation with joint income taxation so as to avoid any excess burden of taxation. The discrepancy between this result and the policy conclusion of previous papers stems from the absence of pure leisure. In order to highlight further the importance of the pure leisure assumption, we may state the following corollary

Corollary 1 *A goods share equal to zero,* $\alpha_X^i = 0$*, in at least one activity is a necessary condition for the optimal tax system to be characterized by individual taxation,* $\tau_P \neq 0$*.*

Proof. This follows directly from the first statement in Proposition 1.

In response to this corollary, one may argue that the pure leisure assumption, while being descriptively unrealistic, is a simple way to capture the presence of untaxable goods. If some market goods are not taxed, then neither are the household activities in which these market goods are used. The standard tax model assumes that there is exactly one such untaxable activity and, by convention, it is termed 'leisure'. These considerations imply that a theoretical justification for individual taxation must be sought in the presence of restrictions in the use of commodity taxes.

4 Restrictions in the use of Commodity Taxes

In practise the use of optimal commodity taxes is obstructed by the presence of administrative costs, imperfect information, political inefficiencies, etc. For these reasons it may be too costly, or even infeasible, to operate the optimal commodity tax system. To study the impact of such restrictions we now consider an exogenously given commodity tax structure $\{\tau^i\}_{i=1}^n$. We then ask if it is possible to improve welfare through a marginal restructuring of the tax system which introduces different marginal tax rates on primary and secondary earners. Due to the equivalence of a uniform value-added tax and a general income tax, we may examine the consequence for welfare formally by, say, raising τ_P and making a uniform reduction of the τ^i's.

Let $\eta^{ki} \equiv \frac{\partial \tilde{Z}^k/\tilde{Z}^k}{\partial Q^i/Q^i}$ denote the elasticity of compensated demand for activity k with respect to the unit cost in activity i. Then,

Proposition 2 *Consider a tax system characterized by a given commodity tax structure, $\{\tau^i\}_{i=1}^n$, and joint taxation, $\tau_P = 0$. This tax system may be improved by a revenue-neutral change of tax rates on primary and secondary earners such that*

$$sign\{\tau_P\} = sign\left\{-\sum_{k=1}^{n}\left[\frac{\tilde{L}_P^k}{\tilde{N}_P} - \frac{\tilde{L}_S^k}{\tilde{N}_S}\right]\sum_{i=1}^{n}\eta^{ki}\tau^i\alpha_X^i\right\}.$$

Proof. See Appendix B.

Note first that the result of the previous section also follows from this proposition as $\tau_P = 0$ when $\tau^i\alpha_X^i = \tau^j\alpha_X^j$ for all i, j since $\sum_{i=1}^n \eta^{ki} = 0$ due to homogeneity of degree zero of compensated demands. When the commodity tax rates are not at their optimal levels individual taxation is typically optimal. However, the elements which determine the optimal sign of τ_P are different from the labor-leisure analyses and do not lead to a general presumption in favor of a higher tax rate on primary earners.

To come to grips with Proposition 2, consider the case where exactly one market good is untaxable. We then have

Corollary 2 *Consider a tax system characterized by commodity tax structure* $\tau_1 = 0$ *and* $\tau^i \alpha_X^i = \tau^j \alpha_X^j$ *for* $i, j = 2, ..., n$ *and joint taxation,* $\tau_P = 0$. *This tax system may be improved by a revenue-neutral change of tax rates on primary and secondary earners such that*

$$sign\{\tau_P\} = sign\left\{\sum_{k=1}^{n}\left(\frac{\tilde{L}_P^k}{\tilde{N}_P} - \frac{\tilde{L}_S^k}{\tilde{N}_S}\right)\eta^{k1}\right\}.$$

Proof. This follows directly by insertion of the considered tax structure in Proposition 2 and using the relationship $\sum_{i=1}^{n} \eta^{ki} = 0$.

Thus, we should impose a relatively low tax rate on the person used mainly in combination with the untaxable good 1 as well as its complements. This rule reflects that selective income taxation tries to compensate for the missing commodity tax instrument. The specific restriction which we impose implies that activity 1 (and complementary activities) are taxed too leniently. To counteract this distortion, income taxation should be designed to raise shadow wages in these activities. This is done through the imposition of low rates on the household member used intensively in these activities.[3]

Reconsidering the general case in Proposition 2, we conclude that the person used intensively in combination with market goods that are taxed too leniently, relative to the rule in Proposition 1, should face the lowest marginal tax rate. On the other hand, if there is no systematic correlation between time intensities and the activities which are taxed to leniently, selective income taxation cannot be used to compensate for inefficient commodity taxation. In any case, whether the income

[3] The introduction of selective income taxation also generates a distortion in the relative time use of the two partners in household production. However, this effect is irrelevant for the optimal sign of τ_P as it is only of second order when starting from a situation with identical rates.

tax ought to favor the primary or the secondary earner (or none at all) depends in the end on the nature of the administrative costs.

5 The Role of Labor Supply Elasticities

According to the standard reasoning, e.g. Rosen (1977) and Boskin and Sheshinski (1983), a selective income tax favoring the secondary earner is good for efficiency because it exploits that the labor supply of secondary earners is relatively elastic. Therefore, a natural question to ask in the context of our model is whether this stylized fact on labor supply elasticities still provides an argument for choosing individual taxation.

First, looking at the case without restrictions in the use of commodity taxes, it should be clear that the answer is no. According to Proposition 1, joint filing is always optimal in this case and the magnitudes of labor supply elasticities are irrelevant for optimal tax design.

In the case of constraints on the commodity tax system, the answer is less straightforward. Proposition 2 shows that individual taxation is typically optimal, but that the difference between tax rates may go either way. Thus, the question is whether empirical estimates of labor supply elasticities may help determine who should face the lowest rate. We therefore derive the (compensated) labor supply elasticity of the two household members. For the primary worker it equals (see Appendix C)

$$\frac{\partial \tilde{N}_P/\tilde{N}_P}{\partial W_P/W_P} = \sum_{k=1}^{n} \frac{\tilde{L}_P^k}{\tilde{N}_P} \left[\left(1-\alpha_P^k\right)\sigma^k - \sum_{i=1}^{n} \eta^{ki} \alpha_L^i \alpha_P^i \right], \tag{16}$$

where α_L^i denotes the cost share for labor in activity i, α_P^i is the share of labor costs attributed to the primary earner, and σ^i denotes the elasticity of substitution between the two partners in activity i. The corresponding elasticity for the secondary earner may be found by substituting S for P in the respective subscripts. Equation (16) shows that a wage increase for the primary earner raises his/her labor supply by inducing a substitution away from primary time towards secondary time in each activity (first component in the bracket) and by inducing a substitution away from the activities using a lot of primary time (second component in the bracket).

Is it possible to uncover the sign in Proposition 2 by using our knowledge of labor supply elasticities? The answer is clearly negative. The observed difference in labor supply elasticities may, for example, be due to different shares in labor costs, i.e. the α_P^i and α_S^i parameters, but they do not enter the equation in Proposition 2. Therefore, it may well be that economic efficiency calls for the lowest tax rate on primary earners although their labor supply is relatively inelastic.

6 Conclusion

The consensus view seems to be that the income tax should be levied on individuals, not families, and that marginal rates ought to be higher for primary earners. This is supposed to be the most efficient way of collecting revenue, because the labor supply of primary earners is less elastic than that of secondary earners. However, this proposition relies on the labor-leisure model, which does not take into account that utility-yielding commodities take the form of activities using the input of both goods and time. Once we recognize this feature of household behavior, it turns out that selective commodity taxation, rather than selective income taxation, is the better instrument to deal with the distortion of labor supply. Indeed, in the absence of restrictions in the use of commodity taxes, joint income taxation is optimal.

Once we account for the presence of non-optimal commodity taxes, it turns out that individual taxation is typically optimal, although not in the usual way. The income tax should try to compensate for the missing instruments and, consequently, the differentiation of tax rates between primary and secondary earners depends on the nature of administrative costs. In particular, there is no obvious relationship with labor supply elasticities and it may be optimal to favor primary earners even if their labor supply is relatively inelastic.

Realistically, the use of income taxes, like commodity taxes, is characterized by the presence of administrative or political constraints. Generally, if the optimal income taxes are not implementable, the case for joint filing is improved. Take the case where tax collection is constrained to be progressive and anonymous, so that people are taxed only on the basis of income, regardless of position within the family. Then the choice of tax unit is one between identical marginal tax rates, on the one hand, and some exogenously given positive excess marginal tax rate for primary earners on the other. Now, if the optimal excess marginal tax rate for primary earners is negative or even slightly positive, a system of joint taxation is still preferred.

Admittedly, joint taxation may create adverse effects not touched upon in the paper, because it changes the price of marriage. In a progressive tax system, the tax liability of two unmarried people living together is generally different from that of a married couple filing jointly. Couples may face marriage subsidies or marriage penalties, depending on the distribution of income between spouses and on the construction of rate schedules. This may lead to distortions in marriage decisions, see e.g. Alm and Whittington (1997, 1999).

Finally, it should be emphasized that the analysis has been silent about distribution. However, as argued by Apps and Rees (1999), the choice of tax unit may have important implications for both inter- and intra-household distribution. Before drawing firm policy conclusions, one should of course account for the presence of such effects.

A Proof of Proposition 1

From the first-order conditions to the problem (15), we get the following conditions for the optimal tax system

$$\frac{\partial D}{\partial P^j}\frac{\partial T}{\partial W_P} = \frac{\partial D}{\partial W_P}\frac{\partial T}{\partial P^j} \qquad j = 1, ..., n.$$

Using (6), (13), $\partial e/\partial Q^j = \tilde{Z}^j$, and Shephard's Lemma, we have

$$\begin{aligned} \frac{\partial D}{\partial P^j} &= \frac{\partial e}{\partial Q^j}\frac{\partial Q^j}{\partial P^j} - \frac{\partial T}{\partial P^j} = \tilde{Z}^j x^j - \frac{\partial T}{\partial P^j}, \\ \frac{\partial D}{\partial W_P} &= \sum_{k=1}^{n} \frac{\partial e}{\partial Q^k}\frac{\partial Q^k}{\partial W_k}\frac{\partial W_k}{\partial W_P} - 1 - \frac{\partial T}{\partial W_P} = -\tilde{N}_P - \frac{\partial T}{\partial W_P}. \end{aligned}$$

Inserting these derivatives in the above optimality conditions, we get

$$-\frac{\partial T/\partial W_P}{\tilde{N}_P} = \frac{\partial T/\partial P^j}{\tilde{Z}^j x^j}, \qquad j = 1, ..., n, \tag{17}$$

i.e., marginal revenue in proportion of tax bases must be equal for all taxes.

From equation (14) and the definition of the tax rates, we obtain the derivatives

$$\begin{aligned} \frac{\partial T}{\partial P^j} &= \sum_{i=1}^{n} \tau^i P^i x^i \frac{\partial \tilde{Z}^i}{\partial Q^j} x^j + x^j \tilde{Z}^j - \tau_P W_P \sum_{i=1}^{n} l_P^i l^i \frac{\partial \tilde{Z}^i}{\partial Q^j} x^j, \\ \frac{\partial T}{\partial W_P} &= \sum_{i=1}^{n} \tau^i P^i x^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^i}{\partial Q^k} l^k l_P^k - \tilde{N}_P \\ &\quad -\tau_P W_P \left(\sum_{i=1}^{n} l_P^i l^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^i}{\partial Q^k} l^k l_P^k + \sum_{i=1}^{n} \frac{\partial l_P^i}{\partial W_P} l^i \tilde{Z}^i \right), \end{aligned}$$

where we have used Shephard's Lemma. Insertion of these derivatives in (17) yields

$$\begin{aligned}
&\tilde{Z}^j \sum_{i=1}^{n} \tau^i P^i x^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^i}{\partial Q^k} l^k l_P^k + \tilde{N}_P \sum_{i=1}^{n} \tau^i P^i x^i \frac{\partial \tilde{Z}^i}{\partial Q^j} \\
= \;& \tau_P W_P \left[\tilde{N}_P \sum_{i=1}^{n} l_P^i l^i \frac{\partial \tilde{Z}^i}{\partial Q^j} + \tilde{Z}^j \sum_{i=1}^{n} l_P^i l^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^i}{\partial Q^k} l^k l_P^k + \tilde{Z}^j \sum_{i=1}^{n} \frac{\partial l_P^i}{\partial W_P} l^i \tilde{Z}^i \right].
\end{aligned}$$

Joint taxation is characterized by $\tau_P = 0$. Thus, joint taxation is optimal if there exists $\{\tau^i\}_{i=1}^n$ such that the LHS of the above condition is equal to zero. This implies

$$\tilde{Z}^j \sum_{k=1}^{n} l^k l_P^k \sum_{i=1}^{n} \tau^i P^i x^i \frac{\partial \tilde{Z}^k}{\partial Q^i} + \tilde{N}_P \sum_{i=1}^{n} \tau^i P^i x^i \frac{\partial \tilde{Z}^j}{\partial Q^i} = 0,$$

where we have used the symmetry of the Slutsky matrix. Using the definition $\alpha_X^i \equiv x^i P^i / Q^i$ and rearranging terms, we obtain

$$\tilde{Z}^j \sum_{k=1}^{n} l^k l_P^k \sum_{i=1}^{n} \tau^i \alpha_X^i \frac{\partial \tilde{Z}^k}{\partial Q^i} Q^i + \tilde{N}_P \sum_{i=1}^{n} \tau^i \alpha_X^i \frac{\partial \tilde{Z}^j}{\partial Q^i} Q^i = 0, \qquad j = 1, ..., n.$$

As $\tilde{Z}^j$ is homogeneous of degree zero, implying that $\sum_{i=1}^n \frac{\partial \tilde{Z}^j}{\partial Q^i} Q^i = 0$, it is now obvious that a solution to these first-order conditions is characterized by

$$\tau^i / \tau^j = \alpha_X^j / \alpha_X^i \qquad i, j = 1, ..., n.$$

Thus, these formulae and $\tau_P = 0$ characterize a solution to the optimal tax problem.

B Proof of Proposition 2

For a given initial commodity tax structure $\{\tau^i\}_{i=1}^n$, we consider the effect on the dead-weight loss of a marginal increase in τ_P and a corresponding reduction in a value-added tax rate, τ, which keeps the tax revenue constant. The value-added tax is proportional to producer prices, giving rise to consumer prices

$P^i = p^i(1+\tau)/(1-\tau^i)$. The effect on the dead-weight loss of a marginal change in these tax rates is given by

$$\Psi(\tau_P,\tau) = \frac{\partial D(\tau,t_P)}{\partial \tau_P} + \frac{\partial D(\tau,t_P)}{\partial \tau}\frac{d\tau}{d\tau_P},$$

where $d\tau/d\tau_P$ is the change in τ which keeps the tax revenue fixed. From $T(\tau,t_P) = \bar{T}$ we get $d\tau/d\tau_P = -[\partial T(\tau,t_P)/\partial t_P]/[\partial T(\tau,t_P)/\partial\tau]$, implying

$$\Psi(\tau_P,\tau) = \frac{\partial D(\tau,t_P)}{\partial \tau_P} - \frac{\partial D}{\partial \tau}\frac{\partial T(\tau,t_P)/\partial t_P}{\partial T(\tau,t_P)/\partial \tau}.$$

Using equations (6) and (13), we have

$$\begin{aligned}\frac{\partial D(\tau,t_P)}{\partial\tau} &= \sum_{j=1}^{n}\frac{\partial e}{\partial Q^j}\frac{\partial Q^j}{\partial P^j}\frac{\partial P^j}{\partial \tau} - \frac{\partial T}{\partial \tau} = \sum_{j=1}^{n}\tilde{Z}^j x^j\frac{p^j}{1-\tau^j} - \frac{\partial T}{\partial\tau},\\ \frac{\partial D(\tau,t_P)}{\partial t_P} &= \sum_{k=1}^{n}\frac{\partial e}{\partial Q^k}\frac{\partial Q^k}{\partial W_k}\frac{\partial W_k}{\partial W_P}\frac{\partial W_P}{\partial \tau_P} - \frac{\partial W_P}{\partial \tau_P} - \frac{\partial T}{\partial \tau_P} = W_P\tilde{N}_P - \frac{\partial T}{\partial \tau_P},\end{aligned}$$

where the last equalities in the two expressions follow from $\partial e/\partial Q^j = \tilde{Z}^j$, Shephard's Lemma, $\partial P^i/\partial\tau = p^i/(1-\tau^i)$, and $\partial W_P/\partial\tau_P = -W_P$. Inserting these expressions in $\Psi(\tau_P,\tau)$ gives

$$\Psi(\tau_P,\tau) = W_P\tilde{N}_P - \frac{\partial T(\tau,t_P)/\partial t_P}{\partial T(\tau,t_P)/\partial\tau}\sum_{j=1}^{n}\tilde{Z}^j x^j\frac{p^j}{1-\tau^j}.$$

On the presumption that $\partial T/\partial\tau > 0$, i.e. the economy is on the upward-sloping part of the Laffer curve, it follows that $\Psi(0,0) > 0$ if

$$\frac{\partial T(0,0)}{\partial\tau}W_P\tilde{N}_P - \frac{\partial T(0,0)}{\partial t_P}\sum_{j=1}^{n}\tilde{Z}^j x^j P^j > 0. \tag{18}$$

From equation (14) we obtain the derivatives of the tax function evaluated around the initial equilibrium:

$$\begin{aligned}\frac{\partial T(0,0)}{\partial\tau} &= \sum_{j=1}^{n}\tilde{Z}^j x^j P^j + \sum_{i=1}^{n}\tau^i P^i x^i\sum_{k=1}^{n}\frac{\partial\tilde{Z}^i}{\partial Q^k}P^k x^k,\\ \frac{\partial T(0,0)}{\partial t_P} &= -\sum_{i=1}^{n}\tau^i P^i x^i\sum_{k=1}^{n}\frac{\partial\tilde{Z}^i}{\partial Q^k}l^k l_P^k W_P + W_P\tilde{N}_P,\end{aligned}$$

where we have used Shephard's Lemma, $\partial P^i/\partial\tau = P^i$, $P^i - p^i = \tau^i P^i$, and $\partial W_P/\partial\tau_P = -W_P$. Inserting these derivatives in (18), we get the condition

$$\begin{aligned}\tilde{N}_P \sum_{i=1}^{n} \tau^i P^i x^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^i}{\partial Q^k} P^k x^k + \sum_{i=1}^{n} \tau^i P^i x^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^i}{\partial Q^k} l^k l_P^k \sum_{j=1}^{n} \tilde{Z}^j x^j P^j &> 0 \quad \Leftrightarrow \\ \sum_{i=1}^{n} \tau^i P^i x^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^i}{\partial Q^k} \left[\frac{x^k P^k}{\sum_{j=1}^{n} \tilde{Z}^j x^j P^j} + \frac{l^k l_P^k}{\tilde{N}_P} \right] &> 0.\end{aligned}$$

Using symmetry of the Slutsky matrix, $\tilde{X}^k = x^k \tilde{Z}^k$, $\tilde{L}^P = l^k l_P^k \tilde{Z}^k$, and rearranging terms the inequality becomes

$$\sum_{i=1}^{n} \tau^i P^i x^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^k/\tilde{Z}^k}{\partial Q^i} \left[\frac{P^k \tilde{X}^k}{\sum_{j=1}^{n} P^j \tilde{X}^j} + \frac{\tilde{L}_P^k}{\tilde{N}_P} \right] > 0.$$

Using equation (4) and equations (8) through (11), this may be written as

$$\sum_{i=1}^{n} \tau^i P^i x^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^k/\tilde{Z}^k}{\partial Q^i} \left[\frac{Q^k \tilde{Z}^k - W_P \tilde{L}_P^k - W_S \tilde{L}_S^k}{W_P \tilde{N}_P + W_S \tilde{N}_S} + \frac{\tilde{L}_P^k}{\tilde{N}_P} \right] > 0,$$

or

$$\sum_{i=1}^{n} \tau^i P^i x^i \sum_{k=1}^{n} \frac{\partial \tilde{Z}^k/\tilde{Z}^k}{\partial Q^i} \left[\frac{Q^k \tilde{Z}^k}{W_S \tilde{N}_S} - \frac{\tilde{L}_S^k}{\tilde{N}_S} + \frac{\tilde{L}_P^k}{\tilde{N}_P} \right] > 0.$$

Symmetry of the Slutsky matrix and homogeneity of degree zero of the compensated demand functions give the following relationship

$$\sum_{k=1}^{n} \frac{\partial \tilde{Z}^k/\tilde{Z}^k}{\partial Q^i} \frac{Q^k \tilde{Z}^k}{W_S \tilde{N}_S} = \sum_{k=1}^{n} \frac{\partial \tilde{Z}^k}{\partial Q^i} \frac{Q^k}{W_S \tilde{N}_S} = \frac{1}{W_S \tilde{N}_S} \sum_{k=1}^{n} \frac{\partial \tilde{Z}^i}{\partial Q^k} Q^k = 0,$$

which implies that the above inequality may be stated as

$$\sum_{k=1}^{n} \left[\frac{\tilde{L}_P^k}{\tilde{N}_P} - \frac{\tilde{L}_S^k}{\tilde{N}_S} \right] \sum_{i=1}^{n} \eta^{ki} \tau^i \alpha_X^i > 0,$$

where $\alpha_X^i \equiv \frac{P^i x^i}{Q^i}$ and $\eta^{ki} \equiv \frac{\partial \tilde{Z}^k/\tilde{Z}^k}{\partial Q^i/Q^i}$. Thus, a small increase in τ_P and a corresponding reduction in τ increase the dead-weight loss if this inequality is fulfilled, and vice versa.

C Derivation of Equation (16)

The labor supply of the primary worker follows from equations (6) - (9):

$$\tilde{N}_P = 1 - \sum_{k=1}^{n} \tilde{L}_P^k = 1 - \sum_{k=1}^{n} l_P^k (W_P)\, l^k Z^k \left(Q^1, ..., Q^n, \bar{U}\right),$$

implying that

$$\begin{aligned} \frac{\partial \tilde{N}_P}{\partial W_P} &= -\sum_{k=1}^{n} \frac{\partial l_P^k}{\partial W_P} l^k \tilde{Z}^k - \sum_{k=1}^{n}\sum_{i=1}^{n} l_P^k l^k \frac{\partial \tilde{Z}^k}{\partial Q^i} \frac{\partial Q^i}{\partial W^i} \frac{\partial W^i}{\partial W_P} \\ &= -\sum_{k=1}^{n} \frac{\partial l_P^k / l_P^k}{\partial W_P / W_P} \frac{\tilde{L}_P^k}{W_P} - \sum_{k=1}^{n}\sum_{i=1}^{n} \tilde{L}_P^k \frac{\partial \tilde{Z}^k / \tilde{Z}^k}{\partial Q^i / Q^i} \frac{l^i l_P^i}{Q^i}, \end{aligned}$$

where the last equality follows from Shepard's Lemma and $\tilde{L}_P^k = l_P^k l^k \tilde{Z}^k$. Now, the labor supply elasticity may be written as

$$\frac{\partial \tilde{N}_P / \tilde{N}_P}{\partial W_P / W_P} = \sum_{k=1}^{n} \frac{\tilde{L}_P^k}{\tilde{N}_P} \left[-\frac{\partial l_P^k / l_P^k}{\partial W_P / W_P} - \sum_{i=1}^{n} \frac{\partial \tilde{Z}^k / \tilde{Z}^k}{\partial Q^i / Q^i} \frac{W^i l^i}{Q^i} \frac{W_P l_P^i}{W^i} \right].$$

Inserting $\frac{\partial l_P^k / l_P^k}{\partial W_P / W_P} = -\left(1 - \alpha_P^k\right) \sigma^k$, $\frac{W^i l^i}{Q^i} = \alpha_L^i$, $\frac{W_P l_P^i}{W^i} = \alpha_P^i$, and $\eta^{ki} = \frac{\partial \tilde{Z}^k / \tilde{Z}^k}{\partial Q^i / Q^i}$, we obtain equation (16).

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