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What Determines the Optimal Commodity Tax Structure from an Intuitive Point of View?

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2002-17

ISSN 0908-7745

The activities of EPRU are financed by a grant from
The National Research Foundation

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November 2002

Abstract

The paper provides an intuitive explanation – seen from an efficiency point of view – of the optimal commodity tax structure as the result of a trade-off between two objectives: 1) the objective of maintaining the first-best pattern of consumption of produced commodities, and 2) the objective of not discouraging the supply of labour. It supports this insight using a utility function with the explicit representation of the use of time, and using a functional form based on this utility function, which has sufficient flexibility not to predetermine the outcome of tax simulations, contrary to commonly employed functional forms which impose separability between consumption and leisure. The paper supplements the work of Atkinson and Stern (1980, 1981) by generalising the parameterised functional form they consider, and by pointing out the optimal tax implication of their analysis. It supplements the work by Sandmo (1990) and others by applying standard results to the analysis of optimal taxation with home production, facilitating the derivation of results and their interpretation, and thus helping to clarify certain conceptual ambiguities.

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Keywords:

Public economics, optimal taxation, home production, tax simulation

JEL classification codes:

H2

Acknowledgements:

The work for this article has been made partly at CES, Catholic University of Leuven and partly at the Institute of Economics, University of Copenhagen. The resources provided at both places for this work are gratefully acknowledged. This paper is a revised version of a paper presented at the 57th Congress of the International Institute of Public Finance, Linz August 2001, at EPRU October 2001 and at the Nordic Workshop on Tax Policy and Public Economics in Uppsala November 2001. Comments from participants in these events, and in particular from Luca Micheletto and Michael Lundblom have been helpful.

1 Introduction

The first order conditions, which characterise the optimal commodity tax structure, are even by experts in the theory of optimal taxation considered “quite impenetrable from an intuitive point of view” (Boadway 1997). This may explain why optimal tax theory has had a limited impact in praxis. Two seemingly contradictory strands of traditional wisdom, one saying that the optimal tax structure should be proportional, and the other that commodities should be taxed according to their price elasticities have in general dominated economists’ contributions to the tax reform debate. The Corlett-Hague (1953) rule that commodities should be taxed according to their complementarity with leisure has also played a role, although a more limited one, partly because misunderstandings with respect to the proper role of normalisation have cast doubt on what significance to attach to the rule. The three sets of ideas may seem contradictory, but each conveys a relevant insight, and the special conditions under which the one or the other corresponds to the optimal tax structure, are well known to those familiar with the theory of optimal taxation. What in general determines the optimal tax structure is, however, not well understood.

An obvious way to gain insight into what explains the optimal tax structure is simulation studies based on estimated parameterised functional forms, and in fact this approach has been pursued from the outset of the development of modern optimal tax theory. However, these efforts received an early set-back with the realisation that the straitjacket imposed by the assumption of additive separability, made in most demand studies, severely restricted the results which could be obtained. A reaction to this impasse was the use of so-called flexible forms (see for example Wales and Woodland 1979), but since they in general do not globally satisfy the conditions on utility functions of monotonicity and quasi-convexity, flexible forms turned out to be of limited use as the basis for tax simulations with the objective of gaining a theoretical insight.

This motivated Atkinson and Stern (1980, 1981) to try a different tack, representing two related aspects of labour supply and commodity demand: 1) that goods are usually purchased for use in particular activities, and 2) that these activities involve the use of time. In conjunction with Gomulka they estimated, based on British survey data for 1973, a linear demand system augmented with the representation of the use of time according to the Becker theory of household production (Becker 1965). They used the estimated system to evaluate the implication of a switch from direct to indirect taxation. But although they justified their approach with the importance for the optimal tax structure of interaction of consumption with leisure, they did not take the analysis to its logical conclusion, neither by investigating whether a tax reform involving higher taxes on goods with high time requirements would improve welfare, nor by deriving optimal tax rates. However, an important aspect of the contribution of Atkinson and Stern is that they demonstrated, drawing on results established by Pollak and Wachter (1975), that when incorporating household production into the utility function, standard theory of demand can still be applied to the resulting demand system.

For a number of years not much attention seems to have been given to this approach. The new line of research opened up by Sandmo (1990) on the implications of taking Becker's theory of home production into account in optimal tax theory did not make reference to the earlier work by Atkinson and Stern. Neither did the subsequent work by Kleven, Richter and Sørensen (1999) based on essentially the same framework as Sandmo, nor the recent contribution by Kleven (2000) who derives the optimal tax structure based on a more general representation of home production.

Computable General Equilibrium models, which are increasingly being used for the quantitative assessment of tax reforms, in general employ functional forms, which impose separability between leisure and consumption, with adverse, and not always fully recognised, implications for the policy relevance of the simulation results. On this background in the context of analyses of optimal support to low income households (Munk 1998) and the welfare implications of green tax reforms (Munk 1999) I adopted a parameterised representation of household preferences, motivated, as Atkinson and Stern, by the need for a flexible representation of the interaction between leisure and consumptions. Building on these previous contributions, the present paper demonstrates, that what I call the Constant Elasticities of Substitution utility function with explicit representation of the Use of Time, CESUT for short, is a useful tool for tax simulation studies and for the calculation of optimal tax structures. Contrary to additive separable functional forms it is sufficiently flexible to represent differences between various commodities with respect to their complementarity with leisure, and still relatively easy to interpret and to implement in simulation studies.

The main objective of this paper is to add to the understanding of what determines the optimal tax structure. It does this by demonstrating, at the level of 1) standard utility functions, 2) utility functions with the explicit representation of the use of time, and 3) in terms of the parameters of the CESUT, how the optimal tax structure can be understood as the result of a compromise between two objectives: 1) the objective of not distorting the first-best pattern of consumption of produced commodities, and 2) the objective of encouraging the supply of labour.

In addition, the paper supplements the work of Atkinson and Stern (1980, 1981) by generalising the parameterised functional form they consider, and by pointing out the optimal tax implication of their analysis; it supplements the work by Sandmo (1990) and others by applying standard results to the analysis of optimal taxation with home production, facilitating the derivation of results and their interpretation, and thus helping to clarify certain conceptual ambiguities.

The paper is structured as follows. In Section 2 I derive the conditions for an optimal tax structure in the standard Diamond and Mirrlees (1971) framework and provide an intuitive explanation of what determines the optimal tax structure based on a standard utility function. In Section 3 I present a utility function with direct representation of the use of time and analyse the properties of the corresponding demand system. In this context I clarify a number of conceptual ambiguities with respect to the definition of leisure, which have given rise to some misunderstandings as to the interpretation of rules

of normalisation and the Corlett-Hague rule. In Section 4 I use the insight gained in the previous sections to explain the optimal tax structure from an intuitive point of view by using a utility function with the explicit representation of the use of time and the parameterised form of such a function, the CESUT. A final section summarises and concludes the paper.

2 The characterisation of the optimal commodity tax structure within a standard Diamond-Mirrlees framework

We consider a competitive economy with one representative household and a government. The household supplies labour to the market and consumes the produced commodities. Labour is labelled 0, and the produced commodities 1,...,N. The index set for the produced commodities is $C \equiv (1, \dots, N)$ and for all commodities $FC \equiv (0, 1, \dots, N)$. The household's endowment is $\omega \equiv (\omega_0, 0, \dots, 0)$, its consumption is $\mathbf{c} \equiv (c_0, c_1, \dots, c_N)$ and its net trade $\mathbf{x} \equiv (x_0, x_1, \dots, x_N) \equiv \omega - \mathbf{c}$. Consumer prices are $\mathbf{q} \equiv (q_0, q_1, \dots, q_N)$ and producer prices are $\mathbf{p} \equiv (p_0, p_1, \dots, p_N)$. The government's resource requirements, $\mathbf{x}^G \equiv (x_0^G, x_1^G, \dots, x_N^G)$, are financed by commodity taxes, $\mathbf{t} \equiv \mathbf{q} - \mathbf{p}$. The household's preferences are represented by a strictly quasi-concave utility function, $u(\mathbf{x})$. Finally, we assume that production takes place according to a linear production structure using labour as the only input. Producer prices may therefore be considered as fixed at unity as a matter of normalisation and we may write the government's expenditures as $G = \sum_{i \in FC} p_i x_i^G$.

In the endeavour to understand what determines the optimal tax structure it is helpful to start by considering two alternative ways of representing the household's budget constraint and the government's maximisation problem. The household's budget constraint may be represented either in terms of its choice of market transactions, x_i ,

$i \in FC$, i.e. as $\sum_{i \in FC} q_i x_i = 0$, or in terms its choice of consumption of commodities, c_i ,

$i \in FC$, i.e. as $\sum_{i \in FC} q_i c_i = q_0 \omega_0$. In the first case the expenditure function is $E(\mathbf{q}, u)$ and the

compensated (net) demand functions are $x_i(\mathbf{q}, u)$, $i \in FC$, in the latter case the expenditure function is $M(\mathbf{q}, u)$ and the (gross) demand functions are $c_i(\mathbf{q}, u)$, $i \in FC$.

Using the expenditure function approach (see Dixit 1975 and Dixit and Munk 1977), the government's problem may thus be formulated either in terms of tax rates, $\mathbf{t} \equiv \mathbf{q} - \mathbf{p}$, based on net trade

$$\begin{aligned}
& \underset{\{q_i, i \in \text{FC}\}, u}{\text{Max}} \quad u \quad \text{s.t.} \quad u \text{ i kursiv} \\
& E(\mathbf{q}, u) = 0 \quad \text{and} \\
& \sum_{i \in \text{FC}} t_i x_i(\mathbf{q}, u) - G = 0
\end{aligned} \tag{1}$$

or based on consumption

$$\begin{aligned}
& \underset{\{q_i, i \in \text{FC}\}, u}{\text{Max}} \quad u \quad \text{s.t.} \\
& M(\mathbf{q}, u) = p_0 \omega_0, \\
& \sum_{i \in \text{FC}} t_i c_i(\mathbf{q}, u) - G = 0
\end{aligned} \tag{2}$$

The standard formulation of the optimal tax problem assumes that only the net trade, x_i , $i \in \text{FC}$, of all commodities including labour, can be taxed; in other words it corresponds to (1). The rationale for making this assumption is that information about net trade is public, involving market transactions between agents, whereas information about consumption is private, as it may be observable only within the household. Differentiating the corresponding Lagrangian expression

$$L = u + \mu(0 - E(\mathbf{q}, u)) + \lambda \left(\sum_{i \in \text{FC}} t_i x_i(\mathbf{q}, u) - \sum_{i \in \text{FC}} p_i x_i^G \right) \tag{3}$$

with respect to \mathbf{q} , we obtain directly the following well-known Ramsey (1927) conditions for an optimal tax structure

$$\sum_{i \in \text{FC}} t_i E_{ki}(\mathbf{q}, u) = -\theta E_k(\mathbf{q}, u) \quad k \in \text{FC} \tag{4}$$

where $\theta \equiv (\lambda - \mu) / \lambda > 0$, $E_k(\mathbf{q}, u) \equiv \frac{\partial E}{\partial q_k}(\mathbf{q}, u) = x_k(\mathbf{q}, u)$ and $E_{ki} = E_{ik} \equiv \frac{\partial^2 E}{\partial q_i \partial q_k}(\mathbf{q}, u)$

Assuming, as a matter of normalisation, that the supply of labour to the market is untaxed, the conditions for an optimal tax structure

$$\sum_{i \in \text{C}} \frac{t_i}{q_i} \varepsilon_{ki} = -\theta \quad k \in \text{C} \tag{5}$$

follows directly from (4), defining compensated demand elasticities in terms of derivatives of the expenditure function as $\varepsilon_{ik} \equiv \frac{\partial^2 E}{\partial q_i \partial q_k} \bigg/ \frac{x_i}{q_k}$, $i, k \in \text{C}$.

The Ramsey interpretation of these conditions is that the compensated demand for all commodities should be reduced in approximately the same proportion compared with the

first-best situation where the same government expenditures are financed by a lump-sum tax (see Diamond and Mirrlees 1971). However, as has been pointed out for example by Boadway (1997) what this means in terms of the optimal tax structure is far from clear.

Considerable insight may however be gained by comparing the two formulations of the government's maximisation problem.

First, consider the formulation where tax rates are based on net trade, i.e. (1). In this case it is clear that imposing a proportional tax structure based on market transactions,

$$\frac{p_i + t_i}{p_i} = T, \quad i \in \text{FC},$$

does not change the household's budget constraint, and therefore does not raise any tax revenue. A proportional tax structure in this sense is therefore not a feasible solution to the government's maximisation problem and therefore evidently cannot be an optimal solution. One commodity, for example labour, may therefore, without loss of generality, be assumed untaxed. Adding $p_0 = q_0$ as a further constraint to (1) therefore does not change the optimal solution.

Consider now the formulation where tax rates are based on consumption, i.e. (2). It is in this case clear that a proportional tax structure based on the consumption of all commodities including leisure,

$$\frac{p_i + t_i}{p_i} = T, \quad i \in \text{FC},$$

does generate a tax revenue corresponding to a tax at the rate $\tau = \frac{T-1}{T}$ on the value of the household's endowment at

producer prices, $p_0 \omega_0$. Whatever the structure of the household's preferences, a proportional tax structure, based on the consumption of all commodities is therefore both feasible and first-best. In this case adding the assumption that leisure cannot be taxed, imposes a binding constraint on the government's maximisation problem, in general preventing an optimal solution from being achieved. Adding $p_0 = q_0$ as a further constraint to (2) therefore does change the solution to the government's optimisation problem. This makes it clear that imposing the condition that the consumption of leisure cannot be taxed not only make it impossible to achieve the first-best solution, but also creates a substitution away from the consumption of produced commodities towards the consumption of leisure, and hence a discouragement of the supply of labour compared with the first best solution (except, as we shall see, under some very special assumptions).

This is a helpful starting point for interpreting the first order conditions for an optimal solution to the standard formulation of the government's problem of choosing tax rates based on all market transactions, i.e. (5), because (1) is equivalent to the problem of choosing optimal tax rates based on the consumption of all commodities assuming that leisure cannot be taxed, i.e. (2), with the added constraint that $p_0 = q_0$. It suggests that a fruitful angle from which to look at the government's problem of choosing optimal tax rates, when it has to finance its resource requirement by taxes on market transactions

rather than by lump-sum taxes, is to consider the optimal tax structure (5) as the result of a compromise between achieving

- 1) the objective of not distorting the first-best pattern of consumption of the produced commodities, $x_i, i \in C$, (*Objective 1*), and
- 2) the objective of maintaining the supply of labour (*Objective 2*).

Starting from a proportional tax structure based on the produced commodities it is in general possible to encourage the supply of labour (and increase social welfare, see Dixit 1975) by increasing the tax on the commodities which are highly complementary to leisure and by reducing those on commodities which are less so. However doing so creates a distortion by making the marginal rate of transformation in consumption differ from the marginal rate of transformation in production for the produced commodities. The optimal tax structure is achieved at the point where the marginal gain in terms of encouragement of the supply of labour corresponds to the marginal loss in terms of distortion of the pattern of consumption of the produced commodities.

In the general case of many commodities it is difficult to explain this trade-off in terms of elasticities or other parameters characterising the households preferences, but it is helpful in the general case in order to establish points of reference to identify two types of utility functions where there is no such trade-off.

When consumption is weakly separable from leisure in the household's preferences and homothetic in produced commodities we have $\varepsilon_{i0} = \varepsilon_{j0}, i, j \in C$. Distorting the pattern of prices for the produced commodities cannot therefore be used to increase the supply of labour. That is why the optimal tax structure is proportional, i.e.

$$\frac{t_i}{q_i} = k \quad i \in C \quad (6)$$

The other special case is where $U(c_0, c_1, c_2, \dots, c_N) = c_0 + \sum_{i \in C} u_i(c_i)$ such that the cross price elasticities between produced commodities are zero. The optimal tax structure is the inverse elasticity rule

$$\frac{t_i}{q_i} = -\theta/\varepsilon_{ii} \quad i \in C \quad (7)$$

This rule is often only related to *Objective 1* and linked to the Ramsey rule (see for e.g. Myles 1995), however the assumption that the cross price elasticities between produced commodities are zero implies $\varepsilon_{ii} = -\varepsilon_{i0}$, and hence

$$\frac{t_i}{q_i} = \theta / \varepsilon_{i0} \quad i \in C \quad (8)$$

The optimal tax structure may therefore alternatively be seen as encouraging the labour supply, compared to a proportional tax structure based on the produced commodities, by having higher taxes on those commodities which are complementary with leisure, i.e. where ε_{i0} is small. In other words, for the inverse elasticity rule to be valid the utility function needs to have a functional form where there is no trade-off between the two objectives.¹

Explaining the optimal tax structure based on the two objectives also provides an intuitive understanding of the Diamond and Mirrlees Production efficiency theorem which states that when optimal lump-sum transfers are not feasible, although Pareto efficiency is not possible, productive efficiency is still desirable if all market transaction can be taxed optimally. In other words, although it is not possible to equate the subjective rate of transformation in consumption with the objective rate of transformation in production, it is still desirable to maintain the same rate of transformation in all production sectors (contrary to what one might expect based on the Theorem of the second-best). The intuition behind this result from the point of view adopted here, is that distorting the rates of transformation between production sectors does not provide any increased leverage with respect to encouraging the supply of labour as long as consumer prices can be fixed independently of producer prices. When on the other hand restrictions are imposed on the government's choice of optimal tax rates, influencing producer prices may be a way to change consumer prices, and the Production efficiency theorem no longer applies (see Dasgupta & Stiglitz 1971 and Munk 1980).

3 Adding structure to the representation of household preferences

3.1. *Justification for an explicit representation of the use of time*

Having reviewed the interpretation of the optimal tax structure based on a general utility function we now add more structure to the representation of household preferences so as to obtain a better understanding of what determines the optimal tax rates from an intuitive point of view.

¹The question is indeed whether the inverse elasticity rule has not been more misleading than enlightening in providing insight into what determines the optimal tax structure. Furthermore, as is not always emphasised, the functional form from which the inverse elasticity rule can be derived requires that the income elasticity of all produced commodities are zero, or in other words that any increase in lump-sum income is used only to increase the consumption of leisure; an implication which is blatantly in contradiction with all empirical evidence.

The main justification for differentiating tax rates is likely to be distributional considerations. However, in order to design an optimal tax structure it is important to know if, based on efficiency considerations, a proportional tax structure is likely to be optimal or not. This issue can be looked at from two different angles, a theoretical and a practical one:

- 1) Is it realistic to assume that household preferences for the produced commodities are homothetic and separable from the consumption of leisure? , and
- 2) Is it possible to obtain the relevant information to make the optimal differentiation of tax rates?

Analysis of utility functions with explicit representation of the use of time helps answer these questions. As far as the first question is concerned, it is, based even on casual observation, clear that consumption of different commodities requires very different uses of time (consider for example child care on the one hand and vacation on the other), and therefore may have different degrees of complementarity with leisure (or non-market use of time to be more precise). As far as the second question is concerned, it is important to point out that the government may be able to base its decision on tax rates on other information than market information even if it need to base the collection of tax revenue only on market information. Even if the complementarities cannot be inferred from traditional econometric analysis based on variation in prices and market transactions, the government may be able to supplement such information with inferences drawn from direct observation of household behaviour with respect to the use of time for the consumption of different products, as is known from for example transport economics.

Much applied work, and in particular applied work based on the use of general equilibrium models, adds structure to the general representation of household preferences by employing additively separable utility functions. However, this assumption severely limits the flexibility of the estimating equations from the point of view of optimal tax theory, always making a proportional tax structure the optimal solution. Deaton (1981, p 1) have formulated it as follows: *“It is likely that empirically calculated tax rates, based on econometric estimates of parameters, will be determined in structure, not by the measurement actually made, but by arbitrary, untested (and even unconscious) hypotheses chosen by the econometrician for practical convenience”* (quoted from Atkinson and Stern 1980). As our initial analysis has suggested, the interaction between consumption of leisure and the consumption of the various commodities is one of the two factors explaining the optimal tax structure. It is therefore essential in adding structure to the representation of household preferences not to assume this interaction away, as is the case when assuming separability between leisure and consumption in the household’s preferences.

3.2. Utility function with an explicit representation of the use of time

In order to avoid these pitfalls, we specify a utility function, which allows the interaction between the consumption of produced commodities and leisure to differ between produced commodities. We define a utility function with an explicit representation of the use of time, as

$$U\left(c_0^0, C\left(C_1\left(x_1, c_0^1\right), C_2\left(x_2, c_0^2\right), \dots, C_N\left(x_N, c_0^N\right)\right)\right) \quad (9)$$

where $c_0^0 = \omega_0 - \sum_{i \in C} c_0^i + x_0$ is “pure leisure”². For each composite good, C_i , the preference for the amount purchased of the commodity, x_i , and the time used for its consumption, c_0^i , is expressed by a concave function $C_i = C_i(x_i, c_0^i)$. These functions may be interpreted as representing either household production or consumption activities³. “Leisure” or “non-market use of time” is therefore $c_0 = \omega_0 + x_0 = \sum_{i \in C} c_0^i + c_0^0$. Aggregate consumption, C , is a concave function of the composite goods, $C = C(C_1, C_2, \dots, C_N)$, and $U(c_0^0, C)$ is a utility function with standard properties.

The assumption that the household maximises utility subject to its budget constraint may, using the expenditure function approach, be expressed as

$$E(q_0, q_1, \dots, q_N, u) \equiv \underset{c_0^i, i=0,1,\dots,N; x_i, 0,1,\dots,N}{\text{MIN}} \quad q_0 x_0 + \sum_{i \in C} q_i x_i \quad s.t. \quad (10)$$

$$u = U\left(\omega_0 + x_0 - \sum_{i \in C} c_0^i, C_1\left(x_1, c_0^1\right), C_2\left(x_2, c_0^2\right), \dots, C_N\left(x_N, c_0^N\right)\right)$$

which has all the standard properties of an expenditure function.

² “Pure leisure” is thus defined as the amount of time spent on activities, which are not associated with the consumption of purchased commodities or the supply of labour to the market. Pure leisure may for empirical purposes be interpreted as non-market use of time which cannot be related to the consumption of any specific commodity, as for example the use of time for relaxation in ones home which typically involves the use of many durable commodities at the same time. This definition of pure leisure and the assumption that it is separable from consumption of produced commodities is useful in applied work, and we are not here going to be drawn on whether or not from an ontological point of view all time is spent on either consumption or labour. Any scientific theory has to be developed in such a way that it can be applied either to data that are available or to data that can potentially be made available, and not by trying to represent the world as it “really” is.

³ The aggregation functions may be interpreted as home production functions, or as just constraining household preferences. In the first case, the composite commodity, C_i , is a physical entity resulting from the combinations of a purchased commodity and time as in the case of food prepared in the home; in the second case, the composite commodity is just a theoretical concept helping to structure the household’s preferences, as in the case of childcare where alternative combinations of non-marketed time and the purchase of a marketed commodity can satisfy the same well-defined need. The one interpretation may be used for one application and the other for another, but it does not matter for the formal analysis.

Assuming that $C_i = C_i(x_i, c_0^i)$, $i \in C$, and $C = C(C_1, C_2, \dots, C_N)$ are homogenous of degree 1, we have

$$\tilde{E}(q_0, Q, u) \equiv \text{MIN}_{c_0^0, C} q_0 c_0^0 + QC \text{ s.t. } U(c_0^0, C) = u, \text{ where} \quad (11)$$

$$Q = Q(Q_1, Q_2, \dots, Q_N) \equiv \left(\text{MIN}_{C_1, C_2, \dots, C_N} \sum_{i \in C} Q_i C_i \text{ s.t. } C(C_1, C_2, \dots, C_N) \right) / C, \text{ where} \quad (12)$$

$$Q_i = Q_i(q_0, q_i) \equiv \left(\text{MIN}_{c_0^i, x_i} q_0 c_0^i + q_i x_i \text{ s.t. } C_i(c_0^i, x_i) \right) / C_i \quad i \in C \quad (13)$$

Since $\tilde{E}(q_0, Q, u)$, $Q(Q_1, Q_2, \dots, Q_N)C$, and $Q_i(q_0, q_i)C_i$, $i \in C$ are expenditure functions

$$E(q_0, q_1, \dots, q_N, u) \equiv \tilde{E}\left(q_0, Q\left(Q_1(q_0, q_1), Q_2(q_0, q_2), \dots, Q_N(q_0, q_N)\right), u\right) - q_0 \omega_0 \quad (14)$$

will also have the standard properties of an expenditure function⁴.

This is an essential point; it implies that the corresponding demand system can be analysed using standard demand theory and that the insight of standard optimal theory of taxation reviewed in the previous section, notably the Corlett and Hague results and the Diamond and Mirrlees Production efficiency theorem, can be applied directly. That we can apply standard results is not only of considerable analytical convenience, but also facilitates the interpretation of results, which exploit the explicit representation of the use of time, as has been pointed out by Atkinson and Stern (1980)⁵. But in order to exploit those advantages it is naturally important to make a correct mapping of the variables based on a general utility function and a utility function with an explicit representation of the use of time.

The mapping between the standard formulation of the household's maximisation problem and the formulation with the explicit representation of the use of time is illustrated in Figure 1. In the case of a standard utility function the household's preferences are defined directly on net trade, x_0, x_1, \dots, x_N . In the case of a utility function with the explicit representation of the use of time, the household's preferences is defined directly only on pure leisure, c_0^0 , and aggregate consumption, C , where aggregate consumption is a function of the consumption of composite commodities, $C(C_1, C_2, \dots, C_N)$, and where the consumption of each composite commodity, C_i , $i \in C$, is a function, $C_i(x_i, c_0^i)$, of the purchase of the corresponding commodity and the time used for its consumption. What

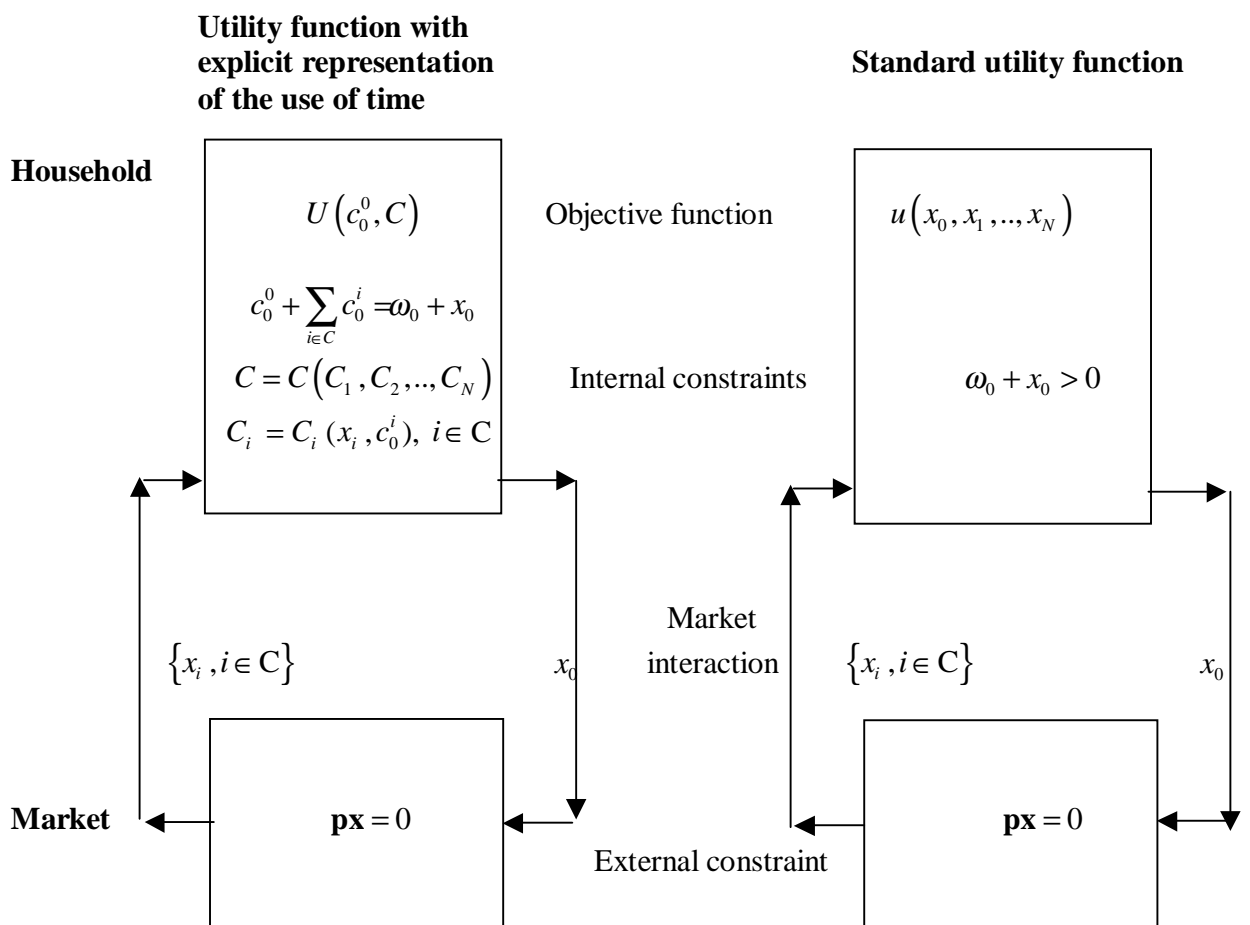
⁴ See also see Pollak and Wachter (1975)

⁵ Atkinson and Stern (1980) write: *In the formal sense [a model incorporating home production] is no different, and we can apply the standard theory of demand, a fact which is worth emphasising in view of the claims sometimes made to the contrary. That we can apply standard results is a considerable analytical convenience, and allows us to see more clearly how the interpretation of the results differs [when incorporating home production]*

we have shown is that the behaviour implied by the utility function with explicit representation of the use of time, $U(c_0^0, C(C_1(x_1, c_0^1), C_2(x_2, c_0^2), \dots, C_N(x_N, c_0^N)))$, is the same as that of an appropriate utility function defined on net trade, $u(x_0, x_1, \dots, x_N)$.

The net trade vector $\mathbf{x} \equiv (x_0, x_1, \dots, x_N) \equiv \boldsymbol{\omega} - \mathbf{c}$ indicates the household's interaction with the rest of the world, which in optimal tax theory is the only aspect of household behaviour, which is assumed to be observable by the government. The use of utility functions with the explicit representation of the use of time provides more structure to the explanation of changes in \mathbf{x} in response to price changes than the general formulation, but remains, as we have seen, a special case of the general formulation. It is thus inconceivable that optimal tax results obtained for the general case should not be applicable to cases where household preferences are represented by utility functions with the explicit representation of the use of time.

Fig. 1: Alternative representation of household behaviour



For example, the Corlett-Hague Rule, which says that commodities, which are complementary to leisure from an efficiency point of view, should be taxed at relatively high rates, therefore also applies in the case where the household's preferences are represented by a utility function with the explicit representation of the use of time. However, to apply the general result naturally requires 'leisure' to be defined in the same way as in the standard formulation. In order to exploit correctly the insight provided by Corlett and Hague's analysis in explaining the optimal tax structure when home production is represented explicitly, it is important to define the term 'leisure' as 'non-market use of time'. In Corlett and Hague (1953) the distinction between 'labour' and 'leisure' reflects only the assumption that "labour" can be taxed and that 'leisure' cannot. Since the word 'leisure' for some carries the connotations of 'pure leisure' (cf Gronau 1977), while by others it is used as synonymous with 'labour' (cf Myles 1995) a more precise terminology should be used when there is a risk of confusion: instead of 'leisure' and 'labour' the expression '*non-market use of time*' and '*market use of time*', respectively, should be used.

Figure 1 may also help to clarify how the Diamond-Mirrless Production efficiency theorem applies in a model with home production. The Diamond-Mirrless theorem implies, as stated above, that, although Pareto efficiency is not feasible when lump sum taxes cannot be used, it is still optimal to maintain the same rate of transformation in all production sectors. Since representing home production explicitly, given certain regularity conditions, may be interpreted as a utility function with the explicit representation of the use of time, which in turn may be considered as a special case of a standard utility function, it follows that adopting a Becker type representation of home production cannot modify the Diamond-Mirrless Production efficiency theorem, as long as the term "production sectors" is defined as by Diamond and Mirrless. In the Diamond-Mirrless framework the term "production sectors" are sectors which produce traded commodities. Within these sectors production efficiency is therefore desirable, even when home production is represented explicitly. However, when household production is explicitly represented it becomes possible to define rates of transformation, which are objective rather than subjective, within the household sector. The marginal rate of transformation in producing household non-traded goods in the household sector, say, between labour and a purchased good, will in general be different from the corresponding rate of transformation in the non household production sectors. This may naturally be considered as a type of "production inefficiency", but not in the sense defined by Diamond and Mirrless. Furthermore if "production inefficiency" is defined in this way, then that "production inefficiency" is desirable follows immediately without further analysis from the well-known result of optimal tax theory, that when taxation has to be based only on market transactions the optimal solution involves that the marginal rate of transformation within the household sector must be different from that within the non-household production sectors. The reason why the optimal solution is not Pareto efficient when lump sum taxation is not feasible is exactly that it is not possible to equate the marginal rates of transformations within the household sector with those within the non-household production sectors and still generate revenue to the government.

Sandmo (1990), Kleven, Richter and Sørensen (2000) and Kleven (2000) have considered optimal tax rules taking Becker's theory of home production into account. Their contributions illustrate that adding structure to the household's utility function has the potential of improving our understanding of what determines the optimal tax structure. The fact that Becker's theory of home production may be seen as a special case of a standard formulation of the household's utility maximising problem, as in this paper, furthermore facilitates derivation of results and their interpretation. For example, Kleven, Richter and Sørensen (2000) find that it may be desirable to tax an input good, i.e. a good, which is used in home production, at a lower rate than other goods, although it is more complementary with what they call "leisure" than with other goods. They interpret this as a counter-example to the Corlett and Hague rule. This is misleading. The apparent discrepancy is a result of their use of the term 'leisure' to indicate *non-market use of time net of time used in home production* (which I have called "pure leisure"), whereas it in the Corlett and Hague framework it is *non-market use of time* (i.e. including time used for home production). Only because they have changed the meaning of words do their results seem to conflict with Corlett and Hague results. They also see the results of their analysis as providing a counter-example to the Diamond-Mirrlees Production efficiency theorem. Also this is misleading. When representing home production explicitly, production efficiency is still desirable when the term "production sectors" is defined as in the Diamond-Mirrlees framework as sectors producing traded commodities and when the home production functions, $C_i = C_i(x_i, c_0^i)$, are concave functions.

The analysis of optimal taxation taking home production into account is, as we have seen, only a special case of the analysis of optimal taxation based on a standard representation of household preferences. It seems therefore inconceivable that results based on a model with explicit representation of home production based on standard concavity assumptions can modify either the Corlett and Hague rule or the Diamond-Mirrlees Production Efficiency Theorem.⁶

3.3. Flexibility with respect to the complementarity of leisure

We define a parameterised utility function, CESUT (Constant Elasticities of Substitution utility function with explicit representation of the Use of Time, (see Munk 1998, 1999) as

$$U\left(c_0^0, C\left(C_1\left(x_1, c_0^1; \sigma^{11}\right), C_2\left(x_2, c_0^2; \sigma^{12}\right), \dots, C_N\left(x_N, c_0^N; \sigma^{1N}\right); \sigma^2\right) \sigma^3\right) \quad (15)$$

where $C_i(x_i, c_0^i; \sigma^{li})$, $i \in C$, $C(C_1, C_2, \dots, C_N; \sigma^2)$ and $U(C, c_0^0; \sigma^3)$ are CES functions characterised by elasticities of substitution σ^{li} , $i \in C$, σ^2 and σ^3 , respectively.

⁶ See also the related point made at page 593 in Kleven, Richter and Sørensen (2000) in response to comments made by a referee.

We now want to demonstrate that the CESUT is quite flexible with respect to representation of household preferences in particular, allowing different commodities to have different degrees of complementarity with leisure.

Differentiating (14) we get the corresponding demand system

$$x_i(\mathbf{q}, u) = \frac{\partial \tilde{E}}{\partial Q} \frac{\partial Q}{\partial Q_i} \frac{\partial Q_i}{\partial q_i} \quad i \in C \quad (16)$$

$$x_0(\mathbf{q}, u) = \frac{\partial \tilde{E}}{\partial q_0} + \frac{\partial \tilde{E}}{\partial Q} \sum_{j \in C} \frac{\partial Q}{\partial Q_j} \frac{\partial Q_j}{\partial q_0} - \omega_0 \quad (17)$$

We define

$$\varepsilon_{ii}^1 \equiv \frac{\partial^2 Q_i}{\partial q_i \partial q_i}(q_i, q_0) C_i \Big/ \frac{x_i}{q_i}; \quad -\varepsilon_{i0}^1 \equiv \frac{\partial^2 Q_i}{\partial q_i \partial q_0}(q_i, q_0) C_i \Big/ \frac{x_0}{q_i} \quad i \in C$$

$$\varepsilon_{ij}^2 \equiv \frac{\partial^2 Q}{\partial Q_i \partial Q_j}(Q_1, Q_2, \dots, Q_N) C \Big/ \frac{C_i}{Q_j} \quad i, j \in C$$

$$\varepsilon_{cc}^3 \equiv \frac{\partial^2 E^2}{\partial Q \partial C}(q_0, Q, u) \Big/ \frac{C}{Q}; \quad -\varepsilon_{c_0}^3 \equiv \frac{\partial^2 E^2}{\partial Q \partial q_0}(q_0, Q, u) \Big/ \frac{x_0}{Q}$$

$$\alpha_i \equiv \frac{q_i x_i}{q_0 x_0}$$

Differentiating (16) with respect to q_j and q_0 , respectively, and defining $a_j \equiv \frac{q_j x_j}{Q_j C_j}$ as the share of the costs of the consumption of commodity j in the total costs of composite j (which include the cost of the consumption of time) and $b_j \equiv \frac{Q_j C_j}{QC}$ the share of the composite j in the total cost of consumption (including the consumption of time except pure leisure), we get

$$\varepsilon_{ii} = \varepsilon_{ii}^1 + a_i \varepsilon_{ii}^2 + a_i b_i \varepsilon_{cc}^3 \quad i \in C \quad (18)$$

$$\varepsilon_{ij} = a_j \varepsilon_{ij}^2 + a_j b_j \varepsilon_{cc}^3 \quad j \neq i \in C \quad (19)$$

$$\varepsilon_{i0} = \varepsilon_{i0}^1 + \sum_{j \in C} (1 - a_j) \varepsilon_{ij}^2 + \sum_{j \in C} a_j b_j \varepsilon_{cc}^3 \quad i \in C \quad (20)^7$$

$$\varepsilon_{0i} = \alpha_i \left(\varepsilon_{i0}^1 + \sum_{j \in C} (1 - a_j) \varepsilon_{ij}^2 + \sum_{j \in C} a_j b_j \varepsilon_{cc}^3 \right) \quad i \in C \quad (21)$$

⁷ This formula may alternatively be derived from (18) and (19) using that $\varepsilon_{i0} = -\sum_{j \in C} \varepsilon_{ij}$ and $\varepsilon_{i0}^1 = -\varepsilon_{ii}^1$ and

$$\varepsilon_{c_0}^3 = -\varepsilon_{cc}^3.$$

In the case of the CESUT, $\varepsilon_{ii}^1 = \varepsilon_{i0}^1 = -(1-a_i)\sigma^{li}$, $\varepsilon_{ij}^2 = b_j\sigma^2$ for $i, j \neq i \in C$

$\varepsilon_{ii}^2 = -(1-b_i)\sigma^2$ for $i \in C$ and $\varepsilon_{cc}^3 = -\varepsilon_{c_0}^3 = -(1-c)\sigma^3$, where $c \equiv \frac{QC}{q_0c_0^0 + QC}$, we have

$$\varepsilon_{ii} = -(1-a_i)\sigma^{li} - a_i(1-b_i)\sigma^2 - a_i b_i(1-c)\sigma^3 \quad i \in C \quad (22)$$

$$\varepsilon_{ij} = a_j b_j \sigma^2 - a_j b_j (1-c)\sigma^3 \quad i, j \in C \quad (23)$$

$$\varepsilon_{i0} = (1-a_i)\sigma^{li} + (a_i - \bar{a})\sigma^2 - \bar{a}(1-c)\sigma^3 \quad i \in 1,2 \quad (24)$$

$$\varepsilon_{0i} = \alpha_i \left((1-a_i)\sigma^{li} + (a_i - \bar{a})\sigma^2 - \bar{a}(1-c)\sigma^3 \right) \text{ do.} \quad i \in 1,2 \quad (25)$$

where $\bar{a} = \sum_{i \in C} a_i b_i$.

The elasticities of substitution between the commodities and leisure, σ_{i0} , $i \in C$, are related to the compensated elasticities by $\varepsilon_{i0} = s_0 \sigma_{i0}$ where s_0 is the share of labour income in full income. Differences in ε_{i0} therefore reflect differences in the complementarity with leisure of the different commodities.

The compensated elasticity of commodity i with respect to the price of labour, ε_{i0} , depends on three elements (see 24):

The **within element**, which is represented by the first term, $\varepsilon_{i0}^1 = (1-a_i)\sigma^{li}$. This element is always positive with respect to the value of ε_{i0} , and is larger, the larger the amount of time used for the consumption of commodity i , $(1-a_i)$, and the larger the elasticity of substitution between time and the commodity within the composite commodity i , σ^{li} .

The **between element**, which is represented by the second term: $\sum_{j \in C} (1-a_j)\varepsilon_{ij}^2 = (a_i - \bar{a})\sigma^2$. This element may be positive or negative with respect to the value of ε_{i0} depending on whether commodity i requires a relatively large amount of time for its consumption, i.e. $a_i < \bar{a}$, or relatively small amount, i.e. $a_i > \bar{a}$. In the first case, an increase in the price of the commodity and hence in the corresponding composite commodity results in a shift to composite commodities which involve the use of relatively less time, drawing in the direction of a small ε_{i0} ; in the second case the opposite will be the case, drawing in the direction of a relatively large ε_{i0} . The elasticity between composite commodities, σ^2 , amplifies the effect whatever its direction.

The pure leisure element, which is represented by the third term: $\bar{a}(1-c)\sigma^3$ is always positive with respect to the value of ε_{i0} , and the larger the share of the household's time endowment used for pure leisure $(1-c)$ and the larger the elasticity of substitution between leisure and consumption, σ^3 , the larger the effect.

In particular we see that

- 1) for $a_i > \bar{a}$, i.e. when a relatively small amount of time is used for the consumption of commodity i , then relatively large substitution elasticities σ^{li} , σ^2 imply relatively large ε_{i0} , and
- 2) for $\sigma^2 > \sigma^{li}$, i.e. when the *between element* dominates, then a relatively large amount of time, $(1-a_i)$, used for the consumption of commodity i imply a relatively small ε_{i0} , but
- 3) for $\sigma^2 < \sigma^{li}$, i.e. when the *within element* dominates, then a relatively large amount of time, $(1-a_i)$, used for the consumption of commodity i imply a relatively large ε_{i0} .

It is thus relatively easy by specifying different values of the parameters of the CESUT, a_i , σ^{li} , σ^2 , to represent different degrees of complementarity with leisure for the different commodities. In contrast to the additive separable utility functions, as the CES, the CESUT therefore allows the complementarity with leisure to differ between commodities. Furthermore each of the parameters of the CESUT has a clear economic interpretation, facilitating the intuitive understanding of the relation between the parameters and the elasticities.

4 The explanation of the optimal tax structure as the result of a trade-off between the two objectives

I want in this section to demonstrate how utility functions with the direct representation of the use of time, and in particular the CESUT may be used to provide insight into how the optimal tax structure is a compromise between the objective of not distorting the first-best pattern of consumption of the produced commodities, x_i , $i \in C$, (*Objective 1*), and the objective of encouraging the supply of labour (*Objective 2*).

4.1. Many commodities

In Section 2 two cases where there is no trade-off between the two objectives has already been identified. Within the framework of a utility function with explicit representation of the use of time it is possible to identify a third case, and furthermore to improve our understanding of why in one of the two cases already identified there is no such trade-off.

As we saw in Section 2, a proportional tax structure, $\frac{p_i + t_i}{p_i} = T > 1$, $i \in FC$, based on the consumption of all commodities, including leisure, is a first-best solution whatever the structure of the household's preferences. Such a tax structure involves higher consumer prices, $\mathbf{q} = (Tp_0, Tp_1, \dots, Tp_N)$, and thus higher prices for composite commodities, $Q_i = Q_i(Tp_0, Tp_i)$, $i \in C$ than the first-best solution based on lump sum taxation where the prices for composite commodities are $Q_i = Q_i(p_0, p_i)$, $i \in C$.

If we impose the constraint that leisure cannot be taxed, i.e. that $q_0 = p_0$, it is, as we have seen, in general not possible to achieve the first-best solution. Although it is possible to choose tax rates for produced commodities to generate prices for composite commodities which create no distortion between the composite commodities, within the aggregation function $C(C_1, C_2, \dots, C_N)$, such tax rates will involve higher prices for produced commodities relative to the price of non-market use of time, thus in general distorting the allocation between the consumption of produced commodities and time within the aggregation functions for the composite commodities, $C_i(x_i, c_0^i)$, $i \in C$.

However, in the case where all the aggregation functions for the composite commodities, $C_i(x_i, c_0^i)$, $i \in C$, are Leontief, and where the household's consumption of pure leisure, c_0^0 , is either a function only of the level of utility or nil⁸, distorting the price ratio between produced commodities and time does not distort the allocation. A tax vector where leisure is untaxed, i.e. $\mathbf{t} = (0, q_1 - p_1, \dots, q_N - p_N)$, will therefore establish a first-best solution if the tax rates on produced commodities are chosen so that the relative prices for the composite commodities are the same as if the government's resource requirement had been financed by a proportional tax structure based on the consumption on all commodities, i.e. if

$$Q_i(p_0, p_i + t_i) = Q_i\left(\frac{1}{1-\tau}p_0, \frac{1}{1-\tau}p_i\right) \quad i \in C \quad (26)$$

where $\tau < 1$ is the rate of tax on the household's endowment of time net of the fixed amount used for pure leisure required to finance the government's resource requirement. Since for this utility function the aggregation functions are Leontief

⁸ This is the case if $U(c_0^0, C)$ is Leontief or if $c=1$, i.e. if the household consumes no pure leisure.

$$Q_i' = 1/(1-\tau)(q_0(1-a_i) + p_i a_i) = (q_0(1-a_i) + (q_i + t_i) a_i) \quad i \in C \quad (27)$$

Therefore assuming $t_0 = 0$ as a matter of normalisation, we see that

$$\frac{t_i}{q_i} = \frac{\tau}{1-\tau} \frac{1}{a_i} \quad i \in C \quad (28)$$

is a first-best solution. Commodities that require relative much time for their consumptions, i.e. where a_i is relatively small, is thus taxed at a relatively high rates.⁹

That the optimal solution for this special utility function involves the commodity tax rates to be inversely related to the share of purchased goods in the value of the corresponding composite commodities provides a useful benchmark for the interpretation of the optimal tax structure for more realistic utility functions with the explicit representation of time.

The utility function considered by Atkinson and Stern (1980, 1981) is a special case of a utility function with explicit representation of time (9) where $U(c_0^0, C(C_1, C_2, \dots, C_N))$ is a Stone-Geary utility function and the $C_i(x_i, c_0^1), i \in C$ are Leontief functions. The corresponding expenditure function is

$$E(\mathbf{q}, u) \equiv \tilde{E}(q_0, Q_1(q_0, q_1; \alpha_1), Q_2(q_0, q_2; \alpha_2), \dots, Q_N(q_0, q_N; \alpha_N); \gamma_i, i \in FC, \beta_i, i \in FC, u) \quad (29)$$

$$E(\mathbf{q}, u) \equiv \sum_{i \in C} (q_i + (1-\alpha_i)q_0) \gamma_i + \prod_{i \in C} (q_i + (1-\alpha_i)q_0)^{\beta_i} \quad (30)$$

where γ_i and β_i are parameters of the Stone Geary utility function. Estimating this functional form on British survey data for 1973 they discovered significant difference in the time requirement of different goods (high for tobacco, low for services).

Since they assume that the $C_i(x_i, c_0^1)$ functions are Leontief, and that households consume no pure leisure the optimal tax structure corresponding to this utility function is thus given by (28) and thus first-best with high rates of taxation on those commodities with high time requirements.

⁹ This case was first identified (but not provided the same interpretation) by Kleven (2000). He derives

(expressed in our notation) the conditions $\frac{t_k}{q_k} \varepsilon_{kk}^1 + \sum_{i \in C} \frac{t_i}{q_i} a_i \varepsilon_{ki}^2 = -\theta, k \in C$ to be satisfied by an optimal tax

structure from the government's tax optimisation problem constrained by a Becker type representation of

home production assuming no pure leisure. He then derive the tax formula $\frac{t_i/q_i}{t_j/q_j} = \frac{a_i}{a_j}, k, j \in C$ from these

conditions in the case where $\varepsilon_{kk}^1 = 0, k \in C$. This is not strictly correct since at the first best optimum $\theta = 0$.

We have thus identified a third case, where there is no trade-off between the two objectives.

- a) The case which we have just considered where $C_i(x_i, c_0^i)$, $i \in C$, and $U(c_0^0, C)$ are Leontief,
- b) the case where both $C = C(C_1, C_2, \dots, C_N)$ and $U(c_0^0, C)$ are Leontief, and thus $\varepsilon_{ii} = \varepsilon_{ii}^1$ and $\varepsilon_{ij} = 0$ (see (17) and (18)). In this case the optimal tax structure corresponds to the inverse elasticity rule given in (7), and
- c) the case where the consumption of individual commodities is not associated with the use of time, i.e. $C = C(x_1, x_2, \dots, x_N)$ is homothetic and the optimal tax structure therefore proportional (6).

As has been pointed out by Kleven (2000), it is possible to derive the optimal tax formulae for each of the three cases based on the utility function with explicit representation of the use of time. However, none of the three different special types of utility functions with explicit representation of the use of time are particularly realistic, and in fact not in themselves very helpful in relation to our endeavour. For different reasons they cannot be used to illustrate the trade-off between 1) the objective of maintaining the first-best pattern of consumption (*Objective 1*), and 2) the objective of discouraging the consumption of leisure (*Objective 2*). *The first case*, where for each good the non-market use of time is fixed as a share of the consumption of the good, a tax structure which is equivalent to a tax on leisure (in the meaning non-market use of time) establishes a first-best solution and there is therefore no trade-off between the two objectives. In *the second case* the pattern of consumption of composite commodities has been fixed by assuming a Leontief structure for the function aggregating the composite commodities. The only substitution possibility is therefore within the composite commodities. However, within a composite commodity a change in the use of time in response to a change in the price of the commodity for which it is used directly determines the change in the consumption of the corresponding commodity independently of any other price changes, and vice versa. Achieving *Objective 2* therefore does not involve any costs in terms *Objective 1*. In other words, in this case the two objectives are not in conflict with each other. In *the third case*, which implies separability between consumption and leisure, there is no trade-off between the two objectives because changing a proportional tax structure for the produced commodities will imply sacrificing *Objective 1* without gaining anything in terms of *Objective 2*. The optimal tax structure therefore involves maintaining the first-best pattern of consumption of produced goods, not because it would not be desirable to reduce the consumption of leisure, but because differentiating the tax rates for the produced goods has no effect on the consumption of leisure.

However, these three cases represent rather extreme assumptions. In general changing the parameters of the CESUT, a_i , σ^i , σ^2 , it is possible to change the trade-off between the two objectives and thus the optimal tax structure. To what extent a differentiated tax structure will encourage the supply of labour (*Objective 2*) depends on to what extent the compensated elasticities with respect to the price of labour are different for different commodities. As we have seen, the compensated elasticities with respect to the price of labour, ε_{i0} , $i \in C$, may be related in a fairly transparent way to the parameters of the CESUT. However changes in the parameters of the CESUT may also affect the costs of distorting the first-best pattern of consumption of produced commodities (*Objective 1*). Larger elasticities of substitution in general result in increased distortionary costs of a differentiated tax structure.

In the case of many commodities it is difficult rigorously to trace how changes in the parameters of the CESUT influence the trade-off between the two objectives and thus the optimal tax structure. For analytical convenience we therefore turn to the case of only two produced commodities.

4.2. Two produced commodities

In the case of only two produced commodities, as originally considered by Corlett and Hague (1953), the trade-off is easier to establish. Solving (4) for the optimal tax rates, assuming $t_0 = 0$ as a matter of normalisation, we have,

$$\begin{aligned} t_1 &= \theta \frac{(\varepsilon_{12} - \varepsilon_{22})}{\varepsilon_{11}\varepsilon_{22} - \varepsilon_{21}\varepsilon_{12}} \\ t_2 &= \theta \frac{(\varepsilon_{21} - \varepsilon_{11})}{\varepsilon_{11}\varepsilon_{22} - \varepsilon_{21}\varepsilon_{12}} \end{aligned} \quad (31)$$

and since $\sum_{j \in FC} \varepsilon_{ij} = 0$, $i \in FC$, the optimal tax structure may also be expressed as

$$\frac{t_1/q_1}{t_2/q_2} = \frac{-\varepsilon_{11} - \varepsilon_{22} - \varepsilon_{10}}{-\varepsilon_{11} - \varepsilon_{22} - \varepsilon_{20}}. \quad (32)$$

Which commodity will be taxed at the highest rate depends entirely on the sign of $\varepsilon_{10} - \varepsilon_{20}$ and, for given value of $-\varepsilon_{11} - \varepsilon_{22}$, the difference is the greater the greater the numerical value of $\varepsilon_{10} - \varepsilon_{20}$, and for given values of ε_{10} and ε_{20} the difference is smaller the greater is $-\varepsilon_{11} - \varepsilon_{22}$.

We therefore define the *Indicator of the objective of maintaining the first-best pattern of consumption of produced commodities (Objective 1)* as

$$I_1 \equiv -\varepsilon_{11} - \varepsilon_{22} \quad (33)$$

and the *Indicator of the objective of increasing the supply of labour (Objective 2)* as

$$I_2 \equiv \varepsilon_{10} - \varepsilon_{20} \quad (34)$$

In the literature (see for example Atkinson and Stiglitz 1980, and Myles 1995) the focus has been on how the optimal tax structure contributes to the second objective, viz. the Corlett-Hague rule that the commodities which is most complementary with leisure, i.e. with the smallest the elasticities of substitution between the commodity i and leisure, σ_{i0} , should be taxed at relative high rates to encourage the supply of labour. However, the optimal tax structure depends, as we have seen, on both indicators. Having this in mind is indeed a key to understanding the optimal tax structure as a trade-off between the two objectives.¹⁰

We now want to show that it is possible to modify the relative importance of the two objectives and thus explain the optimal tax structure by changing the parameters of the CESUT utility function.

In the case of the CESUT utility function the indicators for the two Objectives can be expressed in terms of shares and the parameters of the functional form rather than being endogenously determined as a function of the equilibrium solution. This allows the trade-off between the two objectives to be compared for different values of the parameters of the CESUT and thus the intuition for what determines the optimal tax structure to be enhanced.

Substituting for ε_{ij} , by (22)-(24) the indicators for *Objective 1* now becomes

$$I_1 = (1-a_1)\sigma^{11} + (1-a_1)\sigma^{12} + (a_1(1-b_1) + a_2(1-b_2))\sigma^2 + (a_1b_1 + a_2b_2)(1-c)\sigma^3 \quad (35)$$

and the indicator for *Objective 2*

$$I_2 = (a_1 - a_2)\sigma^2 + (1-a_1)\sigma^{11} - (1-a_2)\sigma^{12}. \quad (36)$$

¹⁰ These results have been derived assuming that labour is untaxed as a matter of normalisation. However, the Corlett-Hague rule does not depend on this particular normalisation rule. Although tax rates change under renormalisation the relative size of consumer prices, and hence the relative size of the tax rates remain the same; if one commodity is taxed at a higher rate than another commodity for one optimal tax vector this will also be the case for other optimal tax vectors: If $\mathbf{t} = \mathbf{q} - \mathbf{p}$, where $t_0=0$, is the vector of taxes before renormalisation, and $\tilde{\mathbf{t}} = k\mathbf{q} - \mathbf{p}$, where $k > 0$, is the vector of taxes after normalisation, then $\tilde{t}_i > \tilde{t}_j$ if $t_i > t_j$. The Corlett and Hague result therefore does not just reflect the normalisation rule adopted, contrary to what for example is argued by Myles (1995).

The indicator for *Objective 2* determines independently of the value of the indicator for *Objective 1* which commodity is taxed at the highest level. However, how much the tax structure diverges from a proportional tax structure depends, on the values of both the indicators.

Substituting in (32) by (18) -(21) and then (22)-(24) we get the following expression for the optimal tax structure¹¹

$$\frac{t_1/q_1}{t_2/q_2} = \frac{a_2\sigma^2 + (1-a_2)\sigma^{12}}{a_1\sigma^2 + (1-a_1)\sigma^{11}}. \quad (37)$$

It is now possible to trace how changes in the parameters of the CESUT determine the optimal tax structure through their effect on the indicators for the two objectives.

To support the intuition for how changes in the parameters change the optimal tax structure we provide some simulation results. The simulation results are summarised in Table 1.

Table 1 Indicators for objective 1 and 2 and the optimal relative tax rates

	Indicator for Objective 1. I_1	Indicator for Objective 2. I_2	Optimal relative tax rates t_1 / t_2
Set 1	0,180	-0,150	3,50
Set 2	0,330	0,080	0,38
Set 3	0,280	-0,150	3,45
Set 4	0,390	0,000	1,00

Benchmark values of government's requirement and of the household's net trade in an economy with two produced commodities and one primary factor, labour, are provided in Annex Table 1. Values for four sets of parameters of the CESUT ($\sigma^{11}, \sigma^{12}, \sigma^2, \sigma^3, a_1, a_2$ and c) are provided in Annex Table 2. The corresponding matrix of compensated price elasticities consolidated at the level of the three traded commodities, $\varepsilon_{ij}, i, j \in (0, 1, 2)$, are provided in Annex Table 3.

The benchmark data and the parameters specified imply that the value of the household's endowment is 300. Since the governments requirement is 50, a tax on the value of endowment at rate $\tau = 1/6$ would therefore be sufficient to raise the revenue required for the government without distorting the resource allocation. In the case of such a tax, the real income for the household would be 100.

¹¹ A somewhat similar tax formula has been derived and analysed by Kleven (2000).

For the first set of parameters the share of full income spent on pure leisure, $1-c$, as well as the elasticities of substitution within the commodity composites, σ^{11} and σ^{12} are all fixed at 0. For this set of parameters the optimal solution is thus first-best, although lump sum taxation is not possible. Assuming $t_0 = 0$ as a matter of normalisation the optimal tax rates are therefore (see (28))

$$\begin{aligned} t_1 &= \frac{\tau}{1-\tau} \frac{1}{a_1} = 1,40 \\ t_2 &= \frac{\tau}{1-\tau} \frac{1}{a_2} = 0,40 \end{aligned} \quad (38)$$

This tax structure is first-best because it effectively raises the price of time by the same amount for all uses as had the revenue been raised directly by a tax on the household's endowment. At the optimum there is therefore no conflict between the two objectives.

The indicator for *Objective 1* (the pattern of consumption of produced commodities) increases with increasing elasticities of substitution, $\sigma^{11}, \sigma^{12}, \sigma^2, \sigma^3$. The larger the elasticities, the larger the distortionary costs of a differentiated tax structure. However the effect of changes in these substitution elasticities on the indicator for *Objective 2* (the encouragement of the labour supply) are more complex. In the general case the impact of changes in a_1 and a_2 on both objectives depend on the level of the substitution elasticities.

To facilitate the interpretation of the optimal tax formulae we consider the less general case where $\sigma^{11} = \sigma^{12} = \sigma^1$.

The indicator for *Objective 1* may in this case be written as

$$\varepsilon_{11} + \varepsilon_{22} = -(2 - a_1 - a_2)\sigma^1 - (a_1 + a_2 - \bar{a})\sigma^2 - \bar{a}(1-c)\sigma^3 \quad (39)$$

and the indicator for *Objective 2* as

$$\varepsilon_{10} - \varepsilon_{20} = -(a_1 - a_2)\sigma^1 + (a_1 - a_2)\sigma^2. \quad (40)$$

A revenue neutral increase in the tax on Commodity 1 accompanied by a decrease in the tax on Commodity 2 has two separate effects on the consumption of leisure. *The first term*, $-(a_1 - a_2)\sigma^1$, the *within effect* is the substitution effect within the composite aggregation functions, $C_1(x_1, c_0^1)$ and $C_2(x_2, c_0^2)$. This effect is positive (i.e. the effect on the supply of labour is negative) if $a_1 < a_2$. *The second effect*, $(a_1 - a_2)\sigma^2$, the *between effect*, is due to the substitution between composite commodities within the aggregation

function $C(C_1, C_2)$. This effect is negative (i.e. the effect on the supply of labour is positive) if $a_1 < a_2$. The relative strength of the two effects determines which commodity is taxed at the highest rate. For example, for $\sigma^2 = 0$ we have from (34) that

$$\frac{t_1/q_1}{t_2/q_2} = \frac{(1-a_2)}{(1-a_1)} < 1 \quad (41)$$

because the second effect dominates, (Changing the benchmark parameters, such that $\sigma^1 = 0.2$, $\sigma^2 = 0$ and $c=1$, results in $\varepsilon_{10} - \varepsilon_{20} = 0,080$ in stead of $-0,150$ and the ratio of optimal tax rates to become $t_1/t_2 = 0.38$ rather than 3,50). Conversely for $\sigma^1 = 0$ we have

$$\frac{t_1/q_1}{t_2/q_2} = \frac{a_2}{a_1} > 1 \quad (42)$$

because the first effect dominates (for $c=1$, $\varepsilon_{10} - \varepsilon_{20} = -0,150$ and the ratio of optimal tax rates becomes $t_1/t_2 = 3.45$). For $\sigma^1 = \sigma^2$ the two effects balance each other out, and

$$\frac{t_1/q_1}{t_2/q_2} = 1 \quad (43)$$

(For $\sigma^1 = 0.2$, $\sigma^2 = 0.2$ and $c=1$, $\varepsilon_{11} + \varepsilon_{22} = 0,00$ and the ratio of optimal tax rates is $t_1/t_2 = 1$).

That commodities, which require a relative large amount of time for their consumption, are relatively complementary with leisure and therefore should be taxed at a relatively high rate may be intuitively plausible and is suggested by the special case where the time-consumption composites are Leontief. However as the analysis of the CESUT illustrates this intuition may be misleading. In the situation where the substitution possibilities within the time-consumption composites are relatively large the indicator for *Objective 2* will be greater than 1 if the share of time in composite 1 is smaller than in composite 2. In this case commodity 1, which use a relatively small amount of time for its consumption, will be taxed at a relatively high rate.

5 Summary and concluding remarks

I have provided an intuitive explanation of what determines the optimal tax structure as a trade-off between two objectives: 1) the objective of not distorting the consumption of produced commodities, and 2) the objective of not discouraging the supply of labour. I have shown that the use of a utility function with the explicit representation of the use of time helps to improve the intuition for this trade-off. The analyses supplements the work of Atkinson and Stern (1980,1981) by generalising the parameterised functional form they consider and by indicating the corresponding optimal tax results; it supplements the work by Sandmo (1990), Kleven (2000) and others, by applying standard results to the analysis of optimal taxation with home production, facilitating derivation of results and interpretation. It thus helps to clarify certain conceptual ambiguities in the literature. Finally, I have demonstrated that such utility functions are not only useful as a basis for theoretical analysis, but can easily be parameterised and thus be used in applied work as an alternative to functional forms, which impose separability between consumption and leisure, and which may therefore result in misleading conclusions from simulations of changes in tax policy.

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Annex Table 1. Benchmark data where the government requirement is financed by a lump sum tax

Government requirement	x_0^G	50
Consumption of commodity 1	x_1	10
Consumption of commodity 2	x_2	90
Supply of labour	$-x_0$	150
Real income	$R(p_0, p_1, p_2, -L; p_0, p_1, p_2)$	100

Annex Table 2: Parameters and optimal tax solutions

Parameters		Set 1	Set 2	Set 3	Set 4
Elasticity of substitution between commodity 1 and the time used for its consumption	σ^{11}	0,00	0,20	0,00	0,20
Elasticity of substitution between commodity 2 and the time used for its consumption	σ^{12}	0,00	0,20	0,00	0,20
Elasticity of substitution between the composite commodities	σ^2	0,50	0,00	0,50	0,20
Elasticity of substitution between consumption and pure leisure	σ^3	0,50	0,50	0,50	0,50
Share of time in composite commodity 1	a_1	1/7	1/7	1/7	1/7
Share of time in composite commodity 2	a_2	1/2	1/2	1/2	1/2
Leisure coefficient	$1-c$	0,00	2,00	2,00	2,00
Results					
		Set 1	Set 2	Set 3	Set 4
Tax on labour	t_0	0,00	0,00	0,00	0,00
Tax on consumption of commodity 1	t_1	1,40	0,22	1,45	0,55
Tax on consumption of commodity 2	t_2	0,40	0,58	0,42	0,55
Labour supply	x_0	150,00	142,30	146,42	141,52
Consumption commodity 1	x_1	10,00	9,29	9,64	9,15
Consumption commodity 2	x_2	90,00	83,00	86,78	82,37
Real income		100,00	98,21	99,17	98,02

Annex Table 3: Compensated elasticities

Set 1: ε_{ij}	Price j		
Quantity i	1	2	0
1	-0,100	0,210	-0,110
2	0,040	-0,080	0,040
0	0,020	-0,030	0,020
Set 2: ε_{ij}	Price j		
Quantity i	1	2	0
1	-0,170	-0,080	0,250
2	-0,010	-0,160	0,170
0	-0,020	-0,150	0,170
Set 3: ε_{ij}	Price j		
Quantity i	1	2	0
1	-0,120	0,140	-0,020
2	0,030	-0,160	0,130
0	0,000	-0,110	0,110
Set 4: ε_{ij}	Price j		
Quantity i	1	2	0
1	-0,200	0,010	0,190
2	0,000	-0,190	0,190
0	-0,020	-0,170	0,190

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