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Cross-Price Elasticities With Leisure: Estimation and Implications for Environmental Taxation

Bakalářská práce

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Abstract

This thesis studies optimal environmental taxes in an economy with preexisting distortions in the labour market. Unlike most previous studies, we do not assume separable preferences of individuals and we show that if the taxed good is a sufficiently week substitute for leisure, the optimal environmental tax is larger than the marginal environmental damage associated with the taxed good. We also examine whether this theoretical possibility actually takes place in reality. Using Czech household level data, we estimate an augmented Almost Ideal Demand System for household expenditure on leisure, residential energy and other goods and services. Contrary to what one would expect, we find that residential energy is an average or even stronger than average substitute to leisure. Consequently, the optimal tax on residential energy should be lower than the marginal environmental damage.

Key terms: cross-price elasticity, labour supply, optimal environmental tax

Abstrakt

Tato bakalářská práce zkoumá optimální environmentální daně v ekonomice, kde jsou přítomné deformace na trhu práce. Na rozdíl od většiny předchozích studií nepředpokládáme separabilní preference jednotlivců a ukážeme, že pokud je daněný statek dostatečně slabým substitutem volného času, optimální environmentální daň je větší než mezní environmentální škody způsobené daněnou komoditou. Dále zkoumáme, zda k této teoretické možnosti ve skutečnosti opravdu dochází. Za použití českých dat na úrovni jednotlivých domácností odhadneme poptávkový systém AIDS pro výdaje domácností na volný čas, na energii a na ostatní zboží a služby. V rozporu s tím, co by se dalo očekávat, zjišťujeme, že výdaje domácností na energii jsou průměrný či silnější než průměrný substitut volného času. Optimální daň na energii spotřebovávanou domácnostmi by tedy měla ležet pod úrovní mezních environmentálních škod.

Klíčová slova: křížová elasticita, nabídka práce, optimální environmentální daň

Bibliografický záznam

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Prohlášení

Prohlašuji, že jsem předkládanou bakalářskou práci zpracoval samostatně a použil jen uvedené prameny a literaturu. Souhlasím, aby práce byla zpřístupněna veřejnosti pro účely výzkumu a studia.

V Praze dne 22. května 2009 Matěj Bajgar

Poděkování

První mé velké poděkování patří panu Mgr. Milanu Ščasnému, PhD za pomoc s výběrem tématu, cenné rady a poskytnutí dat. Druhé směřuje k pracovníkům Centra pro otázky životního prostředí Univerzity Karlovy za poskytnutí přístřeší a výpočetní techniky pro provedení ekonometrických odhadů. Třetí potom patří Jitce Říhové za vytrvalou podporu a koláče přinesené 22. května ráno.

Contents

1 Introduction

Since a pivotal paper by Bovenberg and de Mooij (1994), the issue of optimal environmental taxation in a second-best setting has been a widely discussed topic that has occupied many pages in economic journals. However, the first important contribution in the field was brought by Sandmo (1975) more than quarter a century ago. He showed that when commodity taxes are used to raise revenue, the optimal tax on polluting consists of a revenue-raising term and a Pigouvian tax[1] that are connected in an additive way and weighted by marginal cost of public funds. Terkla (1984) was the first one in this context to suggest that money raised by environmental taxes could be used to cut some distortionary taxes, particularly labour tax, thus yielding a second dividend from improved efficiency in addition to improved environment. He also speculated that the optimal rate might be above the Pigouvian rate. The ideas by Terkla raised two questions that have been in the heart of the optimal environmental taxation debate ever since. The first one asks whether the optimal environmental tax lies above or below the Pigouvian rate. The second one asks whether the double-dividend hypothesis is correct[2].

The opening contribution of a new wave of interest in this topic was the already mentioned paper by Bovenberg and de Mooij (1994) that analytically examined impact of environmental taxes on supply of labour. Its authors discovered that the taxes do not only increase supply of labour by raising revenues that can be used to cut labour taxes but that there is also another effect which works in the opposite direction. Taxes increase prices, which pushes real wages down and under the assumption of positive labour supply elasticity leads to a decrease in the supply of labour. For a special case of weakly separable and homothetic preferences, Bovenberg and de Mooij showed that the latter effect is stronger, double dividend in its strong version does not exist and the optimal tax lies below that suggested by Pigou. They were followed by many others

[1] Pigouvian tax, named after its inventer Arthur Pigou (1937) is a tax that eliminates gap between social and private marginal costs of some activity which are due to an externality. Thus it internalizes the externality.

[2] There are two types of double-dividend hypothesis. The weak form claims that using revenues raised by environmental taxes to cut labour taxes is more efficient than redistributing them in a lump sum fashion. There is a widely held consensus that the weak form holds. The strong form states that the benefits from cutting a labour tax are larger than additional distortions caused by the environmental tax and that the environmental tax therefore leads to a net un-environmental gain.

who further deepened knowledge on the topic[3]. However, most of these papers either assume preferences to be separable in leisure or explicitely impose restrictions on values of cross-price elasticities between polluting goods and leisure. A positive exception in this sense is Kim (2002) who derives his results using a model with non-separable preferences and taxes on both intermediate and final production.

In most countries of the world, there exist substantial taxes on labour which distort the labour market and make people consume more leisure than what would be socially optimal. More than fifty years ago, Corlett and Hague (1953) first demonstrated that in this situation goods should be taxed the more the weaker substitutes or stronger complements to leisure they are. The assumption of separability between consumption and leisure may therefore lead to misleading conclusions about the levels of optimal taxes if the taxed goods are not average substitutes for leisure. This fact has been widely acknowledged for a long time as a theoretical possibility but at the same time ignored in empirical evaluations of optimal taxes. The reason for this contradiction is that usually we do not know the actual degree of substitutability of a particular good with leisure. Only recently, West and Williams (2007) estimated cross-price elasticities between gasoline consumption and leisure for the United States, used these estimates to calculate an optimal gasoline tax and found out that it was more than 50% above the rate calculated from the same data but assuming separability.

In this thesis, we attempt to deepen our current knowledge of how commodity taxes interact with labour supply and see whether the results by West and Williams can be replicated in a different country and for a different commodity. We concentrate on household energy consumption because it is an area with a particularly high potential for energy savings and it is also a primary target of the ecological tax reform in the Czech Republic. It seems reasonable to suppose that household energy should be a weaker than average substitute to leisure or even its complement. We estimate an Almost Ideal Demand System due to Deaton and Muellbauer (1980a), augmented so that we can model joint determination of commodity demand and leisure supply. We use Czech household level data and estimate the model separately for one- and two-adult households. Contrary to what could be expected, we discover that household energy consumption is an average or even stronger than average substitute for leisure

[3] E.g. Bovenberg and Goulder (1996) analysed taxes on intermediate inputs; Parry (1995), Goulder et al. (1997) and Parry et al. (1999) considered policies other than taxes such as godfathered pollution permits, Bovenberg and de Mooij (1998) added capital to their model. Many of these and other works tried to estimate real-world quantitative importance of the effects in focus.

and it should be therefore taxed at rate lower than the marginal environmental damage caused by production and consumption of the energy.

The rest of the thesis is organised as follows: Section 2 uses a model developed by Parry (1995) to explain how environmental taxes interact with supply of labour, what are implications of this interaction and how it is connected to level of substitutability between leisure and taxed commodity. Furthermore, it describes how these results obtained in the field of environmental economics can be relevant for other areas of economics, too. Finally, it briefly studies consequences of the separability assumption in the examined context and presents empirical results on separability. In Section 3, we introduce important studies that have previously tried to estimate jointly determined demand systems for commodities and leisure. We start Section 4 with presenting our model and description of data. Then we move to estimation of the demand system and finally we present our results. Section 5 concludes.

2 Importance of cross-price elasticities

Every imposition of a tax changes prices in the economy and consequently affects, more or less its other parts. The labour market is no exception here. On the other hand what does make labour market exceptional is the fact, that there is usually an exceptionally high wedge between private and social benefits of some activity, in this case work. As a result, changes in prices have often more severe distortionary impacts in labour market than in any other market. This fact has attracted a lot of attention in literature on environmental taxation. In this section, we present the main concepts that environmental economists have developed to address this area.

However, the progress made in the field of environmental taxation with respect to interactions with labour supply has implication in other areas of economics, too. These include trade policy, welfare costs of monopoly and marginal excess burden of taxation. This chapter discusses how, in these areas, cross-price elasticities with leisure affect results. In addition, section 1.5 considers the definition and interpretation of weak separability, its implications for cross-price elasticities and empirical results about whether it holds in real world.

2.1 Environmental taxation

Terkla (1984) and Lee and Misiolek (1986) introduced the questions whether the optimal environmental tax lies below or above the Pigouvian rate and whether the double dividend hypothesis holds. To show mechanisms underlying these questions and to demonstrate how the answers depend on cross-price elasticities, we will follow a paper by Parry (1995). Parry employs a diagrammatic approach that allows him to lucidly uncover various effects that influence social welfare when an environmental tax is imposed. More specifically, Parry distinguishes (i) efficiency improvement in the market of the polluting good, (ii) the revenue effect and (iii) the interdependency effect. Introduced by Parry, the latter two effects appear quite often in writings on environmental taxation as well as in some other literature. However, they are now more commonly referred to as the "revenue-recycling effect" and the "tax-interaction effect"[4] and therefore I will use these names in the rest of this thesis. Provided that only distortions in the labour market are pre-existing, the revenue-recycling effect (RE) is the change in social welfare thanks to using money from tax on the polluting good to cut labour tax. The tax interaction effect (IE) is the welfare change caused by shift in real wages due to higher prices of the polluting good.

Parry assumes perfectly competitive markets, constant marginal costs and linear environmental damage function in the form of cX_j, $c>0$, where X_j is the production of the only polluting good. If pre-tax prices of all commodities and labour are defined to be unity, the aggregate household budget constraint is then written as

$$\sum_{i=1}^{K} X_i + (1-m)N = (1-m)T + G, \tag{1}$$

where X_i are the produced goods, m is labour tax, N is leisure, T is household time endowment and G stands for lump-sum transfers from the government.

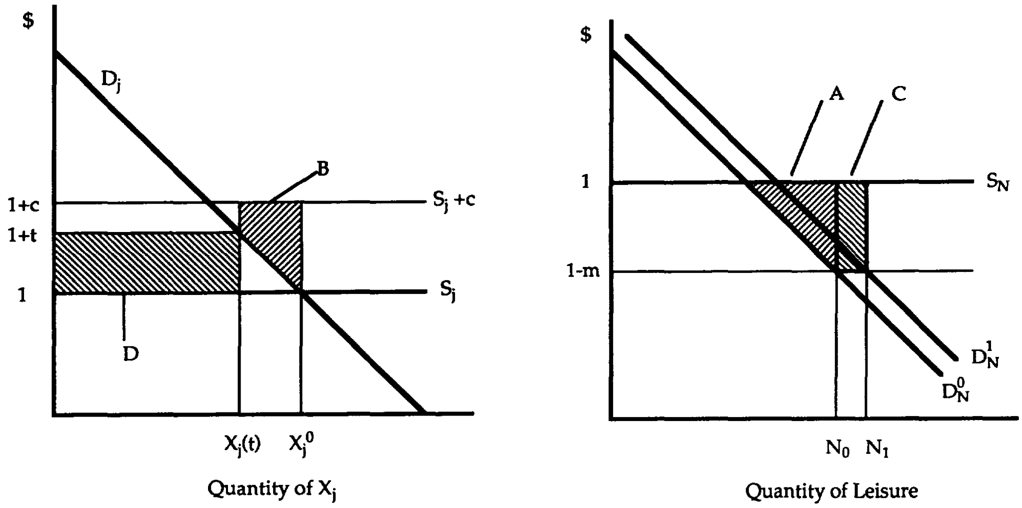

Figure 1. The Welfare Effects of Environmental Taxes (Parry (1995))

Figure one shows market for the polluting good (left) and market for leisure (right), which is an inverse of labour market. S_j stands for supply of X_j and equals marginal private costs of production. S_j+c represents marginal social costs of production. D_j is demand for X_j. S_N is supply of leisure and equals marginal product of labour. D_N^0 represents demand for leisure and it is derived from supply of labour function. All the

[4] These terms are due to Goulder (1995). They are also used for example by Goulder et al. (1997), Parry et al. (1999) and Kim (2002). Outside environmental tax literature they appear for example in Williams (1999).

demand curves in Figure 1 are compensated. Then triangle A shows the initial labour market distortion. It should be noted that throughout his analysis, Parry assumes positive wage elasticity of labour supply, which seems to be consistent with most empirical findings[5]. If a tax on the polluting good at the level of $t \leq c$ is imposed, it leads to the following three welfare effects:

- **Efficiency improvement in the market of the polluting good (trapezoid B).**

The new tax reduces consumption of X_j in a situation where marginal social costs of Xj exceed marginal private utility from its consumption which leads to a welfare improvement. Analytically, the effect can be written as

$$tX_j^0 \eta_{jj} \left(c - \frac{t}{2} \right), \tag{2}$$

where X_j^0 is the initial production of X_j and $\eta_{jj} = -(dX_j / dp_j) / X_j^0$ is the compensated own-price elasticity of demand for X_j. In case $t = c$, the expression in (2) is the widely used Harberger triangle, which we will discuss later in this thesis.

Before proceeding to the latter two effects, it will be useful to define one more term. Raising public funds through labour tax is not a mere transfer from households to the government but it bears also an inevitable efficiency loss. Parry defines "marginal welfare cost" of labour tax revenues, V, as efficiency loss from a marginal increase in labour tax divided by the additional government revenue. The formula for V is thus

$$V = \frac{-m(dN / dw)}{T - N + m(dN / dw)}. \tag{3}$$

It should also be mentioned that in the optimal-tax literature the term "marginal cost of public funds" (MCPF) is often used[6] and it holds that $1 + V = MCPF$.

- **Revenue-recycling effect (rectangle D times V).** The tax on X_j raises revenues equal to rectangle D that are subsequently used to reduce labour tax rate which in turn increases labour supply. Given the wedge between private and social benefits of labour (costs of leisure), m, this effect increases welfare by

$$VtX_j(t), \tag{4}$$

where $X_j(t)$ is the amount of X_j produced after the imposition of tax t on X_j.

[5] For a recent synthesis of empirical findings on labour supply elasticity see Evers et al. (2008)
[6] See for example Bovenberg and van der Ploeg (1994) or Bovenberg and Goulder (1996).

- **Tax-interaction effect (rectangle C times (1+V)).** The new tax raises consumer's prices and thus reduces real wage. This shifts the leisure demand curve up to D_N^1 and reduces labour supply. Two consequences emerge: first, given the labour tax wedge of m, the reduced labour supply leads to an efficiency loss equal to rectangle C; second, tax revenues shrink and therefore there is an additional welfare loss of rectangle C times V[7]. Parry shows that the total welfare loss due to the tax interaction effect can be expressed as

$$(1+V)m\frac{dN}{dp_j}t = VtX_j^0\frac{\eta_{jN}}{\varepsilon}, \tag{5}$$

where η_{jN} stands for compensated elasticity of demand for X_j with respect to price of leisure and ε for compensated labour supply elasticity. From (4) and (5) it is clear that ratio of the RE and the IE equals

$$\frac{X_j(t)}{X_j^0}\frac{\varepsilon}{\eta_{jN}}. \tag{6}$$

Parry also shows that the marginal benefit from the RE when there is a marginal reduction of Xj is

$$\mathrm{MB}_{\mathrm{RE}} = V\left(\frac{1}{\eta_{jj}}\frac{X_j(t)}{X_j^0} - t\right), \tag{7}$$

while marginal costs from the IE are

$$\mathrm{MC}_{\mathrm{IE}} = \frac{V}{\eta_{jj}}\frac{\eta_{jN}}{\varepsilon}. \tag{8}$$

He uses these marginal terms to write optimal tax as

$$t^* = c + MB_{RE} - MC_{IE} = \frac{1+(V/c\eta_{jj})\{1-(\eta_{jN}/\varepsilon)\}}{1+2V}c. \tag{9}$$

Note that the optimal tax lies above the Pigouvian rate if and only if $MB_{RE} > MC_{IE}$.

For further analysis, assumptions about the elasticies in (9) are crucial. By taking the diagrammatic approach, Parry has avoided explicit assumptions about utility function that would lead to specific elasticity values and that can be seen in other works on this topic[8]. Instead, Parry directly assumes that the polluting good is an average substitute for leisure. He claims that this assumption leads to

[7] Total tax revenues are set to be constant.
[8] We will discuss this issue directly in section 1.5.

$$\eta_{jN} = \varepsilon \, . \tag{10}$$

He shows that differentiating the budget constraint (1) with respect to price of leisure while keeping G constant and multiplying the result by (1-m) gives us

$$\sum_{i=1}^{K} X_i \eta_{iN} = (T - N)\varepsilon \, , \tag{11}$$

where η_{iN} is compensated elasticity of demand for X_i with respect to price of leisure. Furthermore, it holds that

$$\sum_{i=1}^{K} X_i = T - N \tag{12}$$

or in words total consumption equals gross income[9]. Then, although trying to show that the polluting good being an average substitute for leisure is a sufficient condition for (10) to hold, he actually only proves that (10) is true if all goods are average substitutes for leisure. To demonstrate that also the former claim is true, it is necessary to make it clear what "average substitute" means. It is reasonable to say that X_j is an average substitute for leisure if η_{jN} is an average of η_{iN} weighted by X_i or

$$\eta_{jN} = \frac{\sum_{i=1}^{K} X_i \eta_{iN}}{\sum_{i=1}^{K} X_i} \, . \tag{13}$$

Then expressing $\sum_{i=1}^{K} X_i$ out of (13), substituting it into (12) and substituting (12) into (11) gives (10).

Note that the strong double dividend hypothesis holds if, for $t = t^*$, the RE is higher than the IE. Assuming that X_i is an average substitute for leisure and therefore (10) holds, (6) shows that the RE is smaller than the IE for any positive abatement. Thus the strong double dividend hypothesis does not hold. In addition, (9) gives

$$t^* = \frac{1}{1 + 2V} c \, , \tag{14}$$

The optimal tax is rate is therefore below the Pigouvian tax, c. However, let us demonstrate that if $\eta_{jN} < \varepsilon$, the results may be quite different. From (6), the RE is stronger than the IE if

[9] This is true because taxes are redistributed back to households as transfers.

$$\eta_{jN} < \varepsilon \frac{X_j(t)}{X_j^0} \tag{15}$$

and hence the strong double dividend hypothesis holds if[10]

$$\eta_{jN} < \varepsilon - \frac{\varepsilon \eta_{jj} c}{1+V}. \tag{16}$$

Furthermore, (9) shows that for $t^* > c$ to be true, it must hold that $MB_{RE} > MC_{IE}$. If we substitute (7) and (8) into the last expression and rearrange terms using $t\eta_{jj} = 1 - \frac{X_j(t)}{X_j^0}$, we get the following condition under which the optimal tax is above the Pigouvian tax:

$$\eta_{jN} < \varepsilon\left(2\frac{X_j(c)}{X_j^0} - 1\right) = \varepsilon - 2\varepsilon\eta_{jj}c. \tag{17}$$

If the term on the extreme left side of (17) were smaller (larger) than the two terms on the extreme right side, MB_{RE} would be larger (smaller) than MC_{IE} and the optimal tax rate would lie above (below) the Pigouvian rate. Also note that the right term in (14) is larger than the right term in (17) and therefore if optimal tax rate is above the Pigouvian rate, the double dividend hypothesis is always valid, while this relationship need not hold in the opposite direction.

Figure 2 illustrates these findings. All four diagrams have quantitiy of abatement on the X axis and a monetary measure of various effects on the Y axis. The upper two diagrams show that while MB_{RE} declines with increasing abatement of X_j, MC_{IE} is constant. At the lower two diagrams, the optimal level of abatement is given by the intercept of lines $D_j - S_j + MC_{IE} - MB_{RE}$ and c. Intercept of a vertical line from this point with line $D_j - S_j$ than sets the optimal tax.

The two diagrams on the left are taken from Parry (1995) and correspond to the case where X_j is an average substitute to leisure. Pigouvian tax would equal c, the marginal environmental costs of production of X_j. However, the optimal tax rate t^* lies below the Pigouvian tax because MC_{IE} is larger than MB_{RE} for any positive abatement.

[10] Substituting $t = t^*$ into (13) and using $X_j^0 - X_j(t) = -\frac{dX_j}{dp_j}t$ and $\eta_{jj} = -\frac{dX_j}{dp_j}\frac{1}{X_j^0}$, we get $\eta_{jN} < \varepsilon(1 - \eta_{jj}t^*)$. Substituting from (11) into the last expression and rearanging terms, we get (14).

The situation is different in the right diagrams where X_j is weaker than average substitute for leisure. As seen in (15), $\eta_{jj} < \varepsilon$ shifts MC_{IE} down. Consequently, $MB_{RE} > MC_{IE}$ for some positive abatement and, in the lower right diagram, the line described as $D_j - S_j + MC_{IE} - MB_{RE}$ also shifts down, so that it intersects the line $D_j - S_j$ in a point corresponding to a positive abatement (where $MB_{RE} = MC_{IE}$). This diagram contains two cases with different marginal environmental costs, c_1 and c_2 . In case one, the optimal tax t_1^* is below the Pigouvian rate c_1 but the difference of the RE and the IE (equal to the dark grey triangle minus the light grey triangle) is positive, thus the double dividend hypothesis holds.

In case two, not only the double dividend hypothesis holds but also the optimal tax t_2^* is above the Pigouvian rate c_2.

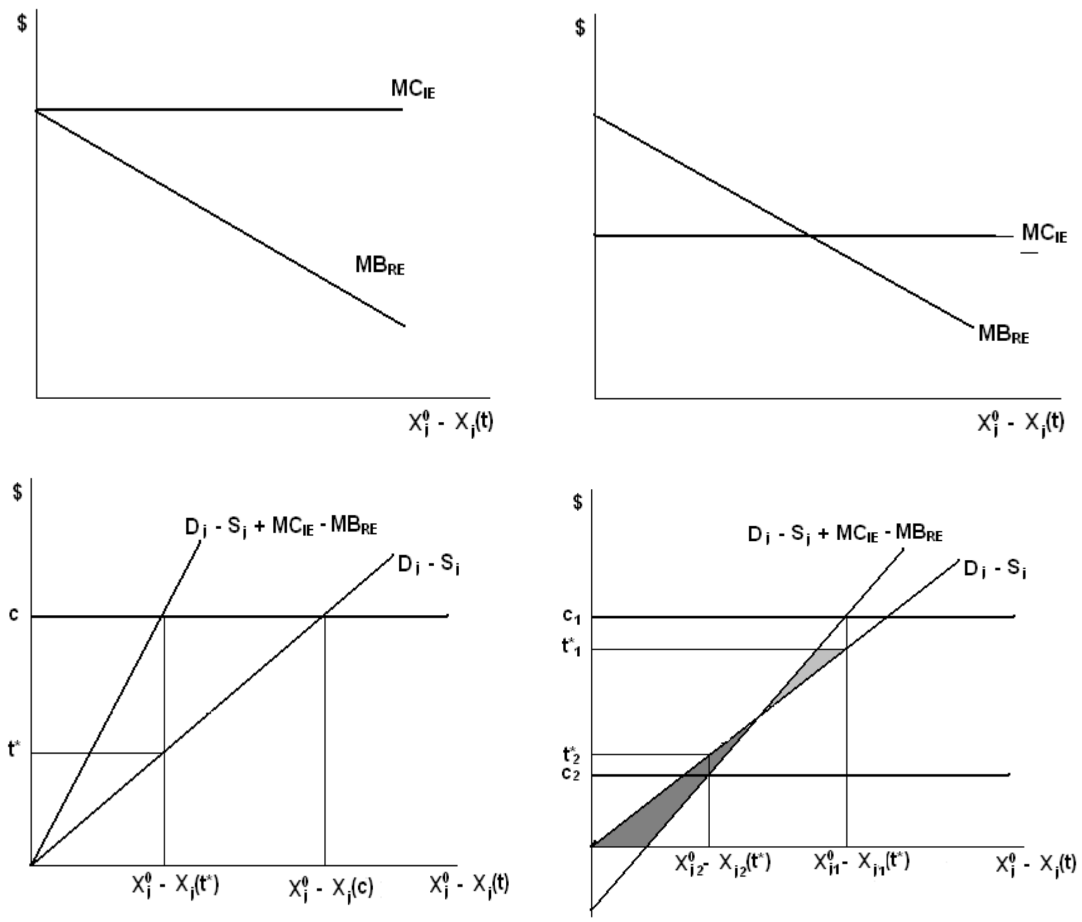

Figure 2. The optimal environmental tax (adapted from Parry (1995))

In this section, it has been explained how the degree of substitutability between a polluting good and leisure influences the optimal tax rate on the polluting product and validity of the double dividend hypothesis. Also the terms of the tax-interaction effect and the revenue-recycling effect have been presented. Implications of the discussed problems nevertheless reach beyond the field of environmental taxation to many other areas. We will discuss some of them in the next sections. It is worth mentioning that while the contexts differ, the basic theoretical principles are quite similar in most cases. That is why we will not discuss the other areas in the same depth as the area in this section.

2.2 Excess burden of taxation

Harberger (1964) developed a comprehensive measure of excess burden of taxation. In its full version, the measure includes effects on all markets. For each market other than the market of the newly taxed good, the excess burden equals tax on the appropriate good times change in production of that good induced by the new tax. The formula is

$$EB = -\frac{1}{2}\tau_k^2 \frac{dX_k}{d\tau_k} - \sum_{i \neq k} \tau_i \tau_k \frac{dX_i}{d\tau_k}, \tag{18}$$

where EB is excess burden of a tax on good k, X_i is quantity of good i and τ_i is tax on good i. Notice that, as Goulder and Williams (2003) put it, "the tax rate represents marginal distortionary cost – the discrepancy between marginal social value and marginal social cost." Formula for excess burden as written in (18) is theoretically correct but its practical use is limited, since we are extremely unlikely to know most of the partial derivatives. That is why most economists estimate marginal excess burden using only the first term on the right-hand side of (18), known as Harberger triangle. Goulder and Williams (2003) have nevertheless demonstrated that while in most cases it is possible to omit effects on markets for other goods, the effects on labour market should be included in the formula because they may be even far more significant than effects in the market for the taxed good itself. It is so because commodity taxes tend to be rather small but labour taxes, and the related marginal distortionary costs, are often substantial. Including interactions with labour market, Goulder and Williams first derive a formula for excess burden from a marginal increase in the tax on good k and then a formula for excess burden from a larger increase in this tax, which has stronger practical implications. When doing so, they assume that demand curves of good k and of leisure are linear and that commodity taxation accounts for only a small share of the total income. Then the formula writes

$$EB = -s_k Y \left[\frac{\tau_k^2}{2p_k^2} \varepsilon_k - \frac{\tau_L \tau_k}{p_k} \varepsilon_L \left(\frac{\varepsilon_{k,L}}{\sum_{i=1}^{M} s_i \varepsilon_{i,L}} \right) \right], \tag{19}$$

where s_i is share of expenditure on i in total income, Y the total income, p_k price of good k, ε_k compensated own-price elasticity of demand for good k, τ_L tax on labour, ε_L compensated labour supply elasticity and $\varepsilon_{i,L}$ compensated elasticity of labour supply with respect to price of good i. The left term in the outer brackets corresponds to the Harberger triangle and therefore distortion in the market for the taxed good whereas the right term to distortion in labour market. The term in the inner brackets represents relative substitutability of good k and leisure. In their numerical calculations, Goulder and Williams assumed good k to be an average substitute with leisure. If good k is a weaker (stronger) than average substitute with leisure, the term is smaller (larger) than 1 and the excess burden diminishes (grows).

Goulder and Williams found that adding labour market distortion effects to the excess burden formula in addition to the Harberger triangle may substantially increase estimated excess burden, sometimes ten times or even more, implying that additional distortion in the labour market may be much more important than distortion in the market of the taxed good. Given that the "substitutability term" directly modifies the labour market distortion term, it is obvious that it would be very useful to know elasticities of labour supply with respect to price of the taxed good, especially if these elasticities differ widely among different goods.

2.3 Trade policy

A tariff causes welfare loss because it introduces a wedge between marginal social benefit and marginal social costs of an additional unit of imports. For long time economists were interested either in this welfare loss or in welfare loss stemming from differential taxation of labour in different industries[11]. However, Williams (1999) shows

[11] See Magee (1976) for more information on interaction of trade with varied taxes on production inputs between industries.

that interaction of trade with preexisting labour taxes may also have serious welfare implications. Tariff raises revenues that can be used to cut taxes on labour and consequently increase labour supply, which is exactly the revenue-recycling effect with origins in environmental taxation theory. Tax-interaction effect can be found here, too, because tariffs increase prices of imported goods, which decreases real wage and causes labour supply to fall.

Williams builds a simple general equilibrium representative agent model with two goods produced with labour and two industry specific production factors, one for production of each good. Good X is imported and good Y is exported. There is a tariff imposed on imports of X, τ_X, and a labour tax, τ_L. Williams derives the following formula for welfare implications of a marginal change in the tariff rate:

$$\frac{1}{\lambda}\frac{dU}{d\tau_X} = \left[\tau_X - p_Y P'(M_X)M_X\right]\frac{dM_X}{d\tau_X} + Z\left(M_X + \tau_X \frac{dM_X}{d\tau_X}\right) - (1+Z)\tau_L \frac{\partial l}{\partial \tau_X} \tag{20}$$

where λ is marginal benefit of income, p_Y domestic price of Y, $P'(M_X)$ world price of X in units of Y, M_X imports of X, l leisure and Z marginal excess burden of labour taxation or

$$Z = \frac{\tau_L \dfrac{\partial l}{\partial \tau_L}}{T - l - \tau_L \dfrac{\partial l}{\partial \tau_L}}, \tag{21}$$

where T is total time endowment and hence $T - l$ is labour supply. Notice that the term is identical to the marginal welfare costs of labour tax revenues, V, as defined when describing the environmental taxation problem.

The first term on the right-hand side of (20) represents the "primary effect" of a marginal change in tariff, and consists of implied change in imports times difference between domestic price of the imported good X and the marginal social cost of an additional unit of imports of X. The second term stands for the RE and it is a simple product of revenues collected and "value" of public funds measured by Z. Finally the third term refers to the IE. It consists of two parts. The first one is the welfare loss from the change in labour supply due to real wage decreased by higher domestic price of X. Second one is the additional cost because of the need to make up for diminished labour tax base by increasing labour tax rate[12]. Note that the forms of the RE and the IE are also quite similar to the forms used in the analysis originating from Parry (1995).

Williams shows that it is also possible to write the IE as

$$IE = Z\frac{\eta_{XL} X\frac{dp_X}{d\tau_X} + \eta_{YL} Y\frac{dp_Y}{d\tau_X} + s_L \eta_{LI}\left(\frac{dp_X}{d\tau_X} + Y\frac{dp_Y}{d\tau_X}\right)}{s_X \eta_{XL} + s_Y \eta_{YL} + s_L \eta_{LI}}, \quad (22)$$

where η_{XL} and η_{YL} are compensated elasticities of demand for X and Y with respect to the price of leisure, η_{LI} is labour supply elasticity, s_X and s_Y are shares of X and Y in total income and s_L is share of after-tax labour income in total household income. Williams writes: "If the exported good is more complementary with leisure than the imported good, then this effect will cause a larger welfare loss. Conversely, if the imported good is more complementary with leisure, this effect will produce a smaller welfare loss, or could even produce a welfare gain, if the imported good is a sufficiently strong complement to leisure."

Williams analyses welfare implications also for other types of trade barriers such as quotas or voluntary export restraints. Then, assuming that X and Y have the same level of substitutability with leisure, he shows that excluding interactions with labour market distortion leads to underestimation of welfare costs of trade barriers in the US economy by approximately 20%. However, it would certainly be interesting to learn how the cost estimates, particularly for some specific trade commodities, change when restrictive assumptions about substitutability with leisure are replaced by precisely estimated cross-price elasticities.

2.4 Welfare cost of monopoly

Welfare costs of monopoly have been traditionally measured by the Harberger triangle which describes inefficiency due to change in the output mix[13]. Such approach implicitly assumes that monopoly reallocates inputs among various sectors in the economy but that the total amount of inputs remains unaltered.

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[12] The first part of the IE is $\tau_L \frac{\partial l}{\partial \tau_X}$, the second part $Z\tau_L \frac{\partial l}{\partial \tau_X}$.

[13] For the original paper see Harberger (1954). For other works see for example Gisser (1986).

Assume that there are two sectors in an economy, each producing one good. The first sector produces good X, the second good Y. In addition, assume that both sectors are perfectly competitive in the beginning, labour is the only factor of production and the labour supply is fixed (as suggested above). If monopol (or oligopol) appears in the sector producing X, the quantity of X produced is reduced and the price of X increases. Labour is reallocated to the competitive sector and the production of Y increases. These changes in production lead to an inefficient output mix measured by the Harberger triangle.

However, inefficient output mix is not the only distortion due to imperfect competition. Assuming negative elasticity of demand for Y, with increase in production of Y, its price falls. As labour is the only factor of production and the production of Y is perfectly competitive, the whole price obtained for a sold piece of Y goes to wages. Consequently, a fall in the price of Y results in a decrease of wages. This decrease takes place in both sectors. With positive elasticity of labour supply, lower wages lead to a reduction in labour supply. Finally, given a wedge between private and social marginal benefits from labour caused by pre-existing labour taxation, reduction in labour supply brings welfare costs additional to those due to inefficient output.[14]

In addition to two effects described so far, a third one emerges if X and Y differ in their substitutability with leisure. Monopoly changes relative prices of X and Y. Therefore if for instance X was a weaker substitute for leisure than Y, then the increase in price of X relative to Y due to monopoly would make the composite consumption bundle relatively more attractive compared to leisure. This might offset at least part of the negative effects on labour supply discussed in the previous paragraph. On the contrary, if X was a stronger substitute for leisure than Y, the change in relative prices of goods would even exacerbate the negative effects discussed above.

Browning (1997) has estimated that the effects of decreased wages as discussed in the previous paragraph may amount up to twenty times the welfare costs due to changes in the output mix. This result demonstrates that interaction of imperfect competition with labour market deserves more attention than it has attracted so far. However, quantitative importance of the welfare costs or benefits due to different substitutability with leisure depends heavily on values of relevant elasticities. That is another reason

[14] For more formal treatment of these effects see Browning (1997)

why it would be useful to estimate such elasticities, as we will try in this thesis, even though we will do so in a slightly different context.

2.5 Separability

A plethora of studies on welfare impacts due to interactions with distorted labour market have used the assumptions of separability and sometimes homotheticity either initially or to derive their principle findings[15]. In this section, we would like to briefly discuss how these assumptions affect values of cross-price elasticities with leisure.

If for the sake of simplicity we assume that only two consumption goods, X and Y, and leisure, l, enter a utility function, a utility function where consumption is weakly separable from leisure[16] can be written as

$$U = u(v(X,Y),l) . \tag{23}$$

Weak separability means that choice between consumption commodities does not depend on the amount of leisure chosen. Put in a different way, it perceives a household as first allocating its time endowment between either work to earn income to purchase consumption goods or leisure and only then choosing the optimal composition of its consumption basket. To show this[17], let us write the budget constraint of a household as

$$T = l + \frac{I}{w} , \tag{24}$$

where

$$I = p_X X + p_Y Y , \tag{25}$$

T is fixed total time endowment of the household, w wage or price of leisure, I income or expenditure on consumption goods and p_i prices of X and Y. For a given level of all prices and each allocation of consumption expenditure, I, and leisure, l, we can maximize v subject to (25). This gives us an indirect utility function

$$\phi \; (p_X , p_Y , I) \tag{26}$$

[15] Separability and homotheticity is assumed by Bovenberg and de Mooij (1994), Bovenberg and van der Ploeg (1994), Bovenberg and Goulder (1996), Goulder et al. (1997), Parry et al. (1999) and many others. Separability without homothecity is assumed for example by Jorgenson and Wilcoxen (1993), Parry and Small (2005) and Ballard et al. (2005)

[16] Weak separabilty is the type of separability which is the most commonly used within the discussed literature.

[17] The following derivation follows Gravelle and Rees' (1992) explanation of properties of weak separability with the only difference that we do not consider separability between goods but between consumption and leisure.

and un overall indirect utility function

$$u^*(\phi(p_X, p_Y, I), l)\,. \tag{27}$$

Now I and l can be viewed as individual goods with prices in time units equal to 1/w and 1 respectively. Then, for fixed prices, we can maximize the overall indirect utility function with respect to I and l, subject to (24). We get

$$\frac{\partial u}{\partial \phi}\frac{\partial \phi}{\partial I}w = \frac{\partial u}{\partial l} = \lambda\,, \tag{28}$$

where λ is marginal utility of time endowment. This gives us the optimal allocation of I^* and l^*. Inserting I^* into (26) and applying Roy's identity gives us individual commodity demands X^* and Y^*.

Moreover, it can be shown that under separability, relative size of compensated cross-price elasticities of demands for X and Y with respect to price of leisure depends only on income elasticities of the goods. Inserting I^* and l^* into (27) gives value of maximised utility u_0. Then continuing to view I and l as individual goods, we can use information from (27) to describe a time expenditure function t, defined as

$$t(p_X, p_Y, w, u) = \left[\min\left(l + \frac{I}{w}\right); u \geq u_0\right]. \tag{29}$$

Then we use Shephard's lemma to define Hicksian constant utility demand for consumption as

$$I^*(p_X, p_Y, w, u) = \frac{\partial t}{\partial w^{-1}}\,. \tag{30}$$

Now we can write compensated elasticities of demand for goods X and Y with respect to price of leisure as

$$\varepsilon_{Xl} = \frac{\partial X}{\partial I^*}\frac{\partial I^*}{\partial w}\frac{w}{X} = \varepsilon_{XI}\frac{w}{I^*}\frac{\partial I^*}{\partial w} \text{ and } \varepsilon_{Yl} = \frac{\partial Y}{\partial I^*}\frac{\partial I^*}{\partial w}\frac{w}{Y} = \varepsilon_{YI}\frac{w}{I^*}\frac{\partial I^*}{\partial w}\,, \tag{31}$$

where ε_{XI} and ε_{YI} are income elasticities of X and Y. In addition, if it is also assumed that $v(X,Y)$ is homothetic, both ε_{XI} and ε_{YI} are equal to unity and both consumption goods are equal substitutes to leisure.

The theoretical observations in this section, as well as discussion in the previous sections, suggest that the assumption of separability plays a crucial role in much economic literature. In contrast to the common use of the assumption in theoretical literature, it is nevertheless almost unanimously rejected in econometric studies. For details see for example Abbott and Ashenfelter (1976), Barnett (1979a), Blundell and

Walker (1982), Browning and Meghir (1991), Kaiser (1993), Madden (1995) or Brannlund and Nordstrom (2002).

3 Estimation of cross-price elasticities (review)

In the previous chapter we have shown that empirical estimates of cross-price elasticities with leisure would be of substantial use in many areas of theory. In the present chapter we will therefore proceed to look at research, which has attempted to estimate these elasticities so far to see which models and data can be used and to discuss possible theoretical difficulties of such estimation. Although the review offered here is not by any means exhaustive, it presents the studies that are either pioneering in their method and data use or are particularly close to our objectives. It should also be noted that all the studies discussed in this section test for some form of separability and they unambiguously reject it. As our primary concern here is estimation of cross-price elasticities, we do not mention separability testing when talking about each individual study.

3.1 Abott and Ashenfelter (1976)

In order to obtain reasonable cross-price elasticities with leisure, one must estimate a model of joint determination of commodity demand and labour supply. To our knowledge, the first economists who attempted to do so were Abbott and Ashenfelter (1976). They use aggregate time-series data from US for the period 1929-1967. More specifically, they take consumption data from U.S. National Income and Product Accounts (NIP), combine the original 85 commodities into 22 mutually exclusive and exhaustive categories and further aggregate these into 7 composite commodity groups: durable goods, food clothing, other non-durable goods, housing services, transportation services and other services. In addition, they use Christensen and Jorgenson's (1970) time-series data on private domestic hours per person and assumption that hours per employee are the same in the public sector as in the private sector. The hourly wages are calculated by dividing the total wages and salaries in the private sector from NIP by the total private hours worked. To obtain net wages, the authors simply use the ratio of personal taxes to personal income, assuming marginal tax rates equal to average rates.

For estimation of commodity demand and labour supply, Abbott and Ashenfelter use three distinct models. The first one is the Linear Expenditure System (LES), augmented by adding leisure as an extra commodity to give the following expenditure functions:

$$p_i x_i = \gamma_i p_i + \beta_i (wT + y - \sum_i \gamma_i p_i - \gamma_l w)\,,\ i = 1,....,n \tag{31a}$$

$$wl = \gamma_l w + \beta_l (wT + y - \sum_i \gamma_i p_i - \gamma_l w)\,, \tag{31b}$$

where x_i and l amounts of commodities purchased and labour supplied, p_j and w prices and wages, T time endowment, y non-labour income and various γ's and β's price and income terms to be estimated.

β_i and β_l are restricted to be non-negative because otherwise the related cost function would not be concave and the expenditure functions from (31a) and (31b) would not be results of a constrained utility maximisation. As shown for example by Deaton and Muellbauer (1980b), under these restrictions, there are no inferior goods and all goods are substitutes to each other. This makes the linear expenditure system in this version completely inappropriate for our purposes because we want to measure cross-price elasticities, not to have them positive due to a priori stated restrictions

The second model used is an augmented version of Houthakker's (1960) indirect addilog model. By its construction, it equalises all uncompensated cross-price elasticities with respect to price of leisure, which again excludes it from the set of tools suitable for us to achieve our goals.

Finally, the authors use an augmented Rotterdam model in the form

$$v_i d \ln x_i = \sum_j \gamma_{ij} d \ln p_j + \gamma_{i,l} d \ln w + \beta_i (\sum_k v_k d \ln x_k - v_l d \ln l) \tag{32}$$

$$- v_l d \ln l = \sum_j \gamma_{lj} d \ln p_j + \gamma_{jj} d \ln w + \beta_l (\sum_k v_k d \ln x_k - v_l d \ln l)\,,\quad i,k = 1,...,n\,,$$

where d stands for first differences and v_i and v_l are shares of commodity expenditure and work income on total money income. The equations are estimated with least squares with intercept included, which allows for time trends.

With the Rotterdam model the authors compute elasticities, including cross-elasticities related to labour/leisure. However, the authors themselves admit that the cross-price terms (used to estimate corresponding elasticities) are not estimated with much precision. For example, most of the terms explaining supply of labour are either non-significant or only weakly significant. Elasticities of demand for commodities with respect to wage are reported. The uncompensated ones are large, but almost only due to income effects, because compensated elasticites are substantially smaller.

Finally it should be noted that the approach taken by Abbott and Ashenfelter is rather straightforward and should be perceived as a first attempt in the area. Some complications of the analysis discussed later in this chapter are avoided by using aggregate data, some are simply ignored by the authors for the sake of simplicity. For instance, no distinction is made between male and female labour decisions nor are constraints imposed by labour demand taken into account. Furthermore, the paper suffers from some modeling and data problems, for example Barnett (1979a) notes that Abbott and Ashenfelter consider leisure only for workers but consumption for the whole population, thus overstating goods share on the total income by more than 100%. For observations on data errors in the paper see also Ham (1978).

3.2 Barnett (1979)

Barnett (1979a) also estimates complete commodity demand and leisure supply with an augmented Rotterdam model, but with a different version, described in Barnett (1979b). Again he uses aggregate U.S. data, this time for period 1890-1955[18]. Commodity consumption data come from Kuznetz (1961), population data from the Historical Statistics of the United States from Colonial Times and labour market data from Barnett (1981). Besides leisure, he defines four commodity groups: perishables, semidurables, durables and services. He estimates his demand system with maximum likelihood estimation and calculates income and cross-price elasticities for all commodity groups and labour supply.

The most important innovation of Barnett's when compared to the paper by Abbott and Ashenfelter (1976) is probably the fact that he includes labour demand constaints of labour supply decision into his analysis. He does not consider wages as price of leisure directly. He rather calculates price of leisure from the following equation:

$$p_l = wE^{\alpha}, \tag{33}$$

where p_l is price of leisure, w wage, E employment rate (1-unemployment rate) and α a parameter. In the discussed paper the estimate of $\alpha = 2.3$ from Barnett (1981) is

[18] War years 1942-1945 were excluded from the data set due to government imposed rationing.

used. Barnett checks robustness of his results based on α and he shows that for $\alpha > 1$ the results are quite stable, while with α declining below 1 the properties of the model deteriorate rapidly, which becomes even more severe as α approaches 0. Barnett (1979a) also emphasizes that $\alpha = 0$ is actually the Abbott and Ashenfelter's case and case of any other research that takes wages as price of leisure.

3.3 Blundell and Walker (1982)

While the two works mentioned so far use aggregate time-series data, Blundell and Walker (1982) work with household level cross-section data from U.K. Family Expenditure Survey of 1974. While their data set covers only one year, which means no variation in prices other than wages, and is rather small[19], their paper is of interest to us as the first attempt to examine substitutability between leisure and commodities with cross-section data. They build their analysis upon a modified form of LES with cost function of a generalised Gorman Polar form due to Muellbauer (1981)[20]. This enables them to estimate parameters that allow calculation of income and substitution effects on demands for commodities due to changes in wage levels. They report neither these effects nor related elasticities, they only report the parameters and verbaly state which commodities are complementary and which are substitutes to leisure. However, the parameters are estimated very imprecisely, probably due to the small sample size, so no serious conclusions can be made based on these results. Moreover, Alderman and Sahn (1993) note that Blundell and Walker's modified version of LES "is likely intractable with a fuller set of commodity prices.

The use of cross section necessarily brings about some complications that must be dealt with. First, wages are only observed for working people, so that only those can be included in the sample, which results in a selection bias. Blundell and Walker benefit from a technique due to Amemiya (1974) and Heckman (1979) to correct for this bias. Second, households usually determine male and female leisure according to distinct pattern. The authors model male and female labour separately and indeed the results

[19] Blundell and Walker's sample only includes households with two married working age adults, where the head of the family is a male manual employee. As wage is not observed for women who are not working, the authors further restrict the sample to households with working wives which gives no more than 115 observations. To reduce undesirable effects of quasi-homothecity induced by the selected cost-function, they also exclude household which are out of a certain expenditure range, which gives them a final number of 103 households in their sample.

[20] The estimated equations are analytically rather complicated and therefore we do not present them here.

differ substantially between the two sexes. Third, preferences of households vary with their composition. Blundell and Walker include a variable representing number and ages of children and such household characteristics have a pronounced effect especially on female labour supply. Last but not least, people may not be free to choose the amount of hours they work. The authors therefore estimate two models, one of which is unrationed while in the other one male working hours are fixed and only women can choose how much they want to work. They find that rationing may be important for household's decision making but they are not able to evaluate to which degree the rationing is present in their sample.

3.4 Alderman and Sahn (1993)

Alderman and Sahn (1993) is the first study discussed here that uses the Almost Ideal Demand System (AIDS) created by Deaton and Mullbauer (1980a). Alderman and Sahn adjust the AIDS so that it incorporates male and female leisure, in addition to five commodities or commodity groups: rice; coconut; wheat products; and meat, fishing and poultry and nonfood. The estimating equations of AIDS are derived from a cost function and expressed in budget shares. After inclusion of male and female leisure, the budget-shares must be written as full-income budget shares, where full income is defined as

$$Y = \sum_j p_j x_j + \sum_i w_i l_i \,, \tag{34}$$

with p_j for commodity prices, x_j for commodity quantities, w_i for opportunity costs of individual household members and l_i for leisure consumption by household members. The estimating equations are then written as

$$s_j = \alpha_j + \sum_k \gamma_{jk} \ln p_k + \sum_i \gamma_{ji} \ln w_i + \beta_j \ln\left(\frac{Y}{P^*}\right), \tag{35}$$

$$\ln P^* = \sum_j s_j \ln p_j + \sum_i s_i \ln w_i \,, \tag{36}$$

where s_j's are budget total-income budget shares and γ_{ji}'s and β_j's are parameters to be estimated.

Alderman and Sahn estimate this model with data from 1980/81 Labour Force and Socioeconomic Survey of 873 urban and 3010 rural households conducted on Sri Lanka by its Department of Census and Statistics. The data set contains detailed information on labour force participation and hours worked as well as on consumption patterns. A clear advantage of the data is that it contains significant variation in both prices and wages. AIDS together with the data therefore allows the authors to calculate income, own-price and also cross-price elasticities for the five commodities and male and female leisure. They do not report standard errors in the original paper but claim that "most parameters were precisely estimated". Surprisingly, they discover that all food commodities are complementary to both male and female leisure.

The discussed paper also deals with several methodological issues. First, the authors face a need for exogenous determination of the time endowment. They say that impact that choice of time endowment may have on results cannot be assessed theoretically but that it is rather an empirical question. Therefore they estimate their model using endowments of 8, 12 and 16 hours and discover that different endowments do not affect the estimates much, for example much less than using a separable model. For their final results they choose the middle time endowment of 12 hours.

Second, hours worked include work in agriculture or own bussinesses but wages are not observed for such work, nor are they observed for the unemployed. That is why Alderman and Sahn run a regression with wages as response variables and than use estimated parameters to calculate predicted wage for each individual. To correct for a potential selectivity bias, they follow Heckman's (1979) two-step procedure. First they estimate a probit on the decision of whether to work or not and subsequently they include calculated inverse Mills ratios into the equations used for the above mentioned wage estimation. Unlike some other studies[21], they use the estimated predicted wages in their principal AIDS estimation, which enables them to keep the whole sample. The alternative would be using the observed wages and reducing their sample only to households that fully participate in wage labour market, while including inverse Mills ratios during the AIDS estimation to correct for selection bias. Alderman and Sahn dismiss the alternative procedure because it would severely cut the number of observation in their data.

Third, they consider corner solutions which appear when some households do not consume a certain commodity at all. They follow Heien and Wessels's (1990) approach to correct for potential bias, which is actually Heckman's procedure applied to censored

[21] See for example West and Williams (2007).

commodities in AIDS. They model decision whether to consume or not with a probit and subsequently compute appropriate inverse Mills ratios to be included in the AIDS estimates.

Fourth, previous studies such as Blundel and Walker (1982) and Browning and Meghir (1991) only included households with two members in labour force or with one adult of each sex but Aldermahn and Sahn make no such restriction, even though they analyse separately male and female leisure. The hypothesis of equality between male and female leisure-good substitutability is decisively rejected.

Finally, they add household specific variables into their model. These are more detailed than in case of Blundel and Walker, as they include separately household size and percentages of members in several age bands, sometimes further split according to genders.

3.5 Madden (1995)

Madden (1995) is the first researcher to directly apply the estimated elasticities for optimal tax purposes, more specifically to calculate marginal revenue costs (MRCs) of taxes on several commodity groups[22]. While in his calculation of MRCs Madden benefits from 1987 UK's Household Budget Survey, which means household-level cross-section data, when estimating elasticities to use them in his model he works with aggregate data, origin of which is not specified. The variables he uses are wages, hours of work and commodity-groups expenditures and price indices (all aggregate).

Madden's model is an augmanted LES with Gorman Polar cost functions, specified similarly to Blundell and Walker (1982). However, Blundell and Walker, unlike Madden, estimated their model with cross-section data. Although the model is not as flexible as for example AIDS, it allows for a reasonable flexibility in substitutability between commodities and leisure. The estimation is done with a non-linear procedure in SHAZAM. Most Madden's estimates are reasonably precise in terms of their t-values but there is a question whether they are really reliable, as data source is not specified and moreover Madden includes no advanced specification that is suggested for models with aggregate data for example by Blundell et al. (1993).

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[22] The concept of marginal social cost is originally due to Ahmad and Stern (1984). Marginal revenue cost is inverse to marginal social cost.

3.6 West and Williams (2007)

West and Williams (2007) produce probably the most reliable estimates of cross-price elasticities between a commodity and leisure so far. They employ an augmented AIDS similar to the one used by Alderman and Sahn where there are three groups of goods: gasoline, other goods and leisure. To do so, they emloy data from the 1996 through 1998 Consumer Expenditure Survey (CEX), carried out in USA. It includes detailed quarterly household level data which the authors pool to get the total of about 20000 households, approximately half with one adult and half with two adults.

As the basic period for estimation is one week, the authors divide quarterly expenditures by 13 weeks to get weekly expenditures. The expenditure on "other goods" is then received by substracting gasoline expenditures from the total. The weekly time endowment is set to 90 hours a week, which is the maximum hours of work in the sample. The authors also try 100 and 112 hours and find, similarly to Alderman and Sahn, that choice of time endowment does not have significant impact on results. Leisure equals time endowment minus hours of work. Wages are computed in two steps. First, gross earnings are divided by hours of work and made net of taxes. Second, Heckman's (1979) procedure is used to correct for selectivity bias. Expenditure on leisure is then calculated as the selectivity-corrected wage times number of hours of leisure. Because of potential endogenity, wage as regressor in the AIDS system is substituted for by an instrumental variable made of an occupation-, state- and gender-specific mean.

The ACCRA cost-of-living index is used to obtain prices of gasoline and other goods. It contains information on prices in about 300 American cities. The CEX contains only information on states, so state price indices were obtained as weighted means of indices of appropriate cities. For household whose quarters overlap two quarters of price data, a weighted average of the two quarters is used.

West and Williams develop a model similar to those presented in the first chapter of this thesis in order to decide whether the optimal tax on gasoline lies above or below the Pigouvian rate. Unlike the previous studies, they do not assume separability between leisure and goods and that is why they need to estimate the cross elasticities. They calculate complete compensated and uncompensated elasticity matrices for all their three commodity groups and they discover that gasoline is not merely a weaker-than-average substitute for leisure but that it is its complement. Their model than suggests that the optimal gasoline tax lies substantially above the Pigouvian rate and that a strictly positive gasoline tax would be optimal even in absence of any environmental externalities.

4 Demand system estimation

In this section, we estimate a complete demand system using a model of joint determination of labour supply and commodity demand. We believe that labour/leisure decisions are made differently in one- and two-adult household and therefore we treat each case separately. For one-adult households, we define our AIDS over three goods: household energy good, other monetary expenditure and leisure, where household energy good consists of expenditure on electricity, natural gas, central heating and solid fuels[23]. In case of two-adult households, there are two leisure goods, one for male leisure and the other for female leisure. We have chosen to focus on household energy consumption for several reasons. First, it is one of the environmentally detrimental areas with the largest space for efficiency improvement, which is nevertheless not well exploited so far[24], which naturally brings it into attention of environmental policy makers. Second, it is an area where the first stage of the ecological tax reform has already been implemented in the Czech Republic and where the scope of environmental taxes is likely to grow in the future. Finally, household energy is a commodity where other than average substitutability with leisure can be expected. Specifically, one would suppose that more money is spent on this commodity by people who work less and spend more time at home.

First we outline our model, then we continue by introduction of our data and description of estimation methods and finally we present our results.

4.1 Model

Blundell et al. (1993) demonstrate that "aggregate data alone are unlikely to produce reliable estimates of structural price and income coefficients". In addition, it seems that AIDS and its modifications are the most useful demand systems nowadays, when appropriate data are available. That is why we have decided to estimate the desired elasticities from an AIDS using a model which we will describe in this chapter. During

[23] For sake of brevity, in the rest of the thesis we will call the household energy good simply energy, despite the fact that it does not include all energy consumption in the economy and not even all direct energy consumption by individual people, as for example gasoline is not included. Similarly, other monetary expenditure will be called simply other expenditure.
[24] The energy savings potential of residential energy is well illustrated with Figure 4.2 in Pachauri and Reisinger (2007).

construction of the model we will partly follow a similar model by West and Williams (2007).

Let us have commodity groups[25] x_j, $j = 1,2,...,J$, households h, $h = 1,2,...,H$ and individual adults i, $i = 1,2$, within each household[26]. Then let us have budget constraint of household h

$$Y^h = \sum_{j=1}^{J} p_j^h x_j^h + \sum_{i=1}^{2} w^{hi} l^{hi} = I^h + \sum_{i=1}^{2} w^{hi} T , \qquad (37)$$

where Y^h is total budget[27], p_j^h price of commodity j, x_j^h its amount consumed, w^{hi} net hourly wage of the i'th adult, l^{hi} hours of leisure of the i'th adult, I^h non-labour income and T the total time endowment. Let us define hours of leisure as

$$l^{hi} = T - L^{hi} , \qquad (38)$$

where L^{hi} stands for hours of work by the i'th adult.

To model demands for the J commodities and leisure, we will use a version of AIDS, where leisure is considered to be an extra commodity with price w^{hi}. If we put $l^{hi} = x_{J+i}^h$ and $w^{hi} = p_{J+i}^h$, the simplest form of the system, which we will use as a point of departure for our analysis, can be written as

$$s_j^h = \alpha_j^h + \sum_{k=1}^{J+2} \gamma_{jk} \ln p_k^h + \beta_j \ln\left(Y^h / P^h\right), \qquad (39)$$

where s_j^h is expenditure share of j'th commodity on the total budget, α_j, β_j and γ_{jk} coefficients to be estimated and P^h an overall price index, with

$$\ln P^h = \sum_{j=1}^{J+2} s_j^h \ln\left(p_j^h / \bar{p}_j\right), \qquad (40)$$

where $\bar{p}_j$ stands for sample mean of price of the j'th commodity. Such price index is only an approximation to what the price index should truly be but its advantage is that it is linear[28] and thus allowing easier estimation.

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[25] For the sake of simplicity let us call commodity groups merely "commodities". Also, let us call the respective price indices "prices"

[26] During the estimation, a significant proportion of observations will come from one-adult households and the model will be estimated separately for these. However, for simplicity, in the description of the model we will act as if all households had two adults. Adjusting of equations for one-adult households is straightforward.

[27] The total budget Y^h can be interpreted either as the sum of expenditure on commodities and leisure or the amount of money that the household would earn each week if both its adults used their whole time endowment for work.

We impose restrictions suggested by microeconomic theory, concretely additivity, homogenity and symmetry. In algebraic terms these take forms of

$$\sum_{j=1}^{J+2}\alpha_j^h = 1,\ \sum_{j=1}^{J+2}\beta_j = 0\text{, and }\sum_{j=1}^{J+2}\gamma_{jk} = 0\ \text{ for additivity,} \tag{41a}$$

$$\sum_{k=1}^{J+2}\gamma_{jk} = 0\ \text{ for homogenity and} \tag{41b}$$

$$\gamma_{jk} = \gamma_{kj}\ \text{ for symmetry.} \tag{41c}$$

The first thing we add to the basic model to make it better fit the reality is writing

$$\alpha_j^h = \zeta_{j0} + \sum_{r=1}^{R}\zeta_{jr}c_r^h, \tag{42}$$

where c_r^h are household individual characteristics and other supplementary variables and ζ_{jr} parameters to be estimated. The household individual characteristics used include age, age squared, education, number of children less than two years old, number of children between three and fifteen, number of other people in the household[29], sex of the head of household (sex for one-adult households only), size of a village or a town where the household lives and a dummy for Czech nationality. In addition, expenditure on energy might depend on temperature and therefore we also use region and year specific average temperatures.

A complication stems from the fact that wages are not observable for people who do not work. Therefore we estimate our demand system only for households where all working age household members work. To correct for potential selection bias, we follow Heckman (1979). We run a probit on the dichotomous choice of whether to work or not, separately for one- and two- adult households and for men and women. Regressors in the one-adult equation are as in the household individual characteristics for AIDS estimation and, in addition, we use regional dummies and logs of energy and other expenditure prices. The estimated parameters are then used to calculate an inverse

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[28] Deaton and Muellbauer (1980b) suggest approximation $\sum_{j=1}^{J+2} s_j^h \ln\left(p_j^h\right)$, we follow West and Williams who added the mean term in the denominator of the logarithm in order to make the index invariant to units of measurement.

[29] These may include for example children above 15 or retired grandparents. We think that these groups' impact on working-age adults' labour/leisure decisions might be quite opposite to that of children. While little children require adults, especially women, to spend more time at home, older children or retired members of household may take care housework and little children and allow adults to work more.

Mills ratio for each household which is included as a regressor into the demand system equations. For two-adult households, there are two inverse Mills ratios, one for each working-age adult.

4.2 Data

4.2.1 Statistics on Income and Living Conditions

Our principal source of data is the Statistics on Income and Living Conditions (SILC), a large household survey carried out by the Czech Statistical Office each year since 2006. It has to be carried out because of European legislation and it is also partly financed by the EU. It contains individual characteristics of all household members, detailed information on various sources of income, hours of labour, facilities available in the household and housing costs. Selection of surveyed households is done by the method of two-stage random selection where in the first stage counting districts are randomly selected and in the second stage households are randomly selected inside the selected districts. The number of observations in each region is proportional to the region's size. Ideally, such a survey should offer a representative sample but due to a significant degree of non-response[30], the sample underrepresents households of the self-employed, the unemployed and people living in big cities, whereas in overrepresents households of pensioners and of people living in detached houses. While the Office corrects the sample when calculating agregate results, we work with the original uncorrected household-level data.

So far, the Czech SILC has been carried out for years 2005, 2006 and 2007, with 4351, 7483 and 9675 surveyed households respectively. During the latter two years, interviewers partly revisited the households from the previous year, partly visited new households. For the purpose of our estimation, we treat all observation as separate households and pool them into one large sample. Then we choose two subsamples of the whole sample. The first one contains households with two working-age adults[31] which form complete families, both with and without children, and where neither the

[30] In cases where a household could not be surveyed for some reason, the interviewer was not allowed to choose a different one instead.

[31] We define working-age adults as those family members who are neither children nor non-working pensioners. Children are in this context defined as children of pre-school age or those attending an elementary school, a secondary school or a university, with the maximum age limit of 25.

head of the household[32] nor its spouse are non-working pensioners. The second one contains households with only one working-age adult who is not a non-working pensioner.

As our representation of the total monetary income we use a corresponding variable which contains all kinds of labour, transfer and capital income. This variable is used to approximate the total monetary expenditure, which implies an assumption that there are no savings in place or alternatively that savings can be treated as one of the goods contained in "other goods". To receive hourly wages of the head of household and of its spouse, we divide the total measure of labour income[33] by hours worked, which are sum of hours worked in the main and additional occupation. We choose the time endowment to be 100 hours[34] a week and we define leisure hours as the time endowment minus hours of work. Then, to get our measure of total budget, we sum the total monetary income with the hours of leisure times hourly wage.

Not every working person worked for all twelve months of the examined year. Assuming that it did would mean that we would divide income earned in a part of the year by number of weeks in the whole year, which would lead to underestimated wages for some households. We correct for this using the SILC variable containing number of months worked.

In addition to the variables mentioned above, SILC also includes all necessary household-specific characteristics such as region, size of settlement and demographic information on household members.

One shortcoming of the SILC is its unclear location in time. Survey for a certain year always takes place in spring of the following year and the variables are defined over periods of differing length and location in time. We overcome the problems with differing length of reference periods simply so that we divide the period by the number of days it refers to and multiply it with seven to receive weekly data. A more serious problem is the position of reference periods in time. While income data and expenditure on solid fuels refer to the previous year, the demographic characteristics and hours worked, as well as monthly payments on energy, refer to the date of interview. This

[32] The SILC sets the man to be a head of household in complete families. In case of non-complete families and non-family households, the head of the family is set according to employment status and level of income.
[33] Into labour income we include incomes from both employment and self-employment from which we substract the income tax and social insurance contributions paid by a person.
[34] The highest number of hours worked in our sample is 99 hours a week. We can make an arbitrary choice over the time endowment because Alderman and Sahn (1993) and West and Williams (2007) have shown that such choice does not have a significant impact on results.

raises serious questions about usability of the data for estimation of a demand system. However, first, it seems reasonable to assume that people think about the past year in light of their current situation and thus the information on all variables is connected by being communicated at the same point in time, second, there is no better data available for the Czech Republic; we therefore treat the data as if they all referred to the past year. For this period we also choose the energy prices, described in the following paragraph.

4.2.2 Prices

A crucial thing when trying to estimate a demand system is to obtain good data on prices. In addition to wages we need prices of price index for household energy and for other expenditure.

We receive energy prices in two steps. First we get separate price indices for electricity, natural gas, central heating and solid fuels and than we compute the overall price index as a weighted average of prices divided by sample mean prices, i.e. according to

$$p_{energ} = s_{electricity} \frac{p_{electricity}}{\overline{p}_{electricity}} + s_{gas} \frac{p_{gas}}{\overline{p}_{gas}} + s_{heating} \frac{p_{heating}}{\overline{p}_{heating}} + s_{solid} \frac{p_{solid}}{\overline{p}_{solid}} \ , \tag{43}$$

where s_i is household specific share of an energy type in household's total expenditure on energy, p_i is price of an energy type and $\overline{p}_i$ is sample mean of its price.

Our data for electricity come from the Czech Energy Regulatory Office and three energy suppliers – CEZ, PRE and E.ON. We miss information on which tariff each household uses, therefore for each supplier, we calculate a mean price of the six main electricity tariffs which are available for all three years that we examine. Than we link prices to households according to year and supplier that operates in the household's region. As in case of natural gas, there is an old division of the country into eight regions linked to specific suppliers, whereas SILC survey works with the current system of 14 regions. We use a convertor table from the 8-region system (KROK) into the 14 region system (NUTS) provided by the Czech Statistical Office to allocate households into the right regions.

Our prices of natural gas also come from the Energy Regulatory Office. Household's gas bills consist of two parts: a fixed monthly payment and a price per MWh consumed. Unfortunately, our analysis is complicated by the fact that the price household pays depends on the amount of gas it consumes. It is the lower the more it consumes. We tried to overcome this problem by taking the natural gas expenditure of each household, substracting a fixed payment[35] and dividing the expenditure by a price per MWh. This provided us with an estimate of the MWh's consumed by the household and the consumption interval the household belonged to. Then, we gave each household a price according to its region, year of SILC and consumption interval. When we estimated a model using this price, we got surprisingly high and significant estimates of energy price parameters. These results were nevertheless fully pulled by endogenous variability in gas prices due to different tariffs. We tried to unambiguously use the lowest tariff, used by a large majority of households, instead and the strong estimates disappeared. In our main estimates we use the latter gas price despite the fact that it has detrimental effect on significance of some of our parameters. Still this is better than to have as an important regressor variable which depends on our response variable rather than explains it.

Our data on price of central heating and hot water come once more from the Energy Regulatory Office. For each year and region, they are obtained as weighted average of price data from individual heating stations, weighted by GJ produced.

Finally, we have not found a suitable region-specific data on prices of solid fuels, nor is it clear prices of which solid fuel to use. We use average a nation-wide price index of lignit provided by the Czech Statistical Office as an instrument which should not have negative impact on our results as first lignit is still the most widely used solid fuel and second only a small share of households in our sample consume positive amount of it.

We also need a measure of prices of commodities other than energy. For this purpose we use decomposed consumer price index statistics from the Czech Statistical Office, from which we calculate an overall price index where only energy prices are excluded.

4.2.3 Temperatures

An important variable when modeling demand for household energy sources is temperature. For our purpose, we use region specific data on deviations of monthly temperatures from monthly averages in period 1961-1990. Because temperatures during warm parts of the year are not relevant here, we work with averages of deviations in January, February, March, April, November and December of each year.

[35] We substract the fixed payment corresponding to the second lowest interval of consumption because it corresponds to the expenditure by a median natural gas consuming household. The price used to divide the expenditure corresponds to the second lowest interval of consumption, too.

4.2.4 Unemployment

Finally, labour supply may be influenced by regional unemployment levels. That is why we use yearly regional unemployment rates published by the Czech Statistical Office. We try to use the rates during estimation of probits on decision whether to work and also when estimating the AIDS. However, in the former case regional dummies well substitute for unemployment rates, in the latter case the rates are not significant. Consequently we do not use the unemployment rates during the estimation presented further in this thesis.

4.2.5 Sample size

Our whole pooled sample contains 21509 households. We nevertheless do not use all observations. Firstly, we only use households with one or two working-age adults, which basically excludes households run by pensioners and also those with more than two adults. Secondly, we exclude households where someone has a secondary job because for these jobs we do not have data on month worked which could result in underestimated wages, as we explain earlier in this chapter. Thirdly, we do not consider households with reported zero expenditure on energy. We do so because these are clearly special cases where reported zero consumption does not mean actual zero consumption of energy but for instance living in a house with another family which pays for all the energy consumed by both households. Fourthly, we exclude two-adult households where head of the family is not a man and the other person a woman. This exclusion allows us easier interpretation of results as related to "male" and "female" leisure. Finally, we exclude households where one of adults works in the army, since professional soldiers probably face different leisure constraints than other people.

When we exclude part of observations as described above, we are left with 3100 households in the one-adult sample and 5489 households in the two-adult sample. It should be noted that the first exclusion from the previous paragraph is by far the most important[36], while the condition of no second job is substantially less restrictive and the effect of all other exclusions is negligible. On these samples, we run probit models for selectivity correction. The demand system estimation then further restricts our sample to households where one or both adults work, which represents 2738 one-adult and 4079

[36] Its importance is pa
rtly caused by a disproportionally high number of retired people in the sample.

two-adult observations. Summary statistics for this final subsample are presented in Appendix A at the end of this thesis.

4.3 Estimation and results

4.3.1 Probit estimation

We start our estimation with probits on the decision whether to work or not. We estimate the models separately for one- and two-adult households and for men and women. Results of the estimation are shown in Appendix B. We will discuss one-adult households first. More estimated parameters are significant in case of females. In males' case, we can only say that probability that a man works increases with education, number of other people in household and size of settlement where the household lives. It is also significantly higher for men living in Prague and Plzen Region and lower from men from Zlin Region. For women, the probability grows with age, which can be interpreted so that younger women have children whereas later, as children grow older and leave parents' household, women have more time for their career. This idea is further validated by the fact that probability of working decreases with number of children in the household, substantially more so when the children are younger than two years. Similarly to men, women are more likely to work if they have higher education. Finally, in case of women, several other regions, in addition to Prague and Plzen regions, have significant impact on probability of working.

When we look at two-adult households, we get a similar picture as above. Women's probability of working increases with age and education and decreases with number of children, again especially those less than two years old. The same holds for men, only number of children is not significant for them. All in all, the obtained results seem quite plausible and in line with common sense.

Previous research on joint determination of consumption and leisure decisions suggests that there might exist a substantial impact of constraints from the side of labour demand. That is why we try to include year and region specific unemployment rate in our equations. However, the related parameter estimate is not significant in any of our probit equations and we therefore do not use unemployment rate as regressor in the final estimates presented here.

Finally it should be said that the probit estimation might be affected by a relatively low of number of observations with adults who do not work[37]. This is especially true for males in both samples, where only 7% of single men and 2.5% of married men do not work. At the same time, 16% of single women and 24% of married women do not work. This is also the reason why we had to exclude number of children under 2 and Liberec region from probit equations for single men. There were very few observations with little children or from Liberec region in our sample, resulting in extremely high standard errors.

4.3.2 AIDS estimation

Having estimated probits, we can proceed to estimation of the demand system. Price of energy, as described above, is endogenous because it depends on household specific shares of various energy types on the total energy expenditure. Similarly, the real income is endogenous because shares used to construct the price index depend on household's decisions what to consume. To prevent the potential bias, we instrument energy price and real income by corresponding terms where sample mean shares are used instead of household specific ones.

All of our estimated equations have the same regressors, therefore disturbances might be correlated. An appropriate method for this situation would be seemingly unrelated regressions. At the same time we are using instrumental variables and this leads us to our actual estimation method - itirated three stage least squares (3SLS). This method puts together two-stage least squares and seemingly unrelated regression, allowing us to instrument for energy prices and real income, impose restrictions on parameter estimates and subsequently estimate our equations simultaneously. As total budget shares add up to unity, we avoid singularity by excluding the equation for expenditure on other goods. Parameters from this equation can be obtained from other estimated parameters thanks to adding up, homogenity a symmetry restrictions mentioned above. We use some of these parameters during computation of elasticities but we do not report them explicitly here, because they are not at the center of our interest.

Results of the estimation are presented in Table 1 and Table 2. The crucial price and income parameters are estimated quite precisely, with the exception of energy share

[37] For sake of brevity, in this chapter we will use words 'single' and 'married' for men and women from one- and two-adult households respectively. However, we are aware of the fact that couples living together need not be married, as well as people living alone may have a partner.

Table 1
One-adult household AIDS estimation results

	Estimate	Standard Error	Pr > |t|
Energy share			
Intercept	0.886	0.174	<.0001
Sex	0.001	0.002	0.752
Age	0.001	0.001	0.365
Age squared	0.000	0.000	0.590
Education	0.000	0.001	0.445
# of children under 2	0.023	0.016	0.155
# of children between 3 and 15	0.005	0.002	0.022
# of other household members	0.009	0.002	<.0001
Size of town/village	-0.006	0.000	<.0001
Temperature	-0.001	0.001	0.432
ln(energy price index)	0.051	0.034	0.135
ln(price of other consumption)	-0.029	0.034	0.403
ln(net wage per hour)	-0.023	0.004	<.0001
ln(total real income)	-0.064	0.009	<.0001
Inverse Mills ratio	-0.017	0.008	0.044
Leisure share			
Intercept	4.344	0.130	<.0001
Sex	0.031	0.003	<.0001
Age	-0.005	0.001	<.0001
Age squared	0.000	0.000	<.0001
Education	-0.007	0.001	<.0001
# of children under 2	0.001	0.025	0.965
# of children between 3 and 15	-0.007	0.004	0.038
# of other household members	-0.012	0.003	0.000
Size of town/village	-0.001	0.001	0.046
Temperature	-0.001	0.001	0.615
ln(energy price index)	-0.023	0.004	<.0001
ln(price of other consumption)	-0.199	0.007	<.0001
ln(net wage per hour)	0.221	0.006	<.0001
ln(total real income)	-0.417	0.014	<.0001
Inverse Mills ratio	0.017	0.013	0.196

equation for one-adult households, where parameters related to energy price and other expenditure price are insignificant. Inverse Mills ratios are not significant in one-adult leisure share equation but they are significant in both two-adult leisure share equations for both sexes, implying that would be a danger of a selection bias if it stayed uncorrected. Surprisingly, temperature is not significant explanatory variable in any equation except for leisure of married females. The reason for that is probably that average temperatures vary in time more than between regions and thus the estimation is affected by the fact that we have data for only three years.

Table 2
Two-adult household AIDS estimation results

	Estimate	Standard Error	Pr > |t|
Energy share			
Intercept	0.8023	0.109109	<.0001
Male age	0.000197	0.000495	0.6904
Male age squared	-9.05E-07	5.65E-06	0.8728
Female age	0.001439	0.00059	0.0148
Female age squared	-0.00002	7.10E-06	0.0249
Male education	0.000901	0.000281	0.0013
Female education	0.000597	0.000332	0.0727
# of children under 2	-0.01011	0.007206	0.1606
# of children between 3 and 15	0.000222	0.000973	0.8197
# of other household members	0.00403	0.000662	<.0001
Size of town/village	0.000074	0.000172	0.6659
Temperature	-0.00054	0.000425	0.2049
ln(energy price index)	0.051776	0.012361	<.0001
ln(price of other consumption)	-0.02933	0.012273	0.0169
ln(net male wage per hour)	-0.01329	0.002621	<.0001
ln(net female wage per hour)	-0.00915	0.001723	<.0001
lntri	-0.05936	0.010458	<.0001
Inverse Mills ratio (males)	-0.00928	0.00995	0.3509
Inverse Mills ration (females)	0.010416	0.005362	0.0522
Male leisure share			
Intercept	2.977416	0.190344	<.0001
Male age	-0.00168	0.001109	0.1304
Male age squared	0.000029	0.000013	0.0237
Female age	0.00179	0.001307	0.1709
Female age squared	-0.00003	0.000016	0.0763
Male education	-0.00273	0.000628	<.0001
Female education	0.002229	0.00074	0.0026
# of children under 2	-0.03808	0.015964	0.0171
# of children between 3 and 15	-0.00427	0.002126	0.0444
# of other household members	-0.00803	0.001421	<.0001
Size of town/village	-0.00108	0.000385	0.005
Temperature	0.000131	0.000632	0.8361
ln(energy price index)	-0.01329	0.002621	<.0001
ln(price of other consumption)	-0.12642	0.007111	<.0001
ln(net male wage per hour)	0.213366	0.005058	<.0001
ln(net female wage per hour)	-0.07366	0.002737	<.0001
lntri	-0.28209	0.019144	<.0001
Inverse Mills ratio (males)	0.087331	0.020895	<.0001
Inverse Mills ration (females)	0.0242	0.011878	0.0417
Female leisure share			
Intercept	1.879364	0.114095	<.0001
Male age	0.000939	0.00071	0.1862
Male age squared	-8.25E-06	8.08E-06	0.3077
Female age	-0.00195	0.00084	0.0202

Female age squared	0.000022	0.00001	0.0278
Male education	-0.00034	0.000404	0.4036
Female education	-0.00106	0.000479	0.0274
# of children under 2	0.033726	0.010235	0.001
# of children between 3 and 15	0.004293	0.001366	0.0017
# of other household members	-0.00332	0.000908	0.0003
Size of town/village	-0.0009	0.000247	0.0003
Temperature	-0.00082	0.000405	0.0435
ln(energy price index)	-0.00915	0.001723	<.0001
ln(price of other consumption)	-0.08221	0.004419	<.0001
ln(net male wage per hour)	-0.07366	0.002737	<.0001
ln(net female wage per hour)	0.165021	0.002142	<.0001
lntri	-0.16296	0.01145	<.0001
Inverse Mills ratio (males)	0.029872	0.013406	0.0259
Inverse Mills ration (females)	-0.01503	0.007617	0.0485

Household specific parameters such as age and education only matter for leisure shares. Other things equal, people consume less leisure if they are older, better educated or live in larger towns. An interesting pattern appears for two-adult households. While female leisure consumption significantly increases with number of children, exactly the opposite is true for male leisure consumption. It suggests that the traditional model of family is to some extent still present. When people have children, women often work less and take care of them while men work more to support the family in financial terms.

We are also able to compare our 3SLS results with 2SLS estimates estimated equation by equation without any cross-restrictions on parameters, which are not reported here. In 3SLS we imposed symmetry restrictions on cross-price parameters between leisure and energy and leisure and other goods. We can see that estimates of

these symmetric parameters are much closer to 2SLS wage terms from energy or other goods equations than to 2SLS price terms from leisure equations. This is in line with the fact that we have substantial variation in wages but little variation in energy and other goods prices. Symmetry restriction imposed, the estimation then naturally draws more information from wage variation then price variation and estimates look according to that.

We try to set time endowment to be alternatively 80 or 120 hours a week and we find that this has only a small impact on parameter estimates, which is in line with results of other authors cited above.

4.3.3 Calculation of elasticities

AIDS is a demand system where neither derivatives of demands with respect to prices or income nor elasticities are directly estimated. Instead, we must compute them from the estimated parameters. West and Williams (2007) show that if we take derivatives of share equations (39) with respect to price, arrange terms and transform shares into quantities, we obtain uncompensated price derivatives. Then dividing derivatives by appropriate quantity and multiplying them by appropriate price, we get uncompensated price elasticities as

$$e_{ji}^{h}=\frac{1}{s_{j}^{h}}\left[\gamma_{ji}-\beta_{j}\frac{s_{i}^{h}+\sum_{k=1}^{J+2}\gamma_{ki}\log\left(p_{i_i}^{h}/\overline{p}_{i}\right)}{1+\sum_{k=1}^{J+2}\beta_{k}\log\left(p_{i}^{h}/\overline{p}_{i}\right)}\right]-\delta_{ji}, \tag{44}$$

where e_{ji}^{h} is uncompensated elasticity of commodity j with respect to price of commodity i and δ_{ji} is a Kronecker delta, where $\delta_{ji}=1$ if $i=j$ and $\delta_{ji}=0$ otherwise. However, these formulas are not correct when i refers to wage, or price of leisure. It is so because change in price of leisure does not affect the real income term of a share equation only by increasing prices but also by decreasing the nominal value of the total income. We therefore write

$$e_{ji}^{h}=\frac{1}{s_{j}^{h}}\left[\gamma_{ji}+\beta_{j}\frac{Tp_{i}^{h}}{Y^{h}}-\beta_{j}\frac{s_{i}^{h}+\sum_{k=1}^{J+2}\gamma_{ki}\log\left(p_{i_i}^{h}/\overline{p}_{i}\right)}{1+\sum_{k=1}^{J+2}\beta_{k}\log\left(p_{i}^{h}/\overline{p}_{i}\right)}\right]+\frac{Tp_{i}^{h}}{Y^{h}}-\delta_{ji} \tag{45}$$

if $i=J+1$ or $i=J+2$, where term $\frac{Tp_{i}^{h}}{Y^{h}}$ may be interpreted as the earning potential of an adult household member as a share of the total budget. Income elasticity can be computed as

$$e_{jY}^{h}=\frac{1}{s_{j}^{h}}\left[\frac{\beta_{j}}{1+\sum_{k=1}^{J+2}\beta_{k}\log\left(p_{i}^{h}/\overline{p}_{i}\right)}\right]+1, \tag{46}$$

where η_{jY}^{h} is elasticity of commodity j with respect to income. Finally, we can calculate compensated price elasticities according to $e_{C\,ji}^{\,h}=e_{ji}^{h}+s_{i}^{h}e_{jY}^{h}$, which after a simple rearranging of terms gives

$$e_{C\,ji}^{\ h} = \frac{1}{s_j^h}\left[\gamma_{ji} - \beta_j \frac{\sum_{k=1}^{J+2} \gamma_{ki} \log\left(p_{i_i}^h / \overline{p}_i\right)}{1 + \sum_{k=1}^{J+2} \beta_k \log\left(p_i^h / \overline{p}_i\right)}\right] - \delta_{ji} \text{ for } i = 1, \ldots, J+2\,. \tag{47}$$

Notice that the formulas that we have just presented refer to household specific elasticities. To be able to evaluate aggregate effects, we need some measure of aggregate elasticities. We use two such measures in this thesis. The first one is elasticity evaluated at mean prices, shares and income. An advantage of this measure is that SAS allows us to estimate it together with 3SLS using a non-linear procedure[38] and provides us with approximate standard errors, so that we learn how precisely the elasticities are estimated. Its serious disadvantage is that it does not inform us on what things look like for households with some variables far from sample means. We shall refer to this measure as elasticities in sample means.

Another possibility is to aggregate elasticities according to

$$e_{ji} = \overline{p}_i \sum_h \frac{\partial q_j^h}{\partial p_i^h} \Big/ \sum_h q_j^h\,, \tag{48}$$

where $\sum_h \frac{\partial q_j^h}{\partial p_i^h}$ is price derivative of commodity j with respect to price of commodity i and q_j^h is a quantity index of commodity j obtained as a ratio of expenditure on j to its price. This approach provides us with a reasonable measure of the aggregate affects. Unfortunately, we are not able to obtain standard errors of elasticity estimates in this case, so that we are not sure whether our estimates are really accurate. This second measure will be referred to as aggregated elasticities.

4.3.4 Elasticities (results)

Estimated elasticities are shown in Table 3. For one-adult households, all reported elasticities in means are significant with the exception of those with respect to price of energy and with the exception of the income elasticity of energy. Compensated elasticity of leisure with respect to price of energy is significant, too. In case of two-adult households, again all uncompensated elasticities are significant, except for those with respect to price of energy. The results are less satisfying as far as income and

[38] Our estimates presented above come from a procedure dedicated to estimation of systems of linear equations. However, this procedure does not let us estimate elasticities. Therefore we use the procedure primarily intended for non-linear models, even though we use it for linear estimation. Difference between estimates produced by the two procedures is negligible.

Table 3
One-adult household elasticities

	Elasticities in means	Approx Std Error	Approx Pr > |t|	Aggregated elasticities
Uncompensated price elasticities				
e11	-0.1798	0.5046	0.7216	-0.0512
e13	0.2149	0.0341	<.0001	0.1978
e31	0.0106	0.0075	0.1586	0.0084
e23	0.9007	0.0101	<.0001	0.4194
e32	-0.0564	0.0099	<.0001	-0.0460
e33	0.0296	0.0067	<.0001	0.0430
Compensated price elasticities				
ec11	-0.1760	0.5052	0.7275	-0.0156
ec13	0.1926	0.0576	0.0008	0.1798
ec31	0.0247	0.0074	0.0008	0.0242
ec23	0.0367	0.0170	0.0314	0.0314
ec32	0.0282	0.0131	0.0314	0.0199
ec33	-0.0529	0.0113	<.0001	0.0219
Income elasticities				
e1y	0.0563	0.1328	0.6717	0.0870
e3y	0.2088	0.0260	<.0001	0.3101

1 = energy, 2 = other expenditure, 3 = male leisure (leisure for one-adult households, 4 = female leisure

compensated price elasticities for two-adult households are concerned. Here, only own-price elasticity of female leisure, both elasticities between female leisure and other expenditure and income elasticity of female leisure are significant.

If we compare elasticities in means and aggregated elasticities, we can see that in most cases they share the same sign and are of roughly same magnitude. There is one exception nevertheless, this exception being own-price compensated elasticities of demand for leisure, for both types of household and for both males and females. Consumer theory predicts that, similarly to compensated elasticities of demand for any another good, they should be negative. This is true for elasticities in sample means[39] but not so for aggregated elasticities, which are in all three cases positive and substantially different from elasticities in sample means. We try several alternations of the model, but this paradox is robust to all of them including changes in time endowments and holds even when the endogenous price index discussed above is used.

Otherwise, our results seem plausible from the theoretical point view. Theory says that if good A is a Hicksian substitute (complement) for good B, good B must be a

[39] Compensated sample means own-price elasticity of demand for married male leisure was calculated to be positive, but it is not significantly different from zero.

Table 4
Two-adult household elasticities

	Elasticities in means	Approx Std Error	Approx Pr > |t|	Aggregated elasticities
Uncompensated price elasticities				
e11	0.2733	0.2880	0.3426	0.4301
e13	-0.1078	0.0211	<.0001	-0.2039
e31	-0.0041	0.0085	0.6301	-0.0059
e23	0.5821	0.0061	<.0001	0.5936
e32	-0.0473	0.0120	<.0001	-0.0493
e33	0.0236	0.0064	0.0002	0.0741
e14	-0.0250	0.0234	0.2862	-0.1041
e41	-0.0087	0.0067	0.1959	-0.0107
e24	0.4219	0.0066	<.0001	0.4429
e42	-0.0690	0.0093	<.0001	-0.0608
e44	-0.0375	0.0055	<.0001	0.2847
Compensated price elasticities				
ec11	0.2566	0.2898	0.3760	0.4205
ec13	-0.0053	0.0615	0.9319	-0.0868
ec31	-0.0007	0.0086	0.9319	-0.0032
ec23	-0.0123	0.0179	0.4913	-0.0005
ec32	-0.0160	0.0232	0.4913	-0.0354
ec33	0.0029	0.0165	0.8612	0.1196
ec14	0.0397	0.0404	0.3260	-0.0234
ec41	0.0067	0.0068	0.3260	0.0038
ec24	0.0471	0.0111	<.0001	0.0501
ec42	0.0735	0.0174	<.0001	0.0500
ec44	-0.0968	0.0084	<.0001	0.2447
Income elasticities				
e1y	-0.3919	0.2452	0.1100	-0.4083
e3y	0.0790	0.0625	0.2060	0.0927
e4y	0.3592	0.0450	<.0001	0.3957

1 = energy, 2 = other expenditure, 3 = male leisure (leisure for one-adult households, 4 = female leisure

Hicksian substitute (complement) for good A. Indeed, all pairs of corresponding compensated cross-price elasticities share the same sign. Furthermore, other things equal, single adults consume more leisure as they get richer and less leisure as their compensated wage grows. In case of two-adult households, results differ for males and females. While male leisure compensated own-price elasticity as well as income elasticities are not significantly different from zero and uncompensated own-price elasticity is positive, female own-price and income elasticities are all significantly negative. In other words, men with families work a lot[40] no matter what their income

[40] The second table in Appendix A shows that married men work on average about four hours a week more than married women.

and wage are or more as their wage falls[41], whereas women choose to work only when they are motivated by low income or high wage.

From leisure demand own-price elasticities, we can easily calculate elasticities of labour supply. We do so because this allows us to compare our results to those obtained by other researchers. Labour supply elasticities are reported in Table 5. For example West and Williams (2007), who use a model similar to ours, arrive at uncompensated and compensated elasticity values 0.04 and 0.35 respectively for one-adult households, 0.06 and 0.09 for married men and 0.24 and 0.34 for married women. Our results are consistently below values estimated by West and Williams and also below values reported in surveys by Fuchs et al. (1998), Blunderll and MaCurdy (1999) and Evers et al. (2008). On the other hand, they are in line with the previous research in the sense that uncompensated elasticities are lower than compensated ones and that elasticities are higher for women than for men.

Table 5
Labour supply elasticities in means

	Uncompensated	Compensated
One-adult household	-0.0405	0.0725
Approx Std Error	*0.0091*	*0.0154*
Two-adult (men)	-0.0289	-0.0024
Approx Std Error	*0.0078*	*0.0202*
Two-adult (women)	0.0556	0.1437
Approx Std Error	*0.0081*	*0.0125*

Finally, let us analyze cross-price elasticities between leisure on one side and energy and other expenditure on the other side. Parry (1995), whose model we describe in the first chapter, works with compensated supply and demand curves and crucial position in his analysis have Hicksian elasticities of demand for compared commodities with respect to price of leisure. In case of one-adult households values of these are 0.193 and 0.037 for energy and other expenditure respectively. Given the estimated standard errors and assumptions of Parry's model, leisure is stronger than average substitute for leisure, the tax interaction effect is always stronger than the revenue-recycling effect, the strong double dividend hypothesis does not hold and the optimal tax lies below the Pigouvian

[41] The positive uncompensated married men's leisure demand elasticity speaks for the famous hypothesis of backward bended labour supply.

rate.[42] In case of two-adult households compensated elasticities with respect to male wage are insignificantly negative both for energy and other expenditure, as well as insignificantly different from each other so that we cannot reject hypothesis that energy is an average substitute for leisure. Corresponding values for female wage are positive but again insignificantly different for energy and other expenditure.

Compared to the previously discussed compensated elasticities with respect to price of leisure, a more straightforward answer to our questions can be found in uncompensated elasticites of demand for leisure with respect to price of energy or other expenditure, as they directly address the question on what happens to the supply of leisure when we impose a tax on energy. As far as one-adult households are concerned, such elasticity is negative for other expenditure and insignificantly positive for energy. On any reasonable significance level we can reject hypothesis that the two elasticities are the same. In two-adult case, all uncompensated cross-price elasticities of leisure demand are negative, even though only those with respect to price of other expenditure significantly. Elasticities with respect to price of other expenditure are again significantly below those with respect to price of energy. Once more, our data suggest that energy is stronger substitute or weaker complement to leisure, both male and female, implying that the optimal tax is lower than marginal environmental damage and the strong double dividend does not hold.

Finally it should be said that all what is mentioned above holds for aggregated elasticities as well, which means that our results are not based only on a specific point of data but have relevance for the sample as a whole.

A difficult question is how to explain our results saying that energy is a comparable or stronger substitute for leisure than other expenditure. A common sense would suggest that the contrary is true because people need to be at home to run electrical appliances and they should also spend more energy on heating if they spend more time at home. One possible solution to the puzzle is that our results are biased because of an omitted variable correlated with our regressors. We are nevertheless not able to tell which variable it might be, because if we were, we would have already tried to include it into our AIDS estimation. An alternative explanation might be that people who spend more time at home pay more attention to economies of energy and probably do some

[42] Please note that all results presented here refer only to the context of taxes on household energy consumption and to the Czech Republic. Results may be completely different in other areas or other parts of the world, as shown for example by West and Williams (2007).

activities themselves instead of using electric appliances. However, we perceive such explanation as too specific and therefore unsatisfying with respect to a pattern that appears throughout the whole sample.

5 Conclusions

The primary topic of this thesis is interaction between environmental taxes and supply of labour. An environmental tax raises revenues that can be used to cut labour taxes and, given positive labour supply elasticity, increase amount of labour supplied. At the same time, however, when a tax is imposed, prices grow, real wages diminish and labour supply contracts accordingly. We call the two effects revenue-recycling and tax-interaction effect respectively and present a model showing analytically that under the assumption of preferences separable in leisure the latter effect is stronger. We show what implications of this result are for the level of the optimal environmental tax and for the double dividend hypothesis. Then we study the possibility that preferences are not separable and demonstrate that if the taxed commodity is a sufficiently week substitute for leisure, the results may be completely different from those in case of separability.

We argue that it would be useful to know the degree of substitutability between the taxed goods and leisure. Natural measures of this degree are cross-elasticities which can be obtained by estimation of demand systems incorporating leisure as an extra good. We review several studies that attempt to estimate such a system and discuss the type of data they use, their models and their results.

In the second half of the thesis we estimate an augmented Deaton and Muellbauer's (1980a) Almost Ideal Demand System for household energy, other expenditure and leisure. We use detailed household level survey data from the Statistics on Income and Living Conditions for the Czech Republic from years 2005, 2006 and 2007. From estimated parameters of the model, we calculate both Marshallian and Hicksian elasticities using two different methods. With the first method we calculate the elasticities at sample means and in addition we obtain their standard errors. With the second method, we calculate elasticities separately for each household and only then we aggregate them. This method gives us a better measure of the aggregate effects but does not allow us to obtain standard errors. We find that both methods produce similar results with the exception of own-price elasticities of leisure, where the latter method gives results implausible from the theoretical point of view.

Unlike what common sense would suggest, we discover that household energy is not a weaker-than-average substitute for leisure and it may even be its stronger than average substitute. If our estimates are correct, it means that in case of residential energy consumption the strong double dividend hypothesis does not hold and the optimal tax should be smaller than the marginal environmental damage arising from production and consumption of the energy.

We are aware of two main limitations of our estimates, both of which are connected with the data we use. The first limitation stems from the fact that only three years of data are available so far. Consequently, we have only a small variation in prices of energy and other expenditure, which prevents us from precise estimation of certain parameters. Moreover, longer series of data would allow us to include region and year fixed effects which would make our principal results more robust to omitted variables correlated both with regions on one side and wages, prices or income on the other. Good news is that a new SILC survey is carried out each year and there should be therefore more data available in future, which will allow more precise estimates.

The second drawback of the data is present in the fact that different variables in each year's SILC refer to different time periods. While some of them refer to the whole year, other refer to the date of the interview, which takes place in spring of the following year. This limitation may be more serious than the first one since it is inherent in the construction of the SILC survey and will become less serious only when substantially longer time-series become available. On the other hand, it seems reasonable to assume that there is a time gap between a change in price and consumers' reaction and that the gap might be especially large in case of energy. Measuring prices in the survey year and energy consumption a few months later might therefore be more correct than measuring both in the same time.

Finally, we see a lot of space for future research in the area that we examine in this thesis. Firstly, it would certainly be useful to replicate our estimation when more or better data are available. Secondly, it is possible to estimate a similar system with other commodities, for example gasoline, or to decompose our residential energy commodity into a number of individual energy sources. Thirdly, it would be very helpful to find standard errors for elasticities computed with our second method. This could be done with the bootstraping procedure. Last but not least, optimal taxes could be estimated using our estimates of relevant elasticities.

6 References

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7 APPENDIX A

A.1 Summary statistics (one adult, works)

Variable	Mean	Standard deviation
# of observations	2738	-
Total energy expenditure per week*	489.4	335.30
Electricity expenditure per week	194.3	141.36
Natural gas expenditure per week	127.1	177.88
Central heating expenditure per week	136.0	240.65
Solid fuels expenditure per week	32.0	82.76
Total money income per week	3964.4	2623.49
Hours of work per week**	42.2	7.87
Net wage per hour	78.0	61.37
Energy share of total income	7%	0.05
Other goods share of total income	41%	0.10
Leisure share of total income	53%	0.10
Share of women	50%	0.50
Age	41.9	11.27
# of children under 2	0.01	0.07
# of children between 3 and 15	0.20	0.52
# of other household members***	0.30	0.55
Education - w/o high school diploma	15%	0.36
Education - with high school diploma	67%	0.47
Education - university	6%	0.23
Village (up to 499 people)	6%	0.23
Small town (500-9999 people)	34%	0.47
Medium town (10000-99999 people)	37%	0.48
Large town (more than 100000 people)	24%	0.43
Prague Region	11%	0.32
Central Bohemian Region	9%	0.28
South Bohemian Region	6%	0.24
Plzen Region	8%	0.28
Karlovy Vary Region	5%	0.21
Usti nad Labem Region	8%	0.27
Liberec Region	4%	0.20
Hradec Kralove Region	6%	0.23
Pardubice Region	4%	0.19
Vysocina Region	4%	0.18
South Moravian Region	11%	0.31
Olomouc Region	7%	0.26
Zlin Region	5%	0.22
Moravian-Silesian Region	12%	0.33

*All monetary variables are measured in Czech Korunas.
**All personal characteristics refer to the only working-age adult
***Other household members are those who are neither working-age adults nor children under 15.

A.2 Summary statistics (two adults, both work)

Variable	Mean	Standard deviation
# of observations	4079	-
Total energy expenditure per week*	623.78	242.89
Electricity expenditure per week	263.30	164.65
Natural gas expenditure per week	180.82	231.04
Central heating expenditure per week	133.85	169.74
Solid fuels expenditure per week	45.81	105.01
Total money income per week	7176.21	3206.06
Male hours of work per week**	44.96	8.46
Female hours of work per week	40.26	6.83
Male wage per hour	93.95	88.96
Female net wage per hour	69.35	38.90
Energy share of total income	4%	0.03
Other goods share of total income	40%	0.07
Male leisure share of total income	31%	0.08
Female leisure share of total income	25%	0.07
Male age	42.76	9.69
Female age	40.18	9.53
# of children under 2	0.03	0.18
# of children between 3 and 15	0.71	0.86
# of other household members***	0.43	0.70
Male education - w/o high school diploma	12%	0.33
Male education - with high school diploma	69%	0.46
Male education - university	6%	0.23
Female education - w/o high school diploma	12%	0.32
Female education - with high school diploma	71%	0.45
Female education - university	6%	0.24
Village (up to 499 people)	7%	0.26
Small town (500-9999 people)	38%	0.49
Medium town (10000-99999 people)	35%	0.48
Large town (more than 100000 people)	19%	0.39
Prague Region	10%	0.30
Central Bohemian Region	10%	0.30
South Bohemian Region	7%	0.25
Plzen Region	6%	0.24
Karlovy Vary Region	3%	0.17
Usti nad Labem Region	7%	0.25
Liberec Region	5%	0.22
Hradec Kralove Region	5%	0.22
Pardubice Region	5%	0.23
Vysocina Region	6%	0.23
South Moravian Region	9%	0.29
Olomouc Region	7%	0.26
Zlin Region	7%	0.25
Moravian-Silesian Region	13%	0.34

*All monetary variables are measured in Czech Korunas.
**All personal characteristics refer to working-age adults.
***Other household members are those who are neither working-age adults nor children under 15.

8 APPENDIX B

B.1 Probit estimation results (one adult)

	Estimate	Standard Error	Pr > ChiSq
Males			
Intercept	2.01	0.79	0.0111
Age	0.01	0.03	0.7282
Age squared	0.00	0.00	0.4317
Education	0.12	0.04	0.0018
Czech nationality dummy	-0.19	0.34	0.5857
# of children between 3 and 15	-0.32	0.17	0.0523
# of other household members*	0.38	0.14	0.0078
Size town/village	-0.12	0.03	0.0003
Prague Region	0.58	0.22	0.0091
Central Bohemian Region	0.17	0.22	0.4340
South Bohemian Region	0.20	0.27	0.4600
Plzen Region	0.88	0.42	0.0366
Karlovy Vary Region	-0.26	0.30	0.3761
Usti nad Labem Region	0.12	0.21	0.5760
Hradec Kralove Region	0.24	0.31	0.4396
Pardubice Region	-0.23	0.23	0.3055
Vysocina Region	-0.02	0.29	0.9460
South Moravian Region	-0.04	0.22	0.8742
Olomouc Region	-0.21	0.23	0.3633
Zlin Region	-0.71	0.22	0.0014

Females			
Intercept	-3.61	0.66	<.0001
Age	0.13	0.03	<.0001
Age squared	0.00	0.00	<.0001
Education	0.30	0.04	<.0001
Czech nationality dummy	0.54	0.25	0.0309
# of children under 2	-2.08	0.18	<.0001
# of children between 3 and 15	-0.43	0.06	<.0001
# of other household members*	0.12	0.10	0.1990
Size town/village	0.03	0.02	0.2172
Prague Region	0.65	0.23	0.0049
Central Bohemian Region	0.32	0.20	0.1205
South Bohemian Region	0.52	0.24	0.0325
Plzen Region	0.60	0.22	0.0065
Karlovy Vary Region	0.58	0.25	0.0185
Usti nad Labem Region	-0.21	0.17	0.2198
Liberec Region	0.32	0.23	0.1699
Hradec Kralove Region	0.77	0.26	0.0030
Pardubice Region	-0.09	0.23	0.7068
Vysocina Region	0.57	0.32	0.0748
South Moravian Region	0.40	0.19	0.0326
Olomouc Region	0.14	0.20	0.4659
Zlin Region	0.20	0.23	0.3775

B.2 Probit estimation results (two adults)

	Estimate	Standard Error	Pr > ChiSq
Males			
Intercept	-0.89	0.71	0.21
Age	0.08	0.03	0.02
Age squared	0.00	0.00	0.01
Education	0.19	0.03	<.0001
Czech nationality dummy	0.80	0.16	<.0001
# of children under 2	-0.04	0.10	0.65
# of children between 3 and 15	-0.07	0.05	0.15
# of other household members	-0.01	0.07	0.93
Size town/village	-0.03	0.02	0.10
Prague Region	0.80	0.23	0.00
Central Bohemian Region	0.44	0.17	0.01
South Bohemian Region	0.39	0.19	0.04
Plzen Region	0.52	0.22	0.02
Karlovy Vary Region	0.10	0.20	0.64
Usti nad Labem Region	-0.11	0.13	0.42
Liberec Region	0.27	0.19	0.17
Hradec Kralove Region	0.50	0.23	0.03
Pardubice Region	0.21	0.18	0.23
Vysocina Region	0.58	0.24	0.01
South Moravian Region	0.30	0.16	0.06
Olomouc Region	0.14	0.15	0.36
Zlin Region	0.41	0.19	0.03

Females			
Intercept	-3.24	0.44	<.0001
Age	0.19	0.02	<.0001
Age squared	0.00	0.00	<.0001
Education	0.12	0.02	<.0001
Czech nationality dummy	0.42	0.12	0.00
# of children under 2	-2.31	0.07	<.0001
# of children between 3 and 15	-0.48	0.03	<.0001
# of other household members	-0.05	0.04	0.23
Size town/village	0.02	0.01	0.12
Prague Region	0.29	0.11	0.01
Central Bohemian Region	0.30	0.10	0.00
South Bohemian Region	0.48	0.12	<.0001
Plzen Region	0.15	0.11	0.18
Karlovy Vary Region	0.20	0.15	0.18
Usti nad Labem Region	0.05	0.10	0.61
Liberec Region	0.29	0.13	0.02
Hradec Kralove Region	0.18	0.12	0.13
Pardubice Region	0.29	0.12	0.01
Vysocina Region	0.18	0.11	0.12
South Moravian Region	0.12	0.10	0.20
Olomouc Region	0.18	0.10	0.08
Zlin Region	0.10	0.11	0.34

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Akademický rok 2008/2009

TEZE BAKALÁŘSKÉ PRÁCE

Student:	Matěj Bajgar
Obor:	Ekonomie
Konzultant:	Milan Ščasný, PhD.

Garant studijního programu Vám dle zákona č. 111/1998 Sb. o vysokých školách a Studijního a zkušebního řádu UK v Praze určuje následující bakalářskou práci

Předpokládaný název BP:

Vliv změn v daňovém systému na distribuci příjmů

Charakteristika tématu, současný stav poznání, případné zvláštní metody zpracování tématu:

Změny ve zdanění práce nebo spotřeby mohou podstatně ovlivnit relativní daňovou zátěž různých skupin obyvatelstva a tím i příjmovou a mzdovou distribuci. Při modelování těchto efektů je důležité vzít v potaz, že výše a forma zdanění má vliv na reálnou mzdu a tudíž i na nabídku práce. Zkoumání tohoto faktu je ovšem ztíženo empirickými pozorováními, že substituovatelnost či komplementarita různých podsložek spotřeby vzhledem k volnému času není nezávislá na množství jiných spotřebních komodit (viz problém separability).
Tato práce má za ambici pokusit se přepovědět dopady různých daňových politik na distribuci příjmů. K tomu využije model DASMOD, vytvořený v Centru pro otázky životního prostředí UK, který obohatí o výše nastíněný problém změn v nabídce práce. K tomuto účelu bude práce obsahovat průzkum zahraniční i domácí literatury o přímých i křížových elasticitách nabídky práce.
Hlavním výstupem práce by měly být simulace různých daňových politik za pomoci zmíněného modelu aplikovaného na česká data, kde autor bude zkoumat jak jejich celkový vliv na distribuci (pomocí indexu Suits nebo Gini), tak jejich dopad na sociálně zvláště citlivé skupiny domácností.

Struktura BP:

1. Přehled literatury o a) přímé cenové elasticitě nabídky práce
   b) křížové cenové elasticitě nabídky práce
2. Popis modelu: a) popis modelu DASMOD
   b) popis rozšířeného modelu
   c) popis indexů Suits a Gini
3. Popis dat - Rodinné účty, SILC
4. Simulace vybraných scénářů: a) dopady nepřímých daní
   b) dopady přímých daní
   c) důsledky odpočtů
5. Vyhodnocení zjištěných poznatků a návrhy pro další výzkum

Seznam základních pramenů a odborné literatury:

Abbott, Michael and Orley Ashenfelter (1976): *Labour Supply, Commodity Demand and the Allocation of Time*, Review of Economic Studies, No.43, pp. 389-411.

Bičáková, Alena, Jiří Slačálek a Michal Slavík (2008): *Labor supply after transition: evidence from the Czech Republic*, ECB Working Paper Series, No.887.

Brůha, Jan a Milan Ščasný (2008): *Model DASMOD pro predikci distribučních dopadů*, CUEC Working Papers Series (forthcoming).

Brůha, Jan a Milan Ščasný (2007): *Predikce sociálních a ekonomických dopadů návrhu první fáze ekologické daňové reformy České republiky*, COŽP UK.

Brůha, Jan a Milan Ščasný (2008): *A Note on Changes in Income Distribution and Inequality in the Czech Republic*. Paper presented at the Conference Income Distribution and the Family, University of Kiel, September 1-3, 2008.

Duclos, Jean-Yves (1995): *Economic Isolation, Inequality, and the Suits Index of Progressivity*, Cahiers de recherche, No.9510, Université Laval - Recherche en Politique Economique.

Paulus, Alari a Andreas Peichl (2008): *Effects of flat tax reforms in Western Europe on equity and efficiency*, EUROMOD Working Paper, No.EM2/08.

West, Sarah E. a Roberton C. Williams III (2004): *Empirical estimates for environmental policy making in a second-best setting*, NBER Working Paper Series, No.10330.

Datum zadání:	Červen 2008
Termín odevzdání:	Červen 2009

Podpisy konzultanta a studenta:

V Praze dne