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DIPLOMA THESIS

Energy Taxation as an Environmental Policy Instrument

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Declaration

Hereby I claim that I elaborated this diploma thesis on my own, and that the only literature and sources I used are those listed in references.

Prague, June 30, 2010 Michaela Cimrová

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Abstract

The recent trend of the environment protection leads to introduction of new policy instruments to reach given goals. The most effective seem to be incentive-based instruments as taxes on energy products and electricity because they efficiently influence consumer and producer behaviour in order to mitigate energy consumption. This thesis is motivated by increasing requirements of implementing such environmental policy into individual tax systems. Energy taxation increases prices of the products, thus leads to the lower energy consumption and the emission abatement. Moreover, if additional revenues are used to cut existing distorting taxes, other positive effects can be reached. This will be discussed as the question of double dividend hypothesis. In the Czech Republic, the year 2008 denoted an important milestone when new taxes on solid fuels, gas and electricity were introduced as the first phase of ecological tax reform. The trend of introduction of new ecological taxes plays an important role not only for producers and providers but also for households since it brings a few pitfalls in the form of significant price regulation. The effectiveness of energy taxation and its distributional, sectoral and social welfare effects will be assessed. The general equilibrium analysis follows to show the major implication with the emphasis on the specific economy.

Abstrakt

Současný trend stále se zvyšující ochrany životního prostředí přináší nové prvky k dosažení stanovených cílů na tomto poli. Jedním z instrumentů, jak nejefetivněji dosáhnout snížení emisí skleníkových plynů a spotřeby neobnovitelných energetických zdrojů, jsou spotřební daně uvalené na energetické produkty a elektřinu. Tyto instrumenty ovlivňují chování spotřebitelů ve smyslu snížení energetické poptávky a následně škodlivých emisí. Tato diplomová práce se zabývá zdaněním enerií v rámci politiky životního prostředí, jež nabývá v současné době na významnosti a je začleňováno do daňových systémů jednotivých zemí. Vyšší ceny energií v důsledku uvalených daní by měly vést ke snížení spotřeby fosilních paliv ve prospěch méně škodlivých produktů. Dále se očekává pozitivní dopad na celkovou daňovou zátěž ekonomických aktérů, pokud jsou dodatečné příjmy z těchto daní použity v jiné oblasti, například snížení daně z příjmu. Zvýšení zaměstnanosti v důsledku snížení daňové zátěže zaměstnavatelů potvrzuje tzv. hypotézu dvojí dividendy. V rámci zahájení první fáze ekologické daňové reformy v roce 2008 byly v České rebublice představeny nové daně z pevných paliv, zemního plynu a elektřiny. Tato práce analyzuje efektivnost zdanění energií, jejich distribuční, sociální a jiné důsledky. Pomocí modelu všeobecné rovnováhy budou zkoumány zásadní efekty energetických daní na danou ekonomiku.

List of Abbreviations

BAU	Business-as-usual
CO_2	Carbon dioxide
CV	Compensating Variation
EC	European Commission
EEA	European Environmental Agency
EU ETS	European emissions trading scheme
EU MS	European Union Member States
EV	Equivalent variation
GDP	Gross domestic product
CH_4	Methane
CHP-electricity	Combined heat and power electricity
IEA	International Energy Agency
LPG	Liquefied petroleum gas
MAC	Marginal Abatement Costs
N_2O	Nitrous oxide

Content

1. Introduction

At the beginning of the 1990s an ecological tax reform turned out to be the most attractive tool for the environmental protection. This trend of introduction of environmental taxes plays an important role not only for producers and providers but also for households since it brings a few pitfalls in the form of significant price regulation. In the Czech Republic, the year 2008 denoted an important milestone when new taxes on fuel, gas and electricity were introduced as the first phase of ecological tax reform. Environmental tax is part of the Coll. 261/2007 on the stabilization of public budgets. The amount of taxation depends on how much the fuel harms the environment. It seems that the most affected households are those that drown coal. On the contrary, it favours natural gas as the most ecological energy source.

However, these taxes are accompanied by a number of problems in compliance with the principle of justice as for example different distributional consequences. The application of the taxes can also constitute a risk of transfer of production to areas with no environmental taxes since the taxes disadvantage producers compared to those who are not burdened by them. Determination of the amount of tax can be problematical. And if we understand eco-tax as remedy of negative externalities, which are hardly quantifiable, it is necessary to take into account that the amount should stimulate a change in consumer behaviour. The aim of the thesis is to assess the impacts of energy taxation and its effectiveness as an environmental policy instrument. An emphasis will be placed on costs/benefits of the fuel, gas and electricity tax.

Generally, there has been an increasing tendency in prices of energies recently.[1] In previous years this increase was enormous, year by year almost in rank of dozens percents. The main reason is the EU Energy policy, liberalization of the market with conditions where demand for energies is higher that its supply, the development of oligopoly companies, the scheme of trading with greenhouse gases emissions, the massive development of renewable resources and also the introduction of energy taxes.

Subjects of taxation according to the EU Directive 200/96/EC are goods and services which production or consumption leads to demonstrable negative impact on

[1] This year a part of final consumers has benefited from decreasing prices of natural gas but the majority of expectations tend to predict growth in energy prices, specifically in electricity sector.

the environment and human health. The purpose of this new energy legislative is to stimulate economic agents´ behaviour and thus lower environmental damage and its impacts on the society.

The aim of the thesis is to present the taxation of energy products which has become an important instrument of the environmental policy. First, in the Chapter 2, I introduce types of environmental taxes and other possible instrument choices. Main advantages and drawbacks of the taxes are demonstrated as well as a comparison with other instruments applied on this field. Particularly, the cost-effectiveness of incentive-based instruments and direct regulatory measurements is assessed. The Chapter 3 presents an overview of likely impacts of the relevant tools discussed in the previous chapter, especially regarding to distributional consequences. In the Chapter 4 I introduce the European Directive 2003/96/EC on energy taxation which currently mandates the minimum tax rates on energy products in the Member states. This refers also to harmonization of taxation within the EU. The final part of the chapter summarizes types of ecological taxes applied in European countries. Next chapter describes taxes on energy products and electricity in the Czech Republic within the framework of Ecological tax reform starting in 2008. The Chapter 6 outlines the theory of optimal energy taxation and the double dividend hypothesis which is often being discussed in research literature. In the end of this part I indicate a simple model of optimal environmental taxes as a baseline of other studies. Finally, in the last chapter of the thesis, a general equilibrium model is applied to assess distributional aspects of energy taxation and its impact on social welfare. The model is adjusted to the relevant sector analysis.

2. Environmental Tax Policy

From the general point of view, taxes have always been considered as additional burden for those who experience them. Although unwelcome, they present necessary burdens that government must imposed on public in order to get revenues and thus finance essential public expenditures. Since taxes distort market signals and reduce the overall welfare in the society, they should be treated in order to influence output of the market as little as possible when it concerns the income, consumption and wealth (Atkinson and Stiglitz, 1980).

With the growing interest in the ecology, it often leads to the introduction of environmental taxes, which can help solve problems relating to the environmental damage. Despite the inefficiencies resulting from the imposition of taxes, environmental taxes may help to reduce one of the biggest environmental problem today - emissions of harmful gases such as CO_2, and others.[2] Today very widespread energy taxes lead to reduction of energy consumption and hence emissions from burning fossil fuels. Besides, there are also taxes levied directly on emissions unit, as for example most common carbon tax. Other important instruments on this field are emission allowances representing the rights for companies to emit given amount of emissions. Nowadays, they are traded on the relevant market. As well as in case of emission taxes, polluters are charged per unit of emissions.

According to economists, environmental taxation is regarded as a way to internalize negative externalities because environmental taxes may improve economic efficiency by requiring economic actors to take into account all costs of their behaviour (Bovenberg and Goulder, 1994). To the extent that activities such as production, transportation, or consumption impose environmental costs that are not taken into account by those engaged in the activity, economic analysis suggests that involved actors will engage in too much of the activity – equating marginal benefits with marginal private costs while ignoring environmental costs (Goulder, 1993).

[2] The other most harmful greenhouse gases are CH_4, N_2O, and fluorocarbons.

2.1 Types of Environmental Taxes

The designing of environmental taxes consist in the stimulation to abatement the pollution or other ecological target. An effectiveness of these instruments is crucial as poorly targeted taxes are likely to generate fewer benefits and more economic costs. There are several types of environmental taxes and each of them may differ across countries as they design them according to their specific policy objectives. Fullerton (2008) classifies environmental taxes into three main groups:

1) Taxes on emissions

These are common instruments used, particularly within Europe. Taxes are levied on measured units of emissions. Their advantage lies in the transparency as they penalize the real amount of polluting emissions. The polluter's tax base depends on the amount of emissions it produces. Thus, it pays proportionally an additional tax as the level of emissions rise. The polluter's incentive to reduce the tax burden, hence, has a positive effect on total amounts of air pollution. Besides taxes on CO_2 emissions, there are some other polluting sources charged. The example can be found in Sweden where nitrogen oxides emissions are taxed or in Netherlands where polluters pay tax on water contamination (Fullerton, 2008).

2) Taxes on products/goods related to emissions

This indirect taxation refers to goods or services which cause environmental damage or are somehow associated with it (energy products, electricity, petroleum, fertilisers, batteries, etc.). In the form of excise duty, VAT or sales tax, they are applied to goods which are believed to be more environmentally harmful than their substitutes (Fullerton and Heutel, 2007). Contrary to the direct taxes on emissions, they may not encourage polluters to the targeted behaviour in the right way. Indeed, they may try to cut tax expenses in some other way which is not, indeed, environmentally helpful. Nevertheless, administratively they are supposed to be less costly, especially in the case of already existing VAT which can be differentiated.

3) Combined instruments

A “multi-part” instrument combining more indirect taxes may be sometimes more efficient than a single tool. The purpose of such instrument is to design a combination of policy measures which can create more targeted environmental incentives if they are insufficient compared to the direct taxation. For instance, concerning abatement car pollution, the more convenient seems to be a tax on petrol together with some subsidy as for purchases of more fuel-efficient cars or for substituting by less polluting fuels. Similarly, the effective output effects may arise from the combination of excise tax on energy and subsidy of new technological equipments. Where the emissions are not possible to measure, designing a targeted tax can be complicated if it is not levied on market transaction. However, if market transactions as the sale of output and the purchase of clean inputs are charged, administrative costs will be lower (Fullerton, 2008).

2.2 Public Approach to Environmental Policy Choice

The choice of appropriate environmental policy has become an important question lately. Before economic instruments begun to be used in broader measure, there was rather a command and control approach. As green taxes and tradable permits on emissions have become popular, it asks for the deeper analysis of the market based instruments also from the public choice point of view. What is the willingness to apply such policies and why are they now more common than in previous years? In fact, the tendency to apply economic instruments seems to be increasing, especially trade with emissions allowances. Moreover, new instruments have been introduced in last years as for example voluntary agreements.[3] The more detailed division of the instruments will be discussed in the Chapter 2.4.

To cover public choice approach to environmental policy, one can discuss the behaviour of the main groups of actors - voters, politicians, and the economy representing owners, managers and employees of the regulated industries and their interest groups (Kirchgässner and Schneider, 2002). The first group, voters, has certainly a crucial role in the determination of environmental policies. Their view on environment has changed over the last decades as society has become more cautious with human health and ecology in general. Nevertheless, ecological interests of the voters may contradict for

[3] Voluntary (also called negotiated) agreements are agreements between businesses that achieve higher than required environmental outcomes , http://www.environment-agency.gov.uk

instance pure economic behaviour. The important question which is posed by the voters is who actually pays the costs of the environmental improvement. As this is a public good, the benefits from increased quality pertain to everybody. Regarding the costs, the significant role is played by the price elasticity of demand and supply for the good. Consider, on one hand, low price elasticity of demand and/or perfect price elastic supply, hence the costs pertain to the consumers (and thus also to the voters).[4] On the other hand, if the price elasticity of demand is high, the producers, managers, shareholders and employers bear the majority of the costs. Only a small part of the burden is shifted to the consumers, if any. Hence, the interests of the voters may differ according to possible price changes of the good. Similarly, the regions with high number of producers whose interests oppose to measurements for environmental improvement may register lower willingness to accept such policies.

Obviously, ecological objectives mean higher burden for the producers and hence reduced profits, wages and lower employment in the region. Empirical evidences in Germany found that in the regions with higher unemployment the green policy receives lower votes than somewhere else. Also in the regions with higher concentration of steel and chemical industries the Green Party has lower favour of voters (Kirchgässner and Schneider, 2002). Since the ecologically oriented policy evidently weakens the position of the industries, the local voters in own self-interest might oppose any program for environmental improvement. Ironically, these regions often need such policies the most.

However, there are new arguments in favour of environmental policies because of the possible double dividend which will be more discussed in the Chapter 6.3. For the introduction, the hypothesis assumes that at least two positive effects can steam from emissions abatement - better environment and higher employment if tax revenues from green taxes are used to cut labour taxes, for example. Despite the Kirchgässner and Schneider (2002, p.7) state that "*...the case of a double dividend where employment is rising with a stricter environmental policy is an exception in environmental policy making, which to a large extent depends on the existence of involuntary unemployment*.", many research papers confirm the double dividend hypothesis. However, since there is a trade-off between the environmental improvement and the production (and thus real

[4] This can be the case of mineral oil prices in small countries, where the prices are determined by the prices in international markets (Kirchgässner and Schneider, 2002).

income), the voters' decision-making may be biased. In such case, they choose between higher real income and improvement of the environment. Moreover, their decision is influenced by how informed they are about consequences of environment deterioration. Here, it should be reminded that there is a lag between implementing policies and actual improvement in quality which also affects the voters' decision-making.

The second discussed group, the politicians, are much more affected by voters' decisions and one may expect they apply a populist policy. They have to consider citizens' preferences in implementation of environmental policy if they want to be successful in an election. Obviously, if there are many voters satisfied with the actual state of measurements on the environmental field and they do not want much to change it, the politicians will have no incentives to promote ecological policies and will probably follow dominant voter's statements (Goulder and Pizer, 2006). However, sometimes the wish of the median voter is not the preferred one when there is a strong power of a green party in a coalition government. Also, if the voters of the government behave more economically, they will hardly prefer ecological provisions which lower the output of the consumer goods and their income.

The other significant feature is the transparency of the policy. If the voters prefer more visible measurements, this can lead to greater application of bureaucratic instruments. The government is usually better informed than the average voter, thus it might be rather in favour of economic instruments while assuming they are more efficient. Moreover, economic instruments in form of taxes mean additional revenues for the government, which can be an important incentive as well. Since the revenues might be recycled in cutting some other taxes, for example income tax or social and health contributions of employers, it seems like it would be much more satisfactory for the voters to accept environmental taxes which they evidently experience less than direct taxes. Thus, the resistance against any other taxes to improve environmental quality will probably be lower. Regarding emissions allowances, they might be less acceptable for people who perceive them as unethical or just as a "licence to pollute". Hence, the government might apply populist policy in form of other instruments.

Behaviour of regulated industries can be quite easily predicted. They certainly do not favour any policy which causes them higher production costs than the other one. In fact, every environmental measurement means additional burden for them. One might expect them to prefer economic instruments to command and control policy, however, this in not so unambiguous.[5] Regarding the choice between taxes, levies and emission permits, the most beneficial seem to be tradable permits which are distributed by grandfathering.[6] The question is if the regulated industries can benefit from any environmental policy. After all, some market based measurements may have positive impacts on the industry leading to the saving of some costs. One of the reasons is distributional consequences. Industries may prefer standards because in that case they do not pay for the emissions as under the taxes and allowances. Thus, these saved costs are regarded, in a certain sense, as additional revenues attractive for owners and employees. Moreover, in the command and control policy the companies have some opportunity to negotiate with regulating institutions and use their informational advantage. If environmental taxes are applied, the firms are not limited in emissions; they just pay for it in the production costs.

The important role in the regulated industries plays the power of organisations during negotiations. On one hand, together with business interest groups they have influence on politicians while lobbying and may affect their decisions in implementing policies. On the other hand, interest groups oriented on environment seem to have weaker power to influence legislative proposals (Oates, 2001). They rather convince voters who think ecologically.

During the last decades the use of environmental policies has changed. Economic instruments have become more popular recently, especially tradable permits which market has developed in the EU. Also green taxes are often applied within framework of introduction of ecological tax reforms. For example, gasoline taxes have quite a long history in Europe; however, in the beginning their purpose was rather to gain additional revenues than ecological.[7]

Not only green parties are in favour of the environmental taxes but also left-wing parties that need new sources to finance their social programs. Moreover, they generally

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[5] Kirchgässner and Schneider (2002) point out that although the industries hesitate about instruments, they seem to rather prefer policy of command and control.

[6] Grandfathering is an allocation method under which the government gives free of charge allowances to entities based on their historic production, emission or consumption levels (Climate Policy Centre, http://www.cleanair-coolplanet.org/cpc/glossary_cpc.php, 25.4.2010).

[7] In early 1990s the German government increased taxes on mineral oils to finance the German unification. Similarly, in Switzerland an increase of mineral oil taxes was accepted in 1993 and besides ecological purpose, the main reason was to generate revenues to finance transportation infrastructure (Kirchgässner and Schneider, 2002).

focus more on labour market and fighting unemployment than right-wing parties. Thus, the idea of double dividend hypothesis passes such policies to public acceptance.

2.3 Environmental Policy Instrument Choice

A common environmental regulation has become an important part of the EU policy in the last decades as well as the justification for greater harmonization between the MS. There have been green parties fighting for the implementation of environmental policies, especially in Western European and Scandinavian countries. Moreover, in historical scale, the EU has always had a significant power to persuade countries with less developed environmental regulation (Rousseau and Proost, 2004). Political pressures play a major role in this field and, certainly, stay behind introducing many green taxes. Protection of nature and human's health is popular today and thus has quite a strong power in negotiating. Similarly, the question of an environmental tax reform has become popular and subsequently officially realized in several countries. The practice of the reforms has been different, some were less ambitious whereas others quite painful. The reason for many tax reliefs for specific products or industries, as for example energy-intensive industry, is to avoid downfalls of companies. Hence, the affected industries are often successful in negotiating exceptions. Revenue recycling and revenue neutral tools have become part of the reforms because of additional tax burden levied on industries and households which should be compensated in some way. Besides, such ideas are useful to capture voters´ interest.

There are no homogenously used instruments of environmental policy. In fact, a great variety of instruments are applied within the EU. Since the majority of industries and their functioning are complicated to be regulated only by taxation, many countries implemented a mix of regulation and tax policy instruments. The Table 1 shows an overview of usual environmental policy instruments according to Sterner and Köhlin (2003).

Table 1. An overview of environmental policy instruments.

Policy Instruments			
Information/ Persuasion	Creating rights	Regulation/legal	Price-based instruments
• Public participation	• Property rights	• Standards Permits	• Subsidies (Subsidy Reduction)
• Information disclosure	• Tradable permits	• Bans, Zoning	• Environmental charges/taxes
• Voluntary agreements	• Tradable quotas	• Public goods	• User charges
• Labeling schemes	• Offset systems	• Liability	• Deposit -refund systems

Source: Sterner and Köhlin (2003, p.120)

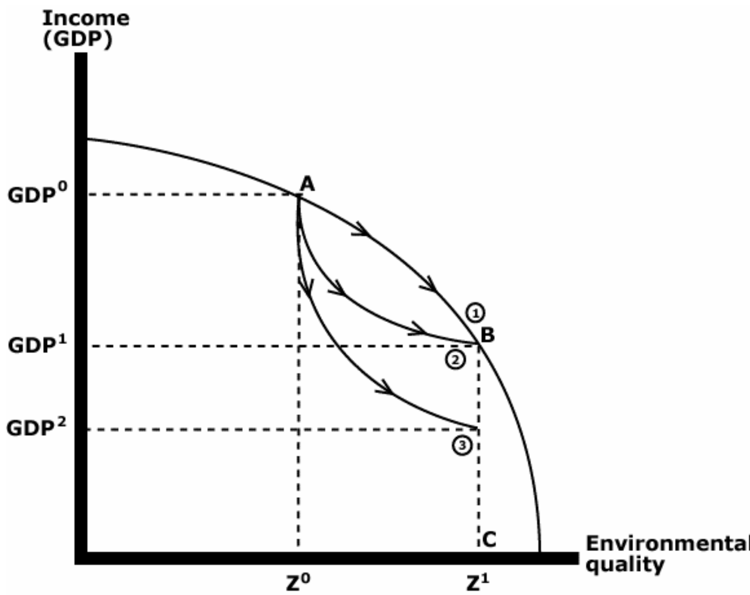
With constantly growing concerns about global warming and environmental pollution there has been a tendency to examine its impacts from the European point of view. Energy and other relevant policies which have been implemented in recent years are approaching and do not differ across countries so much as it was earlier. Especially, the EU policy of tax harmonization takes part in this development. Not only energy taxes but also other instruments get attention as subsidies for renewable energy sources. Among others, the most discussed environmental policy has recently become the European emissions trading scheme (EU ETS).

This part of the chapter summarizes major studies analyzing environmental regulations and their consequences on the European economies. An increase of energy prices higher production costs that affect particularly energy intensive sector and industries with goods traded internationally. The costs of clean energy policies deserve an attention despite they seem to be relatively small from macroeconomic point of view (Dannenberg, Mennel and Moslener, 2007). To be more precise, this can be the case when tax recycling works and some sectors gain from regulation of the other one. Of course, the more ambitious targets the higher costs. Setting a suitable and efficient regulation approach is the key determinant for the cost burden.

2.4 The Cost-Effectiveness of Environmental Policy Instruments

The basic illustration of the costs of improving quality of environment can be found by Kriström (2003). The Figure 1 shows its conception. The improvement is represented by shift from Z0 to Z1 and costs refer to the income loss distributed across producers and households. Thus, efficient policy works at minimum costs in term of income which is the case of smoothly adjusting economy (an income loss $GDP^0 - GDP^1$) and shift from the point A to the point B.

Figure 1: The Environmental Policy Costs



Source: Kirström, 2003

However, there is heterogeneity between companies and households in reality; hence the adjusting to policy implementation varies across the actors (in the Figure 1 highlight by the curve 2) attributed to "transition costs".[8] Furthermore, if the given policy target is reached but less efficiently, the income costs will be higher ($GDP^0 - GDP^2$). Such case presents the shift from the point A to the point between B and C (the curve 3).[9]

The cost-effectiveness of the environmental instruments is the crucial factor of the policy implementation. The effect of individual instruments is discussed below.

[8] There are some resources of the economy that are not utilized during adjusting. For example labour decrease when firms have become closed (Kriström, 2003).

[9] According to the conception, distributional impacts may be analysed comparing consequences of a given policy relative to the baseline scenario (the point A).

2.4.1 Incentive-based Instruments

The most common instruments with incentive effects are emission taxes and tradable emissions allowances. Regarding the previous discussion, these two measurements may be the most satisfying the common price for emissions. For the taxes it is obviously due to the fee per unit, in case of the allowances, that their price is also unique for all participants no matter if they are distributed free or through an auction. Every additional emission unit corresponds to a firm's cost in an amount of the price level. Hence, the relevant companies shift their costs of emissions to the consumers in form of higher prices of products.

Other widespread incentive-based instruments are taxes on products, goods or inputs which are somehow connected with pollutions, for example energy taxes, taxes on gasoline or air transport. The intention of such taxation is to reduce consumption of the products associated with emissions. Specifically, the taxes here are reflected into the product prices followed by decrease in consumer demand. The lower consumption of such goods means lower polluting. Contrary to the previous taxes on emissions that penalize externalities, these discourage even from incurrence of emissions if the products are used less or substituted to the more environmental-friendly ones. The problem seems to be that no substitution for cleaner fuels is always expected, especially on the production side. Reflecting the costs into the product prices, the emissions are lowered, however, it does not unambiguously mean that they have incentive to innovations or energy saving policy.[10]

2.4.2 Direct Regulatory Measurements

Instruments of the direct regulation have some significant disadvantage contrary to the incentive-based ones. The first problem is the lack of information that regulatory agencies have to face. They are less informed and less efficient in cost-minimizing than producers or consumers. Moreover, direct regulations are unlikely to optimally provide various ways of pollution reductions. Among these policies belong technology mandates

[10] In case of the electricity tax, it lowers demand but it automatically does not provides incentive to use cleaner fuels in power generations or an adoption of electrostatic emissions scrubbers. Similarly, the taxes on gasoline provide no incentive for people to drive cars that burn gasoline more cleanly (Goulder and Parry, 2008).

or performance standards. The first are specific requirements which have to be satisfied in production, the latter refer to specific standards on output or input as for example maximum emission rates per energy unit, minimum requirements for renewable fuels in power generations, energy efficiency standards for houses or fuel requirements for cars (Goulder and Parry, 2008). The lower ability to maximize cost-effectiveness (marginal costs of abatement equal for all firms) stems from the fact that firms have to face different costs if a mandate stands good for all participants. The regulatory institutions are unlikely to be enough informed to set the most effective mandates regarding cost-minimizing as well as they are not able to customize the performance standards to an individual company. Both mentioned instruments do not reduce output sufficiently to lower emissions since the firms are not charged for remaining emissions. Thus, contrary to emission taxes, the output prices are lower.[11]

The following Table 2 summarizes the cost-effectiveness of alternative instruments of environmental policy. The most suitable seem to be taxes on emissions and tradable allowances, i.e. the instruments where emissions are reduced by pricing the pollution externality. The other incentive-based instruments are unlikely to optimally engage all major ways to reduce emissions as well as the direct regulatory measurements which also fail to ensure the same marginal costs of reducing emissions across heterogeneous firms.

[11] An example can be the following rules: standards for economy fuel in new cars do not reduce emissions through incentives to cut vehicle output in sense of reduction travelled miles, compared to gasoline taxes which do.

Table 2: Attributes of Alternative Emissions Control Instruments

	(1) promotion of lowest-cost combination of input choice, end-of-pipe treatment, and output reduction	(2) equalizing of marginal emissions reduction costs across heterogeneous firms	(3) minimization of general equilibrium costs from interactions with broader tax system	(4) political attractiveness (low share of regulatory burden falling on emitters)	(5) household equity (limiting disproportionate burden on low-income groups)
Emissions Control Policies					
emissions tax (revenue-neutral)	*	*	*		*
subsidy to emissions abatement		*			
tax on good associated with emissions		*	*		
tradable emissions allowances					
-- auctioned (revenue-neutral)	*	*	*		*
-- freely allocated	*	*		*	
mandated abatement technology				*	*
(non-tradable) performance standard				*	*

Notes:

1. The asterisk indicates that a given instrument has an advantage along the dimension in question. It does not mean that other instruments have no impact along that dimension.

Source: Goulder and Parry, 2008

Despite these arguments, there are some cases where the cost advantage of the incentive-based instruments is scaled down. For example, if emissions taxes have no significant effect on product prices, their ability to exploit the output reduction will be doubted. Thus, the relative differences in cost-effectiveness between the instruments may become marginal. Similarly, supposing that firms are rather homogenous, and then a single technology mandate might ensure almost equal marginal costs of abatement for all participants.

2.4.3 Environmental taxes in comparison with other policy instruments

Energy taxes are among the other environmental taxes considered to have the greatest fiscal potential because they generate significant revenues to the government's budget.[12] The additional revenues in framework of environmental tax reform thus enable reduction of other distorted taxes as cuts in labour income taxes. However, revenue

[12] Energy taxes together with taxes on road transport are the most significant sources of revenues among eco-taxes (Smith, 1998).

sustainability is doubtable since effects of taxes on revenues are likely to change over time (Stavins, 2004). In short run, the adjustment to the taxes is limited due to constraints of existing capital equipments. Nevertheless, revenues are likely to be lower in long run when producers and consumers are able to adjust, at least to some extent.

Clearly, the consequences on environment are obvious since they contribute to the emission reduction; however, fiscal effects of the recycling tax are much more contentious. Contrary to regulatory instruments as emissions standards or technology mandates, environmental taxes are likely to cut the costs of achieving a certain standard of environmental protection (Goulder et al., 1998). The advantages of ecological taxes among other mentioned instruments are mainly in term of reducing emissions; on the other hand in some cases other policies may be more appropriate. In this chapter I summarize some major advantages and limitations of ecological taxes.

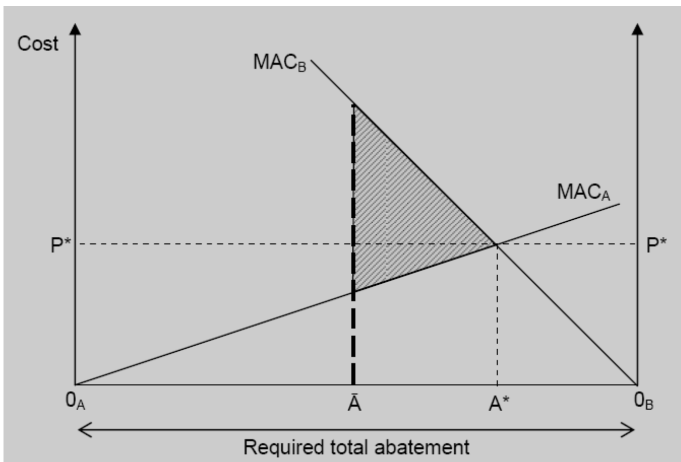
The main positive sign of taxes levied on emissions is their incentive character. They provide an incentive to lower emissions on both producers and consumers sides. Since a price increase of the commodity on which the tax is levied (or goods from industries affected by the tax) leads to excess costs for the actors, the expected reaction is a decrease in demand and its substitution for cleaner products. Due to additional costs, next incentive for polluters is to search for possibilities how to reduce emissions as in form of innovations. Because of the tax payments on unit of emissions, they might go below their current cost-effective level, in comparison to the policy of regulations.

Reallocation of abatement is another argument in favour of the taxes because they are supposed to minimize costs of pollution abatement if the costs differ across polluters. To be more specific, where other instruments are not able to distinguish companies with different marginal costs of abatement, the taxes can achieve a specific abatement level less costly. Contrary, where other instruments take into account differences in costs of pollution abatement between polluters, taxes can sidestep the need for the regulator to get information about firm's abatement costs and thus lower costs of regulation (Smith, 1998).

The Figure 2 shows the possible gain from reallocation of abatement. Point A* is an optimum in the least-cost division of a total abatement requirement between two polluters with marginal abatement costs (MAC). Each of polluter has different MAC, in the Figure denoted by MAC_A and MAC_B, measured from the origins 0_A and $0_{B,}$

respectively. The both pollutants are considered uniformly mixed so that the environmental benefits are a function only of the total abatement achieved. Incentive-based instruments should achieve point A* as for example due to emissions trading in a competitive market, with equilibrium allowance price equal to P*, or through an emissions tax set at a rate P* per unit of emissions (Fullerton, Leicester and Smith, 2008). However, if a regulator, due to the informational limitations of command-and-control regulation, gives the two types of polluter equal abatement requirements, represented by point Ā in the Figure; it would result in higher total abatement costs (the shaded triangle area).

Figure 2: The Efficiency Gain from Reallocation of Abatement Costs



Source: Fullerton, Leicester and Smith (2008)

Under command and control of regulatory policies, the pollution abatement is more efficient where various levels are required for various polluters than where there is a uniform abatement standard (Fullerton, Leicester and Smith, 2008). However, the regulator might be captured here[13] in sense that he is dependent on the information from regulated companies about their costs of abatement, and then a leeway for negotiation here is possible. Controlling the prominent factor of the process, regulated companies may have opportunity to argue for less strict required level of abatement. The green taxes also limit costs of regulated polluters who do not take risk of excessive costs under regulatory requirements. There is no limit on quantities of pollution under environmental taxes. Polluters will not care about polluting; they will rather pay taxes than abatement if costs of taxes per unit are lower than costs per unit of abatement (Smith, 1998).

[13] According to capture theory of regulation, for more see for example Stigler (1988).

However, there are some disadvantages of the taxes. Besides uncertainty about their impacts on environment which are not simply identified, they may represent really substantial burden for economic actors since they have a potential to raise a commodity's price the most (Morgenstern, 1995). Furthermore, together with regulatory standards they need an enforcement provision which means with administration additional significant expenses. In some cases, regulatory policies can be more cost-efficient because under the taxes, the polluters have to make decisions about the convenient strategy.[14] Nevertheless, the costs and benefits of relevant instruments are not the only factors of actors´ decision-making. There could be a tendency to adhere regulatory measurements because of that "capture of a regulator" discussed above which for example stakeholders can prefer and keep some negotiating power. Other arguments are adverse distributional consequences. If the taxes are not offset somewhere else, it may be more desirable to keep their level low and supplement them with other instruments (Stigler, 1988).

Besides, there has been another important consequence of energy taxation – an impact on industrial competitiveness. Negative impact can be found in decreased competitiveness of the affected industries on international market caused by taxes implementation. The most concerns refer to the energy-intensive sector.[15]

In the energy sector, the environmental taxes are levied either on emission unit or as excise taxes on energy products consumption. The latter depends on involvement of energy inputs and impact on the environment. The target of emission reduction has been reinforced by the extension of energy excises to other fossil fuels as coal and natural gas.[16] The most reasonable taxation seems to be the one where a fuel is taxed according to its carbon content. Thus, the tax rates would vary across various fossil fuels; and those with higher carbon content per energy unit (coal) would be taxed more than fuels with lower carbon content per unit (natural gas).[17] This taxation system, if followed by proportional increase in product prices, encourages to substitution from for example coal to natural gas. Since energy consumption in general is supposed to decrease, together with substitution effect it leads to the reduction of carbon emissions.

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[14] They have to balance the gains by considering marginal costs of abatement and cuts in tax payments while addressing more polluting abatement (Smith, 1998).

[15] Therefore, there are many sector exemption applied in the EU.

[16] The origin energy taxes were levied on motor fuels and mineral oils.

[17] Within the EU, the most common principle is extended systems of fuel excise taxes with different rates on different fuels.

Regarding the taxation of electricity, there are two possible ways according to Kohlhaas et. al (2004). The first is to levy tax on fuels used in electricity generation, the second is to tax electricity sales at a rate corresponding to average fuel inputs while exempting taxation of fuels used in energy production. The second approach may discourage electricity producers to use low carbon fuels during the production process, hence the first approach seems to be more efficient. Despite this argument, the taxation of electricity sales was preferred by the EU Commission because of some meaningful reasons. Obviously, if electricity is traded internationally, it is better to apply the second approach, excise tax principle, and attribute tax revenues to the country where it is finally sold. There can be another reason as not giving any fiscal privilege to nuclear power generation (Kohlhaas, 2000).

3. Impacts of Environmental Policy Instruments

There are several approaches in research literature of environmental policy to analyse taxes associated with emissions. The first trend is oriented on finding optimal taxation in terms of appropriate tax rates on pollution. The main task is to assess the introduction of a correcting tax into a given tax system with already distorting taxes and to find the most efficient way in mitigating costs of environmental externalities (pollution). Theory of optimal taxation employs maximizing of social welfare and individual utility concept. The point is to find optimal level while maximizing social welfare. The fundamental criteria are economic efficiency and fairness.[18] Optimal system is understood as the situation where the total social welfare cannot be higher without lowering total tax revenues. According to Atkinson and Stiglitz (1980) tax distortion implies inefficiency and loss in social welfare. In a perfectly competitive market, socially optimal level of pollution is then regarded to the situation where marginal product equals marginal environmental damage. The second trend in the environmental tax literature focuses on analysing costs and benefits of the taxes in comparison with other instruments. Distributional and structural impacts are being examined as well.

The first effects of the implementation of a new environmental policy, especially in the case of the taxes, are obvious. Some of them have already been mentioned above as the increase of energy products prices after introducing or enhancing energy tax rates as a result of additional production costs. Moreover, it may refer not only to energies but also to other goods as products of energy-intensive sectors.[19] The decrease in consumption of higher priced products is anticipated. The most prominent impacts are described in this part of the thesis. Besides, there are some other significant impacts of the environmental policies. The ecological tax reform affects the competitiveness of the production sector or even the whole economy. Such called "spill-over effect" occur for instance when measures to reduce carbon emissions leads to higher carbon emissions in other countries due to lower competitiveness.[20] The technological effects are other possible phenomenon. The effort of the producers to reduce energy consumption can lead to investing to the new technologies and intermediates which are more energy-efficient. These purchases would

[18] Atkinson and Stiglitz (1980) mention other criteria for optimal tax system as administrative simplicity, flexibility or political responsibility.
[19] However, this does not have to be the case when energy-intensive sectors are exempted adequately that the producers would not change the product price.
[20] Such shift of carbon emission is being called „carbon leakage" in the relevant literature.

positively affect aggregate demand in the economy and the reduction of energy consumption may offset the final energy expenses. Moreover, higher production of energy-efficient companies may partially or even completely offset possible decrease in production due to higher energy taxation.

3.1 Distributional Impacts

There are more ways how to classify distributional impacts of various environmental policies. Besides distribution between different involved groups, one can also consider regional or generational impacts. Nevertheless, they are not subject's matter of the thesis, so I focus only on the basic description of distributional impacts between different household income groups and between polluters and other involved groups as consumers, employees or other agents of the process.

One of the most important impacts to consider is a distribution between households which differ in their incomes. In general, a low-income household spends greater proportion of its budget on energies and gasoline than high-income households (Johnstone and Alavalapati, 1998). Since the cost impacts vary across the households, they are supposed to be unfair. The provision of the fairness of the distributional impacts becomes one of the major tasks by applying pollution policies. In particular, the way how the involved groups are affected depends on the revenues from different use of policies. The additional revenues from carbon taxes or emissions permits are supposed to be recycled and thus lower the burden of the participants.

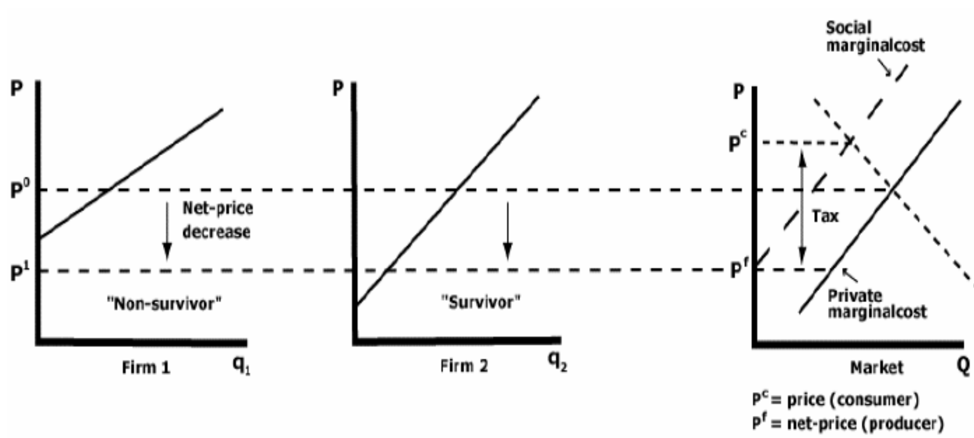
There are many research papers which examine distributional impacts of environmental policy instruments. For example, Metcalf (2000) considers revenues from carbon taxes and carbon allowances distributed by an auction and analysed impacts of their recycling in low-income households' incomes.[21] He found that such recycling might, to some extent, mitigate differences in distributional burdens, however, it might not be the case of households who demand energy assistance programs as unemployed or senior households. Regarding emissions allowances, the way how they are distributed affects the household differently. The permits allocated free tend to higher disparity in burden-to-income ratios between the households because firm's equity value increases with higher

[21] He considers reduction of the burden via e.g. payroll tax rebates, lump-sum transfers or higher income tax thresholds (Metcalf, 2000).

producer surplus and upper-income households own a disproportionate share of such equity (Goulder and Parry, 2008).

The fact that costs of environmental policies are passed fully or to some extent to the consumers through higher market prices is evident. How the individual economic actors adjust to a new policy and how costs are distributed will be discussed in this section. First, assume that other markets are not affected and social damage is proportional to the production level. Imposing an ecological tax on production sector is showed in the Figure 3.

Figure 3: Market Distributional Effects of Environmental Policy



Source: Kriström, 2003

The Figure 3 illustrates distributional effects of an optimal environmental policy in terms of affecting the producers in the market. Since a specific environmental policy means additional costs for the firm, consumer price increases and firm's net price declines at range of the levied per unit tax ($P^0 - P^1$). The Firm 1 exits the market while the survived Firm 2 experiences the decline in its profit. The policy is optimal because the sum of the benefits exceeds aggregated costs. The final price is set at social marginal cost compared to status quo with private marginal cost as shown in the last picture in the Figure 3. However, the distributional impacts of individual environment instruments cannot be generalized because the burdens caused by their installations vary across firms and households.

Regarding the distribution of regulatory burden, there are some important empirical findings in research literature. Since trading with allowances has become popular among policymakers lately, the new question concerning their distribution arose. Whether distributed freely or by an auction, both motivate profit-maximizing firms to increase their output prices with additional carbon emissions costs. In case of freely distributed permits, firms are likely to bear a significantly smaller share of regulatory burden as they do not have additional expenses associated with an auction purchases and keep rents from higher output prices. Bovenberg, Goulder and Gourney (2003) assessed tradable permit system in the U.S. and found that fossil fuel suppliers earn higher profit in case of freely allocating all carbon permits. The considerable distributional feature is that, whereas taxes and auctioned allowances are the most effective in term of cost (revenue-raising), freely distributed allowances may lower political resistance (Goulder and Pizer, 2006).

The other comparison of distributional impacts can be found in the research paper of Quirion (2006). He examines three environmental policy tools, concretely taxes, energy-efficient certificates[22] and standards and their distribution between energy suppliers. While implementing the second instrument, the suppliers are recommended to set their target relatively to the current output. A target set in absolute terms may significantly decrease supplier's profit because of lower possibility to shift costs regarding certificates to consumers. Moreover, in such case the rebound effect is very likely.[23] In comparison to standards, however, the energy-efficient certificates with targets expressed as a share of energy sales create lower rebound effect; and contrary to taxes they mobilise more a part of the no regret potential (Quirion, 2006).

3.2 Structural Changes

Introducing exemptions in applied policy instruments causes structural changes in an economy. One good example is exemptions for the energy-intensive sector within the framework of an energy tax reform. Presently, many European countries administer such discrimination in energy taxes which favours the exempted sector and brings additional costs for other sectors.[24] Indeed, many researchers find energy tax exemptions to be more costly than a uniform tax for all sectors. To assess structural changes and energy use, Schleiniger (2001) simulated four scenarios of energy tax reform applied differently in

[22] Also called „white certificates", in the literature.

[23] The rebound effect may occur when consumption of an energy service increases due to the decrease in marginal costs of an energy service.

[24] Denmark and Germany were among the first states applying exemptions for energy-intensive export sector. In Denmark, moreover, the tax revenues are redistributed back to the industrial sector in favour of the exempted sector (Schleiniger, 2001).

energy-intensive sector producing tradable commodities and labour-intensive sector with non-tradable goods. In the first one, there are no exemptions within sectors and tax revenues are redistributed to the households in form of lump-sum compensation. The results are negative output and all substitution effects (between factors labour, capital and energy). As production is shifted to the exported commodity, energy inputs then increase. The second scenario applied exemptions for energy-intensive export sector without any discrimination between sectors in revenue redistribution while in the third one, only exported goods are exempted, not the whole sector. In the last scenario, after the fashion of Danish tax system, all sectors are taxed at the same rate and revenues are recycled in the reduction of producer labour price in the non-tradable sector.[25] This case implies positive output effect on energy use because of just discrimination in redistributed revenues. The similar effect generates the second scenario where the positive signs are caused by exemptions of energy-intensive sector. Where only exported commodities are exempted of taxation, as in the third case, there is no significant output effect on total use of energy as the relative price of non-exported commodities does not change (Schleiniger, 2001).

The other comparing of systems with tax exemptions to uniform taxation can be found in Böhringer and Rutherford (1997) who show that the combination of a uniform tax on carbon dioxide with wage subsidies in the German energy industry is less costly than when tax exemptions are applied. Bovenberg and Goulder (2001) examine uniform CO2 tax in the U.S. with the similar result, i.e. they find that welfare is reduced less in case of compensation of profit losses in the energy industry in term of subsidies. The study of Bjertnaes and Faehn (2004) confronts tax exemptions for Norwegian energy-intensive export sector with the case when it is included into the electricity tax system. They find rather small welfare gains after eliminating the exemptions.[26]

3.3 Impacts of Uncertainty

There are some other considerations that have to be taken into account as uncertainties. Obviously, all real consequences of alternative environmental policies are hardly perfectly predictable. Policy-makers face two main uncertainties as a choice of a

[25] In this and the first mentioned scenario, the price of a non-tradable commodity rises because of higher energy tax while the price of a tradable commodity stays the same (Schleiniger, 2001).

[26] However, they point out some disadvantageous of the Norwegian system with such exemptions as for example impeachment of legacy of discriminatory practice or possible conflicts with competition rules of the European Economic Area (Bjertnaes and Faehn, 2004).

convenient instrument and expected gains from relevant policies. The first refers to unknown aggregate emissions quantity under taxes while the price of emissions is established at the outset or uncertain price in case of tradable allowances where quantity of emissions is given by their number on the market. To mitigate the uncertainties Murray, Newell and Pizer (2008) suggest establishing a certain price ceiling or conversely a price bottom for emissions allowances. More specifically, if the price achieves the ceiling, hence the regulatory authority has competence to issue some additional permits to the market in order to prevent from price increase.[27]

Although this process without doubt reduces price uncertainty on one hand, it leads again to uncertainty about emissions amount. Similarly, the uncertainties regard also other policy instruments. Under taxes on energy products or gasoline the quantity of emissions is unknown. In case of direct regulations, only emissions limits for a firm can be determined but not the overall quantity again. Moreover, the effective price (MAC) of emissions is uncertain under standards or technology mandates.

[27] Conversely, if the price reaches the established bottom, regulators might withdraw the emissions allowances from the market by purchasing them.

4. The EU Implementation of Energy Taxes

The European Union adopted a new regulation (Regulation 2003/96/EC of 27 October, 2003), which broadens the list of items on which excise duty is applied in at least the minimum rate set, uniformly across the EU.[28] Apart from fuel excise taxes, which are usually already taxed, since 1 January, 2004, a taxation of other energies occurred. Consumers or entrepreneurs experienced new taxes on natural gas, coal and electricity. It is not just about the introduction of entirely new taxes but also about increasing the minimum rates of excise duty on petroleum products (petrol, diesel), which have already been taxed previously. Furthermore, there have been changes on the amount of the lowest tax rates for energies for industrial and commercial heating purposes, so far in the EU Member States selected. Before this, at the EU level, the minimum amount of excise duties was not changed since 1992.

4.1 The EU Directive on Energy Taxation

Within the EU, the Council of Ministers adopted the new Directive 2003/96/EC of October 27, 2003[29] widening the scope of the minimum taxes levied on mineral oils to all energy products. The Directive entered into force on 1 January, 2004 and has replaced the previous Council Directive 92/81/EEC of 19 October, 1992.[30] The framework for energy products taxation has been restructured, new obligatory minimum tax rates for coal; natural gas and electricity were introduced.[31] So far, only prevailing minimum tax rates of energy products referred to mineral oils (Council Directive 92/81/EEC on the harmonization of the structures of excise duties on mineral oils, Council Directive 92/82/EEC on the approximation of the rates of excise duties on mineral oils). Along with new tax structure, the EC proposed special transitional agreements for the Accessing Countries, two amendments to the Directive - Council Directive 2004/74/EC[32] and Council Directive 2004/75/EC[33].

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[28] This measure was adopted unanimously at the meeting of Ministers of the Member States in Luxembourg.
[29] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:283:0051:0070:EN:PDF, 20.3.2010
[30] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0081:EN:HTML, 20.3.2010
[31] Previously to the admission of the Directive, the EU Council of Ministers discussed the first proposal to taxation of all competing energy sources, including minimum tax levels, in 1997. Such proposal, however, was considerably changed before being adapted in 2003.
[32] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:195:0026:0030:EN:PDF, 22.3.2010
[33] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:195:0031:0032:EN:PDF, 22.3.2010

4.1.1 Legal Framework for Energy Taxation in the EU

Further legal instruments for energy products are Council Directive 95/60/EC of 27 November 1995 on fiscal marking of gas oils and kerosene. In June 2006, the Commission decided to establish a common fiscal market for gas and kerosene (for more see 2006/428/EC[34]).

Particularly, the main aims of this initiative are following:

- to ensure greater environmental protection;
- to improve proper internal market functioning;
- to reduce distortions currently existing between Member States, i.e. to enhance tax harmonization (more in the Chapter 2.2);
- to improve unemployment by tax revenues recycling (will be discussed later).

According to the amendment 2004/74/EC, certain EU Member States (EU MS) have been allowed to apply for reduced tax levels or even for being excluded from setting minimum rates for a temporary transitional period. Such provision measures were applied to new ten Accessing Countries in 2004 because of their relatively low income levels and great possibility of serious economic and social difficulties due to increased prices. Moreover, their ability to balance the tax burden with some other tax reduction was supposed to be limited. Generally, minimum tax rates followed by increase in energy prices are likely to cause negative effect on national economies, at least in the short run, as for example extensive burden for small and medium-sized companies.

The general transitional period for applying advantageous tax levels for new EU MS was set until 1 January, 2007. However, the transitional periods differ across the countries as well as for energy products. In the case of the Czech Republic, the final date to be exempted or apply reduced tax rates of electricity, natural gas and solid fuels was extended until 1 January, 2008. Nevertheless, as the amendment 2004/74/EC specifies, the MS should progressively lower their respective gaps between actual and required minimum tax levels during the transitional periods.[35] The Council Directive 2004/75/EC

[34] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:172:0015:01:en:HTML, this repealed Commission Decision 2001/574/EC, 22.3.2010

[35] "*However, where the difference between the national level and the minimum level does not exceed 3 % of that minimum level, the Member State concerned may wait until the end of the period to adjust its national leve.*" (Council Directive 2004/74/EC, p. 96).

amended the Directive 2003/96/EC and refer to the Republic of Cyprus. It refers to temporary exemptions and reductions in taxation levels which Cyprus may apply.[36]

In June 2006, the Commission reviewed derogations in Annexes of the Council Directive 2003/96/EC expiring by the end of 2006 which authorize the MS to apply exemptions or lower rates of energy taxation.[37] Some of the derogations were already implemented in Council Directive 92/81/EEC.

4.1.2 The Taxation System According the Directive 2003/96/EC

In this section I summarize the main characteristics of the Directive 2003/96/EC for energy products and electricity taxation.

- Business use of energy products and electricity may be treated differently than non-business use (lower rates for business use are possible).
- Energy products taxation refers to the products used as fuel or for heating purposes, otherwise they are exempted as raw materials, use in chemical reductions, electrolytic, metallurgical or mineralogical processes. Also dual use of energy products is exempted.
- Energy inputs to heat generation are taxed; however, inputs to regional heating are not.
- Electricity is taxed as an input; however, as an input to electricity generation it is exempted.
- Specific treatment may be applied in case of the taxation of diesel motor fuel used by hauliers, in particular those engaging in intra-Community activities. Such provisions include for instance the introduction of a system of road user charges, in order to limit the distortion of competition which hauliers might be confronted with.
- Energy products used for international air transport or maritime transport within Community waters are exempted from taxation.

[36] Specifically, the transitional period for adjusting their national tax rates was set until 1 January 2008 in the case of gas oil and kerosene.
[37] The Directive contained additional 127 derogations (Annexes II and III). The review from June 2006 counted 111 derogations expiring on December 2006.

- Other exemptions may apply to renewable energy sources, energy used for combined heat and power generation and CHP-electricity[38], energy used in the public transport of goods and passengers (train, metro, tram or trolleybus).
- There are many special allowances, to apply other exemptions or reduced tax levels, anticipated as long as they are not harmful to the Internal Market functioning and do not distort a competition among the EU MS.
- The taxation of energy intensive industry may be limited (if a company has energy costs at least 3 % of the production value or if energy tax amounts to at least 0.5 % of the added value).
- Companies that have entered into commitments or where tradable permit schemes are implemented (down to zero in the case of energy-intensive businesses and down to 50 % in the case of other businesses) may apply reduced tax levels as well (Directive 2003/96/EC).

4.2 Harmonization of Taxation within the EU

In general, the Directive declared two main objectives of these tax measures. The first is the harmonization argument: it is necessary to harmonize the minimum excise duty on energy within the EU countries. Now a very different set of tax rules distort competition across the EU. Companies from countries with lower taxes have a competitive advantage over countries with higher taxes. Lower tax rate means lower costs and rules of equality in the European companies are therefore compromised. The Commission further has noted that these measures eliminate the competition between the uses of various energy sources because they will all be taxed and not only petroleum products, so far.

The second objective of the action taken by taxes is to avoid excessive use of fossil fuels. With the introduction of the minimum tax, enhancements will be the noticeable and higher prices will lead to greater use and promotion of alternative energy sources. For example raising taxes on petroleum products can be practical in order to force car producers to begin to use more environment friendly fuels engines (Sterner and Köhlin, 2003). According to media reports, ecologists welcomed this measure despite many

[38] This means combined heat and power electricity.

exceptions and transitional periods as a fact that the decision is seen as a first step in the fight against the use of fossil fuels.

4.2.1 Minimum Tax Rates

The minimum energy tax rates are those corresponding to the Directive 2003/96/EC. The rates are related to final energy demand exclusive to the non-energy use.[39] The implementation suggests adaptation of the rates over time to the general relative price evolution in the individual EU MS.

In the event that the fuel and energy, including electricity, are used for agricultural production, fisheries and forestry sectors, member states may set a minimum tax rate lower or even equal to zero. This difference in taxation reflects the different approach of the EU on agriculture and is fully consistent with the Common Agricultural Policy and its peculiarities. The minimum tax rates regarding individual fuels are shown in the Table 3. Compared to 2004, the rates were increased in case of diesel and kerosene while natural gas, gasoline and liquified petroleum gas (LPG) stay at the same level in 2010.

Table 3. Minimum Tax Rates: Fuels

	Minimum rate in 2003	Minimum rate since 1.1.2004	Minimum rate since 1.1.2010
Petrol (€/1000 l)	337	421	421
Unleaded petrol (€/1000 l)	287	359	359
Diesel (€/1000 l)	245	302[1]	330
Kerosene (€/1000 l)	245	302	330
LPG (€/1000 l)	100	125	125
Natural gas	100 (€/1000 kg)	2.6 (€/1 GJ)	2.6 (€/1 GJ)

Source: http://europa.eu/legislation_summaries, 2008

EU MS may differentiate fuel for commercial from non-commercial use and set for these two types different tax rates. The rate for diesel fuel for commercial use must not be less than the rate applicable in each country member since January 1, 2003. Lower tax rates may also be applied in case of fuels with low sulphur content (see the Table 4).

[39] The minimum rates do not apply on energy production and transportation.

Table 4: Minimum Tax Rate: Fuels in Industry and for Commercial Purposes

	Minimum tax rate in 2003	Minimum tax rate since 1.1.2004
Diesel (€/1000 l)	18	21
Kerosine (€/1000 l)	18	21
LPG (€/1000 kg)	36	41
Natural gas	36 (€/1000 kg)	0.3 (€/1 GJ)

Source: http://europa.eu/legislation_summaries, 2008

Different rates apply to fuels used for heating purposes (see the Table 5). For instance, natural gas is minimally taxed around seventeen times less when used for heating than in the case of other non-commercial purposes.

Table 5: Minimum Tax Rate: Fuels for Heating and Electricity

	Minimum rate in 2003	Minimum rate since 1.1.2004 (industry)	Minimum rate since 1.1.2004 (households)
Gasoline (€/1000 l)	18	21	21
Heavy heating oil (€/1000 kg)	13	15	15
Kerosine (€/1000 l)	0	0	0
LPG (€/1000 kg)	0	0	0
Natural gas (€/1 GJ)	none	0.15	0.3
Coal (€/1 GJ)	none	0.15	0.3
Electricity (€/Mwh)	none	0.5	1.0

Source: http://europa.eu/legislation_summaries, 2008

4.2.2 Transitional Period

However, the regulation establishing minimum tax rate in EU MS generally allowed a transitional period until 1 January, 2007, if the immediate introduction of minimum taxes would threaten price stability in the country. Since it is a relatively important change in taxes and prices, most EU countries bargain for this kind of period. The same procedure has been seen in new EU MS including the Czech Republic; where the European Commission confirmed the possibility to set a transition period for new EU MS. For example Portugal asked for full or partial waiver of at least a minimum tax on electricity for households by 2010; Ireland wanted the same until 2008. The transitional period for the minimum excise duty has been set on petroleum products as well. For example, Spain, Belgium, Luxembourg, Austria, Greece and Portugal wanted lower marginal tax rates on fuel for cars from 2007 till 2012. While the decision to impose a new tax was unanimously declared, it is clear that the negotiations cause difficulties. Indeed, a common minimum tax rate will apply only within the EU after all the negotiated transition periods and exemptions expire.

4.2.3 The EU Harmonization Assessment

The study of Kouvaritakis et. all (2005) analyses impacts of energy taxation in three scenarios in the framework of the EU harmonization. The first scenario works with the previous proposal of minimum tax rates COM (97)[40] and assumes that all the EU MS will implement minimum rates till 2005. The taxes are levied only on final energy consumption while energies used as inputs in industrial sector or energy production is exempted. Thus, the minimum rates have significant impacts on existing energy taxes and final prices in a majority of the states. On the contrary, in Denmark, Sweden, Finland and the UK, the impact is rather insignificant because of already similar or even higher tax rates on energy products. The Appendix 1 shows the minimum tax implementation compared to the tax rates in 2003. Western European countries have already higher taxes than minimum rates (with the exemptions of coal). In majority of new EU MS minimum scenarios were applied because energy products were not taxed before. This does not refer to transport fuels where existing taxes had to be increased to fulfil the minimum rates requirements.

Effects on GDP, employment, real wage rate or private consumption were found positive if tax revenues are used to reduce income tax, corporate tax or employers' social security contributions. In favour of the EU tax harmonization and emissions reduction speaks also substitution consequences as coal consumption is expected to fall while other energy commodity use rises.[41]

The second scenario considered by Kouvaritakis et. all (2005) is more environmentally friendly as minimum rates are higher and have a different structure (15 EUR/tonne of CO_2). The revenues from taxes are compensated in form of reduced social

[40] http://ec.europa.eu/energy/library/599fi_en.pdf, 10. 6. 2010

[41] The study examines also sectoral changes which imply the small negative impact in case of ferrous and non-ferrous metal production.

security contributions. The energy prices increase in a greater extent, and unemployment, real wages and private consumption are affected slightly positively. However, GDP increase in this case is significantly smaller than in the previous one. Within the EU the total energy consumption falls by 1.4 % favouring electricity which slightly rises compared to little decrease in the consumption of coal.

In the third scenario, minimum tax rates are imposed in a level to meet Kyoto target[42] in every country in the year 2010, although only CO_2 emissions are considered. All policy measures used to mitigate emissions according to Kyoto protocol are taken into account. Furthermore, two relevant cases are assessed - firstly, where minimum rates refer to all sectors without exemptions and, secondly, where only trading sector is exempted from minimum rates. Despite the strongest positive effect on emissions mitigation, GDP falls in almost all countries. Since revenues are recycled, employment is still affected positively in most states. Tradable allowances prices are 15 EUR/tonne of CO_2 and by 0.4 % higher in case with and without exemptions, respectively. Since the emissions targets are different across nations, the efforts for abatement pollutions vary too.

4.3 Environmental Taxes in Europe

According to Kyoto protocol, minimum energy taxes shall be implemented on electricity and specific fuels (Arcas, 2001). However, such tax rates differ within Europe. Since some countries, especially the new EU MS may experience distortion of competition due to commanded tax levels, many exemptions or rebates have been offered to them for some specific period. This refers mainly to energy intensive industries.[43] The Figure 4 portraits carbon dioxide emissions in the EU MS and their levels of Kyoto target 2012.

[42] Kyoto target is set amount of emissions which must be reduced until given year according to the Kyoto Protocol to the United Nations Framework Convention on Climate Change. For more see for example http://unfccc.int/kyoto_protocol/items/2830.php

[43] For example, the tax rate for the industrial sector in Sweden is only 25 % of the general tax rate. Energy-intensive companies in Denmark can choose whether to commit for reducing their emissions to a negotiated level. Contrary, there are no such tax reliefs in the Netherlands (Schleiniger, 2001).

Figure 4: CO2 Emissions in EU MS (2003-2007)*, Meeting Kyoto Target 2012

EU MS	2003	2004	2005	2006	2007	Kyoto Target 2012	% Under Kyoto Target
Latvia	10,7	10,7	10,9	11,7	12,1	23,3	48,07%
Estonia	21,2	21,2	20,7	19,2	22	40	45,00%
Lithuania	16,7	21,1	22,6	22,8	24,7	44,1	43,99%
Romania		160,1	153,7	153,9	152,3	259,9	41,40%
Bulgaria		68,9	69,8	71,5	75,7	127,3	40,53%
Hungary	83,3	79,5	80,5	78,8	75,9	114,9	33,94%
Slovakia	51,1	49,5	48,7	49	47	67,2	30,06%
Poland	382,5	396,7	399	399,3	398,9	551,7	27,70%
Czech Republic	147,5	147,1	145,6	149,1	150,8	180,6	16,50%
Sw eden	70,9	69,7	67	66,9	65,4	75,2	13,03%
United Kingdom	658	660,4	657,4	647,9	636,7	678,3	6,13%
France	560,9	556,1	553,4	541,7	531,1	564	5,83%
Greece	137,2	137,6	139,2	128,1	131,9	139,6	5,52%
Belgium	147,6	147,6	143,8	136,6	131,3	135,9	3,38%
Germany	1024,4	1025	1001,5	980	956,1	972,9	1,73%
							% Over Kyoto Target
Netherlands	215,4	218,4	212,1	208,5	207,5	200,4	3,54%
Portugal	83,7	84,6	85,5	84,7	81,8	77,4	5,68%
Ireland	68,4	68,6	69,9	69,7	69,2	63	9,84%
Finland	85,4	81,2	69,3	79,9	78,3	71,1	10,13%
Slovenia	19,7	19,9	20,3	20,5	20,7	18,6	11,29%
Italy	577,3	580,5	582,2	563	552,8	485,7	13,82%
Denmark	73,6	68,2	63,9	71	66,6	54,8	21,53%
Austria	92,5	91,2	93,3	91,6	88	68,7	28,09%
Spain	407,4	425,2	440,6	433	442,3	331,6	33,38%
Luxembourg	11,3	12,8	12,7	13,3	12,9	9,1	41,76%
Malta	3,1	3,2	3,4	2,9	3	No Target	
Cyprus	9,2	9,9	9,9	9,9	10,1	No Target	

Source: Europe's Energy Portal, http://www.energy.eu/#CO2
**Figures are in Megaton (Mt CO2-eq).*

This chapter focuses on some policy measures on the national level within Europe, particularly in EU MS who first introduced an environmental tax reform. Specifically, Netherlands and Scandinavian states were among the first countries which introduced CO_2 taxes. Germany increased existing motor fuels and heating fuels taxes and implemented new taxes on electricity in 1999 within framework of an environmental tax reform. The revenues from higher taxation have been compensated by reduction of employment social security contributions. Additionally, some special provisions for business sector have been introduced in form of reduced tax rate.[44] According to Kohlhaas's study (2005), who examined the effects of the German reform on GDP, labour market and CO_2 emissions[45], the overall impacts are positive. He found out that the environmental reform would

[44] 60 % of the regular tax rate for the manufacturing and the agriculture sector. Moreover, if the company's tax burden exceeds its pension contribution reliefs, the company will be refunded 95 % of the differential amount (Dannenberg, Mennel and Mosener, 2007).
[45] He used empirical general equilibrium model LEAN2000 with the BAU baseline.

increase employment by something between 0.41 and 0.76 % per year during the period 2003 - 2010. GDP would increase in range between 0.13 and 0.47 % as well. CO_2 emissions would decrease by 2 - 3 % per year. Nevertheless, the trade balance would deteriorate in the short-run due to increased import and decreased export until 2003 followed by moderate import decrease and convergence of exports to the BAU[46] level after 2003. However, the other study by Conrad and Löschel (2005) found different results. Their analysis of the environmental reform with focus on the double dividend hypothesis[47] showed some deterioration. In the case of lump-sum recycling of revenues, employment would decrease by 0.15 % and welfare by 0.55 %. In the second case when non-wage labour costs were lower, employment would increase by 0.43 % and also welfare losses would be mitigated.

New taxes were introduced in the United Kingdom in April 2001. Nevertheless, the UK[48] has a tradition of fiscally motivated taxes on energies. The Climate Change Levy[49] has determined coal, electricity, natural gas, and LPG taxes; however, they regard only the industrial and commercial use of energies, leaving households and transportation untouched.[50] Similarly, tax revenues have been used mainly for the reduction of employers' insurance contributions.

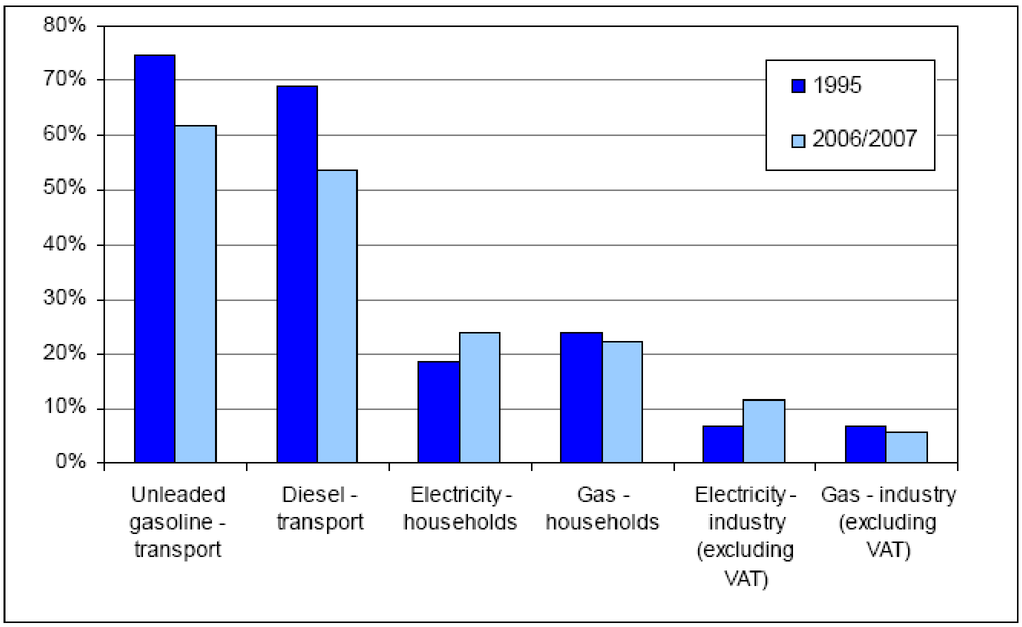
In 2007 energy taxes (taxes on mineral oils, electricity and natural gas) amounted to 1.8 % of GDP in the EU27. These taxes represent almost three quarters of the total environmental tax receipts in the EU (Eurostat, 2009). The Appendix 2 shows the share of energy and transport fuel taxes as a percentage of GDP and total taxation in the EU MS and Norway. In 2007, the highest share of energy taxes on GDP was in Bulgaria (3 %) as well as the percentage of total taxation (8.9 %) can be found in this country. The second place is occupied by Poland with its 6.9 % share of energy taxes on total taxation. Netherlands had the same percentage of GDP as Poland (2.4 %), however, in respect to the total taxation it lags behind. The Czech Republic, in this measurement, stays also quite high as it occupied the fourth place in share of total taxation (6.3 %) among the countries. Regarding taxes on transport fuels, the highest share on total energy taxes were in Latvia (100 %) followed by Lithuania (98 %) and Luxemburg (98 %). Contrary, the lowest rates

[46] Business-as-usual.
[47] They introduced a fictitious CO_2 tax in the level which reduces emissions required in the Kyoto Protocol.
[48] as well as Italy.
[49] The Climate Change Levy is a tax on energy in the UK for non-domestic consumers, for more see http://www.cclevy.com/
[50] Energy intensive sectors negotiated tax reliefs to 80 % discount of the Climate Change Levy.

were in Denmark (52 %), Sweden (56 %) and Netherlands (68 %). Together transport fuel taxes counted more than 80% share of energy taxes in the EU27 in 2007.

As shown in the Figure 5, energy taxes represent a significant part of the prices which is quite enormous by gasoline and diesel (over 70 % and nearly 70 %, respectively, in the EU15 in 1995). Until 2006 these proportions fell down to about 60 % and 54 %, respectively. Natural gas has the same path as transport fuels as its tax share was higher at the beginning of the period. Tax share in price of electricity for households' consumption, in contrast, increased to about 24 % in 2007 compared to 18 % in 1995.

The Figure 5: Proportion of Tax in Energy Prices, EU15, 2005



Source: EN32 Energy Taxes, 2008
Notes: Latest data are for 2006 for gasoline and diesel in EU-25 and for 2007 for electricity and gas in EU-15. Value Added Tax (VAT) is excluded from industry fuel taxes. Taxes are those applicable in January of each year in each Member State and have been weighted by national energy consumption to calculate average values for the EU-15.

The variability can be found by energy used in industry where the proportion of tax in its price is almost three times lower than for households. Trends in the average tax component in final energy price of household and industry purposes of transport fuels, natural gas and electricity can be found in Appendix 3.

5. Energy Taxes in the Czech Republic

Taxes on energy goods were implemented into Czech tax system within the framework of ecological tax reform. Under authority of the EU and its common policy, the Czech Republic ought to realize arrangements to contribute to mitigate main ecological problems as greenhouse gas emissions. As discussed above, the first binding enactment is the EU Directive 2003/96/EC governing taxation and mandating deadlines for implementation of minimum tax rates on energy use. According to the Directive, each EU MS has to establish or adjust, with some possibility of exemptions, its energy taxation so that they meet the minimum tax rates requirements. The structure and the phases of the reform have been discussed long before its entrance as well as its effects which are still not clear. The first aim of the reform is to provide incentives to economic agents to behave for the benefit of environmental improvement. Thus, the objects of the taxation are goods and services whose production or consumption harms environment or human health. From fiscally viewpoint, the reform increased government revenues in 2008 (see the Table 6).

Table 6: Revenues from Taxes on Energy Products and Electricity in the Czech Republic (2006 - 2008)

	Revenues from all Mineral Oils		Natural Gas		Coal and Coke		Electricity		Total Revenues from Taxes on Energy and Electricity	
	mill CZK	*mill EUR*	*mill CZK*	*mill EUR*	*mill CZK*	*mill EUR*	*mill CZK*	*mill EUR*	*mill CZK*	*mill EUR*
2005	75420,6	2484,13	-	-	-	-	-	-	75420,63	2484,13
2006	76625,3	2639,52	-	-	-	-	-	-	76625,31	2639,52
2007	80828,3	2936,52	-	-	-	-	-	-	80828,34	2936,52
2008	82064,4	3112,75	1002,88	38,04	431,6	16,37	1019,18	38,66	84518,1	3205,82

Source: Excise Duty Tables, European Commission, 2009

5.1. Ecological Tax Reform

The first phase of the Czech ecological reform was initiated in January, 2008. New excise taxes were introduced on consumption of fossil fuels (coal, coke), natural gas and electricity. A taxpayer is considered every legal or physical entity that supplies solid fuels, natural gas or electricity to a final consumer.[51] A supplier is the physical or personal entity who gathers electricity, solid fuel or natural gas in order to other sale. The obligation to

[51] Principy a harmonogram ekologické daňové reformy, 2007 (http://www.czp.cuni.cz/ekoreforma/EDR/Koncepce_EDR-20070104.pdf)

declare and pay the tax arises with day of the final delivery of the goods. Otherwise, if the good is consumed either by a producer, trader, transition system operator or distribution system operator, the obligation to pay the tax arises with the day of the consumption. If the physical or legal entity who acquired already taxed or exempted fuels, natural gas or electricity supply to other entity, she is no obliged to pay the tax. Taxation of solid fuels, natural gas and electricity in the Czech Republic is provided by Coll. 261/2007, about stabilization of public budget. The taxes conform to minimum tax rates provided by EU Directive 2003/96/EC.

According to Article 2 of EU Directive 2003/96/EC the following uses of energy products and electricity are exempted from the taxes:

- energy products used for other purposes than as motor fuels or as heating fuels;
- dual use of energy products, i.e. simultaneously used for heating and other purposes than heating or as motor fuel;
- energy products used in chemical reduction and in electrolytic and metallurgical processes;
- when used in mineralogical processes;[52]

Other exemptions apply to individual commodities as given by Coll. 261/2007,[53] about stabilisation of public budget.

According to schedule, in the second phase of the reform (2010 – 2013) the tax rates set in the first phase are going to be amended. Besides, subjects to taxation might be extended as revisions and impact assessment will be realized. The third phase is planned for the period 2014 – 2017 and its content will be set on the basis of an amendment of the EU Directive 2003/96 which is planned to be forced since the beginning of 2012. Moreover, the impact assessment of the first two parts of the Czech reform should be taken in.

[52] *'Mineralogical processes' shall mean the processes classified in the NACE nomenclature under code DI 'manufacture of other non-metallic mineral products' in Council Regulation (EEC) No 3037/90 of 9 October 1990 on the statistical classification of economic activities in the European Community* (EU Directive 2003/96/EC, Article 2).

[53] Available at http://www.sagit.cz/pages/sbirkatxt.asp?zdroj=sb07261&cd=76&typ=r (cited X.X.2010)

5.2 Tax on Solid Fuels

The tax base is amount of solid fuels in GJ of burnt heat in origin sample.[54] The tax rate is 8.50 CZK/GJ[55] of burnt heat in origin sample. The exemptions according to the Coll. 261/2007 refer further to:

- use for electricity production;
- dual production of electricity and heat in generators with given minimum efficiency, when heat is supplied to households;
- production of coke;
- use as a fuel in ships (this does not apply to private recreational sail);
- use in chemical reductions in blast furnaces;
- Technological purposes of the producer of the fuels.

5.3 Tax on Natural Gas

As a tax base is considered the amount of natural gas in MWh of burnt heat. Tax rates for the gas used as a motor fuel or for other purposes, except of below points 2 and 3, are following:

1. 264.80 CZK/MWh of burnt heat for natural gas of nomenclature codes 2711 29 and 2705[56];
2. the tax rate for natural gas of nomenclature codes 2711 11 and 2711 12 is:

   - Zero in the period 1.1.2008 – 31.12.2011

   - 34.20 CZK/MWh of burnt heat in the period 1.1.2012 – 31.12.2014

   - 68.40 CZK/MWh of burnt heat in the period 1.1.2015 – 31.12.2017

   - 136.80 CZK/MWh of burnt heat in the period 1.1.2018 – 31.12.2019

   - 264.80 CZK/MWh of burnt heat since 1.1.2020

[54] Burnt heat in origin sample is being demonstrated by special accredited laboratory at least once a year.
[55] FX rate as of 7. 7. 2010 is 25.55 CZK/EUR (www.cnb.cz).
[56] Nomenclature codes as a reference number of the commodity liable to tax for the purposes of board of customs.

3. 30.60 CZK/MWh of burnt heat for natural gas used for heat production or others (see Coll 261/2007, Article LXXII, §4).

Here, also petrol stations which sell natural gas as a motor fuel is taxed. The exemptions apply to:

- for heating purposes in households and gas fired boiler houses;
- when used for electricity production;
- for dual production of electricity and heat in generators with given minimum efficiency, when heat is supplied to households;
- as a fuel used in ships, it does not apply to private recreation sail (Coll. 261/2007).

5.4 Tax on Electricity

The tax base is considered as the amount of electricity in MWh and tax rate is 28.30 CZK/MWh. Electricity is exempted when:

- Classified as ecologically favoured;[57]
- Used in public transport of goods and passengers in railway, tube railways, trams, trolleys or electro buses;
- Produced and consequently consumed in transportation;
- Used to cover losses in transmission or distribution systems;
- Used for technological purposes essential to production and keeping ability to produce electricity or dual production of electricity and heat (Coll. 261/2007).

To compare Czech and other EU MS' minimum excise duties by energy products and electricity in accordance with Directive 2003/96/EC can be found in the figures in Appendix 4. The indices of energy prices in Czech Republic by mineral oils, coal, natural gas and electricity are shown in the Appendix 5. The significant part of increased energy prices represents VAT which has been increased in 2010 to 20 % from previous 19 %.

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[57] That is, as classified in §2 of Article LXXIV, Coll..261/2007, Article LXXII, electricity Generated from sun, wind or geothermal energy production; produced in wind generators; produced from biomass or products made from biomass; produced from methane emissions from coal mines or made from fuel assembly.

6. Optimal Energy Taxation

Each tax system shapes consumers' behaviour and therefore deforms a financial sector. Also an excise tax has the same impact, i.e. they tend to lower tax burden by limiting consumption of a product. However, some taxes can have correcting character when they are used for raising efficiency and for disposal of some market failure, e.g. negative externalities. Nevertheless, taxes lead to changes in general equilibrium in an economy; this influences distribution of incomes in society, however often in opposite direction to origin intention. The distortion is more significant in long run because economy does not comply with changes in taxation immediately.

The main idea is that energy tax may correct some environmental damages. The question is whether there could be a better tool as some similar goals may be achieved by other instruments as for example emission regulations or quotas. Regarding environment, Pigovian tax[58] is levied on industries where elimination of pollution is preferable. Theoretically, this tax penalizes those who create excess social cost, and thus reduce negative externalities in the economy since market fails to provide a suitable incentive to eliminate such externalities. This way of punishing companies that cause such costs is supposed to encourage more environmentally friendly behaviour. Generally, Pigovian tax is regressive (Atkinson and Stiglitz, 1980), i.e. the lower-income households pay proportionally more from their income) than higher-income households. Moreover, it still has the similar characteristics as other taxes, i.e. deadweight loss caused by its imposition.

Majority of European countries are net importers of energy (as shown in the Table 7). According to strategic trade theory, net importers may improve to some extent their trade terms by imposing tax on a commodity, for instance taxes on energy products or electricity. To be more specific, they may reduce profit of exporters, and thus capture part of the resource rent (Asche, Osmundsen and Tveteras, 2001). However, there are some limits of imposed duties. Energy taxes must be competitive on national level to discourage companies from moving elsewhere (Schjelderup, Osmundsen, and Hagen, 1995). Also distributional effects of energy taxes are supposed to be adverse since households with lower incomes usually spend a larger share of their budget on fuels than high-income households.

[58] Pigovian tax is a tax on externality (e.g. pollution) based on the theory of Arthur Pigou. It is more discussed in the Chapter 6.4.

Table 7: Energy consumption, net imports and dependency in Europe, 2008

	EU Member State	Gross Energy consumption[1]	Net imports	Energy Dependency[2]		EU Member State	Gross Energy Consumption	Net imports	Energy Dependency
1	Cyprus	2,60	3,00	100,0%	15	Germany	349,00	215,50	61,30%
2	Malta	0,90	0,90	100,0%	16	Finland	37,80	20,90	54,60%
3	Luxembourg	4,70	4,70	98,9%	17	EU27	1825,20	1010,10	53,80%
4	Ireland	15,50	14,20	90,9%	18	Slovenia	7,30	3,80	52,10%
5	Italy	186,10	164,60	86,8%	19	France	273,10	141,70	51,40%
6	Portugal	25,30	21,60	83,1%	20	Bulgaria	20,50	9,50	46,20%
7	Spain	143,90	123,80	81,4%	21	Netherlands	80,50	37,20	38,00%
8	Belgium	60,40	53,50	77,9%	22	Sweden	50,80	19,80	37,40%
9	Austria	34,10	24,90	72,9%	23	Estonia	5,40	1,90	33,50%
10	Greece	31,50	24,90	71,9%	24	Romania	40,90	11,90	29,10%
11	Latvia	4,60	3,20	65,7%	25	Czech Republic	46,20	12,90	28,00%
12	Lithuania	8,40	5,50	64,0%	26	United Kingdom	229,50	49,30	21,30%
13	Slovakia	18,80	12,00	64,0%	27	Poland	98,30	19,60	19,90%
14	Hungary	27,80	17,30	62,5%	28	Denmark*	20,90	-8,10	-36,80%

Source: Europes Energy Portal, 2008, http://www.energy.eu/#CO2, 15.6.2010
Notes:1) Gross energy consumption in Million tonnes oil equivalent (Mtoe). It is defined as primary production plus imports, less exports.
2) Imports divided by gross consumption.
** Denmark is a net exporter of energy.*

6.1 Traditional Optimal Environmental Taxation

Every government has to face different interests while implementing public policies. The problem of optimal environmental protection meet with theory of public economics since property rights for air and water are hardly to define and as public goods they are shared with non-rivalry and non-exclusiveness. There are no markets for such goods due the lack of private ownership. Therefore, use of these commodities is suppose to be inefficient, and this market failure need to be governed by intervention of an authority. Public policy should improve distortion market behaviour, i.e. to convert the inefficient public goods consumption to the efficient one. An absence of required ownership leads to a tendency to implement command-and-control approach which adequately contributes to intended environmental goals.

There are many interest groups with very different opinions. On one hand, energy-intensive industries rightly fear that substantial environmental regulation in sense of increasing protection will induce serious costs and burden to them. The lower income and capital outflow are not the only impacts of higher prices and lower output in an economy.

Environmental groups, on the other hand, support more ambitious goals of environmental protection. They believe that better environmental standards induce higher air, soil and water quality and that these benefits may overcome an undesirable increase of overall production costs. Such conflicting arguments generate a necessity to investigate real consequences of environmental protection in economic opportunity costs. The question is to compare costs of public expenditure with benefits from higher environmental quality, and thus to find out the real costs of the protection.

6.1.1 The Ramsey Tax

Ramsey's theory has become important guiding principle in the theory of taxation and public economics. Considering a competitive market with a linear demand and cost structure, Ramsey examined minimizing of society loss while government collects part of tax revenue.[59] He arrived at conclusion that under these conditions the efficient tax reduces all outputs by the same proportion (Jin and Lasselle, 2005). However, the reality differs and thus there is a tendency to examine his results under imperfect market competition, concretely monopoly, Cournot and Bertrand oligopolies.[60] Jin and Lasselle (2005) demonstrated that Ramsey proportional tax is loosing its efficiency under oligopoly market contrary to the case of the monopoly. They conclude that the tax revenue maximization is the same independently on the market structure. Ramsey tax is always efficient in competitive market and in monopoly. It maximizes the potential tax revenue in all markets. The partial equilibrium approach of the Ramsey's tax problem was for example analysed by Atkinson and Stiglitz (1980).

6.1.2 Tax Incidence Theory

The important task is to investigate who is actually cost bearer of energy taxes. Generally, market participants who are inflexible are usually cost bearers because they can not escape the tax. Thus, to analyse burden problem, it is necessary to investigate demand elasticity's of consumers. For a given supply elasticity the less elastic demands the larger share of tax burden. Traditional models showing tax incidence assumed spot trading.

[59] His major work on this field is the paper A Contribution to the theory of Taxation, published in the Economic Journal, 1927.
[60] Surely, there are some limitations in Ramsey's theory as linear demand and cost structure.

Asche, Osmundsen and Tveteras (2001) presented econometric analysis to investigate incidence of energy taxes and natural gas demand in the EU. However, they argued that in the case of long-term contracts, that are typical for natural gas trade, the traditional spot market tax incidence is no longer valid. The tax shift depends on the system for renegotiations of long-term contracts; however, the spot market forces may play some role in bargaining.

To get some theoretical background, let's first follow a partial equilibrium approach and a static model of incidence of an excise tax on a product by Kotlikoff and Summers (1986).[61] Consider no taxation, thus in equilibrium demand equals supply:

$$D(P) = S(P) \tag{1}$$

Imposing excise tax, τ, the new equilibrium while buyers collect the tax is:

$$D(p' + \tau) = S(p') \tag{2}$$

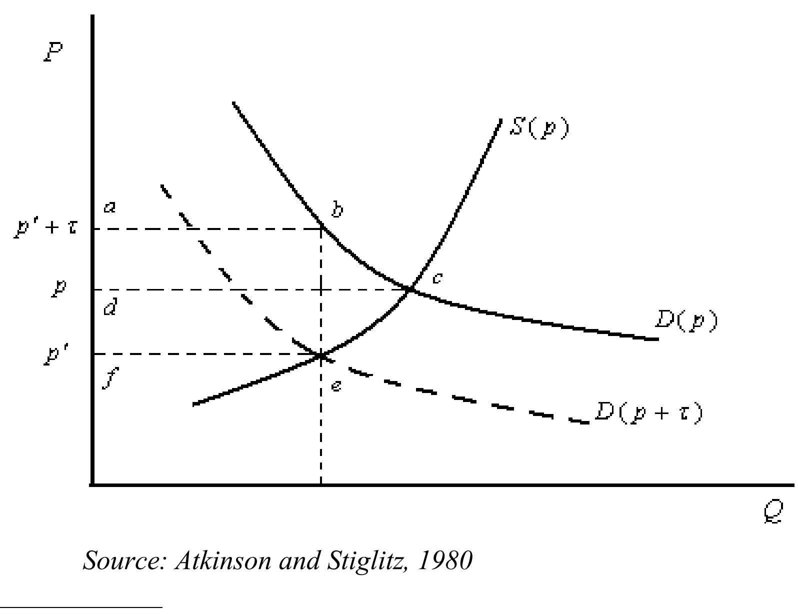
Similarly, if the tax is collected from sellers, the equilibrium satisfies:

$$D(p'') = S(p'' - \tau) \tag{3}$$

From the equations (2) and (3.) we can see that the tax presents a wedge between prices paid by the producers and consumers:

$$p'' = p' + \tau \; . \tag{4}$$

Figure 6: Tax Incentive



Source: Atkinson and Stiglitz, 1980

[61] The assumption is that such product has a relatively small market compared to the whole economy. It is necessary for using partial equilibrium theory (Kotlikoff and Summers, 1986).

The situation is illustrated in Figure 6 where in the equilibrium before imposing a commodity tax, in the point *c*, the consumer and producer price equals. The introducing tax leads to a shift in the demand curve facing suppliers or a shift in the supply curve facing consumers. In both cases, the equilibrium is the same point. Hence, it is obvious that generally the tax incidence does not depend to whom the tax is levied on. However, introduction of the tax reduces the quantity of the product and causes traditional efficiency loss, i.e. deadweight loss, given in the Figure 6 by *bce* "triangle". The area *abcd* represents the reduction in consumer surplus while the area *cdfe* the reduction in producer surplus. Since the price of the product decrease on both sides, the tax burden is shared.

Further, by differentiating (2):

$$\frac{dp}{d\tau} = \frac{D'}{S' - D'} = \frac{e_D}{e_S - e_D}, \tag{5}$$

where $D' = \dfrac{dD(p)}{dp}$ and $S' = \dfrac{dS(p)}{dp}$. As representing elasticity's of demand and supply, these can be marked as e_D and e_S, respectively. Now, the tax incidence can be assessed by changes in equilibrium due to the tax imposition. Considering a small tax, the changes in consumer and producer surplus are given by the following:

$$\frac{dCS}{d\tau} = -\frac{e_S D(p)}{e_S - e_D}, \tag{6}$$

and

$$\frac{dPS}{d\tau} = \frac{e_D S(p)}{e_S - e_D}, \tag{7}$$

where CS and PS are consumer and producer surplus, respectively. The first equation shows that consumer surplus is negatively affected by the change in the consumer price times the initial demanded quantity.

Regarding some extreme cases, we can better determine on whom the tax burden lays. For example, consider perfectly elastic supply, i.e. $e_S = \infty$, and $dp / d\tau = 0$, thus the whole burden is borne by the consumers. Illustratively, this means horizontal supply curve, hence, the producer price is given and tax burden is shift to the consumer. Contrary, if the demand is perfectly elastic, i.e. $e_D = \infty$, and $dp / d\tau = -1$, the whole tax is borne by producers. In the Figure 6, the demand curve would be horizontal and the consumer's price will be taken as given. Nevertheless, infinite elasticity is unlikely and the most common cases are those where demand and supply have finite elasticity (Kotlikoff and Summers, 1986).

There are some emerging principles of this analysis. First, the tax burden does not necessarily bears the person on whom the tax is levied, and second, being more elastic in demand and supply means bigger possibility to escape the tax and shift the burden to …. Generally, the players who can not adjust (inelastic buyers or sellers) are captured by the taxes.[62]

Coming back to empirical analysis of Asche, Osmundsen and Tveteras (2001), they estimated income elasticity and cross price elasticity from an econometric model of household energy demand to examine some general equilibrium effects of energy taxes. The net importing countries might tend to increase energy taxes, and thus cause windfall loss of the exporting business. However, the lower energy supply following by higher prices and reducing of investment incentives would mean higher costs. Tax increase or regulation, hence, has a significantly negative impact on investment incentives caused by additional costs. Moreover, they showed that an extra energy tax burden is also shifted to the producer, to some extent, and the effect on investment incentives is the similar, i.e. reducing.

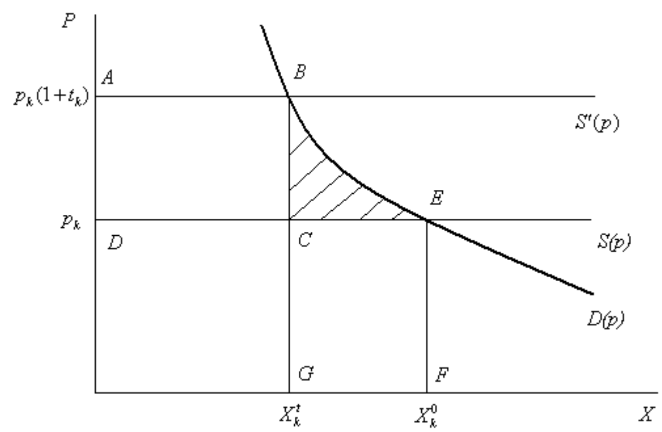
6.2 The Structure of Indirect Taxes

The public economic theory describes the structure of indirect taxation, what is in fact the case of taxes on energy consumption. The standard approach to partial equilibrium

62 Regarding energy trading, the taxes can be shifted, on one hand, to transmission companies (TSO), distribution companies (DSO) or to consumers, and, on the other hand to producers.

analysis as demonstrated in Atkinson and Stiglitz (1980) is going to be outlined in this part of the chapter.[63] Using the similar analyse as above, consider that without taxation the economy is in the equilibrium, i.e. the point *E* (the Figure 7). Assume that the supply curve is perfectly elastic in its price. After imposing the tax on good *k* (ad valorem tax), the new price of the good is $p_k(1+t_k)$ which generates the new equilibrium point *B*. X_k^0 is the quantity before tax while X_k^t denotes the new quantity after the tax is imposed. Similarly as shown above, the distortion due the tax (excess burden H_k) is projected in the area *BCE*, i.e. the loss of consumer surplus because of the horizontal supply curve.

Figure 7: Excess Tax Burden



Source: Atkinson and Stiglitz, 1980

This area can be measured as difference between the areas BEFGC and CEFG which is:

$$H_k \equiv \int_{X_k^t}^{X_k^0} q_k \ dX_k - p_k(X_k^0 - X_k^t), \tag{8}$$

where $q_k(X_k)$ is the Marshall demand function with the after tax consumer price $q_k = p_k(1+t_k)$. From (2.1) we get $\frac{\partial H_k}{\partial t_k} = -q_k \frac{\partial X_k^t}{\partial t_k} + p_k \frac{\partial X_k^t}{\partial t_k}$ which can be rewritten as:

[63] The analysis is considered in the case where no cross-price effects and income derivatives are.

$$\frac{\partial H_k}{\partial t_k} = -p_k t_k \frac{\partial X_k^t}{\partial t_k} \ . \tag{9}$$

If there are more tax rates $(t_1,...,t_n)$ on different goods, the revenue constraint[64] with required level of revenues R_0 is similar to the following:

$$R \equiv \sum_{k=1}^{n} t_k p_k X_k^t = R_0 \,. \tag{10}$$

The government maximizes its revenues while minimizing total tax excess burden. Solving the optimization problem and combining it with the equation (9), we get:

$$\frac{\lambda}{1+\lambda} = \left(-\frac{t_k}{X_k^t}\right)\frac{\partial X_k^t}{\partial t_k} = \left(\frac{t_k}{1+t_k}\right)\varepsilon_k^d \,, \tag{11}$$

where

$$\left(-\frac{t_k}{X_k^t}\right)\frac{\partial X_k^t}{\partial t_k} = \left(\frac{t_k}{1+t_k}\right)\left[\frac{p_k(1+t_k)}{X_k^t}\right]\left[-\frac{\partial X_k^t}{\partial p_k(1+t_k)}\right] = \left(\frac{t_k}{1+t_k}\right)\varepsilon_k^d \,, \tag{12}$$

and ε_k^d is the price elasticity of demand.

To maximize revenues, the Lagrange function is set as: $L = -\sum_{k=1}^{n} H_k + \lambda(R - R_0)$ and the first-order conditions: $\frac{\partial H_k}{\partial t_k} = \lambda \frac{\partial R}{\partial t_k} = \lambda p_k X_k^t + \lambda p_k t_k \frac{\partial X_k^t}{\partial t_k}$ for all k. For the precise solution see Atkinson and Stiglitz (1980), p.371-374. For the precise solution of the optimization problem see Atkinson and Stiglitz (1980 p.371-374).

The equations (11) and (12) imply the inverse proportion of the tax t_k and the elasticity ε_k^d. If the demand for the good *k* is perfectly inelastic, the excess tax burden is zero which suggests taxing the good *k* to raise revenues. Otherwise, *„the optimal tax structure can be uniform only where all goods have the same elasticity of demand. “*

[64] Producers' prices are fixed.

(Atkinson and Stiglitz, 1980, p. 369).[65] Despite these generally accepted conclusions in public finance theory, this framework has many restrictive assumptions, for example omission of cross-price elasticity or income effect.

6.3 Theory of Double Dividend

Taxes on pollution have been for a long time regarded to assist in internalization of pollution externalities. In early 1980s, the hypothesis of possible double dividend appeared as many analysts began to consider other positive feature of the taxing pollution. Besides improving environment (the first dividend), pollution taxes might reduce other distortions in tax system (the second dividend). Some analysts concluded that the existence of the second dividend can argued for a higher pollution tax than the first-best Pigouvian prescription[66], where the tax is set at level of the social marginal damages of pollution (Metcalf, 2000).

The basic features of the optimal environmental taxation research are analyses of partial or general equilibriums, mainly in static conception.[67] They assume either a first-best world with no other distortions, or the second-best world where distorting tax system already exist. The common assumption of the models in former literature is a perfect competitive market; however, many recent works examine also imperfect market structure.[68] Among the fundamental researches of optimal design of environmental tax belongs the research work of Bovenberg and DeMooij (1994). Their crucial contribution is that they found the optimal pollution tax typically lying above social marginal damages, in the presence of pre-existing distorting taxes. This detection evokes concerns about validity of the double dividend hypothesis, hence many subsequent analytical papers emphases on examine the second dividend.

The effect of most taxes is undesirable behavioural adjustments leading to labour supply or investment reduction. New taxes typically increases welfare costs by an amount called "marginal excess burden". However, such burden may be moderated by reduced

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[65] With quotation of Pigou, they remark that for given revenue the best are tax rates which are progressively higher as demand or supply are less elastic.

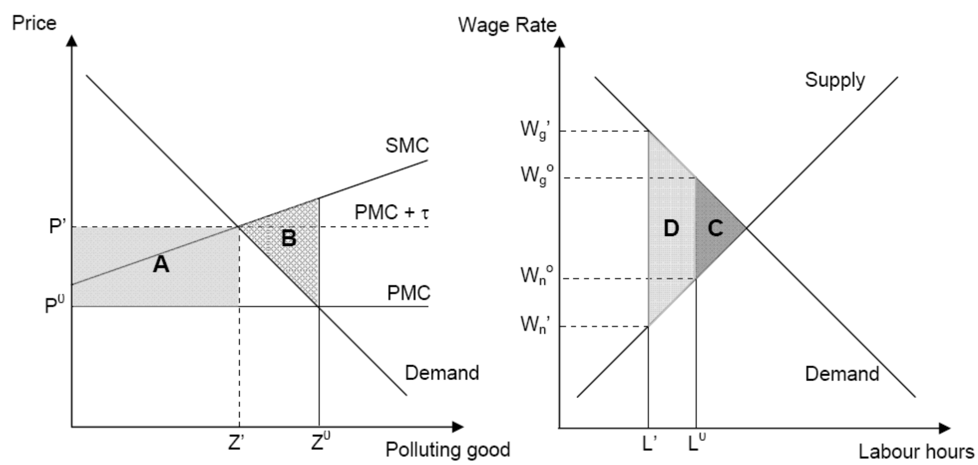
[66] The Pigouvian prescription for correcting an externality.

[67] For dynamic approach of optimal environmental taxation see for example Glomm, Kawaguchi and Sepulveda (2004).

[68] See for example Küster and at. (2007).

welfare cost for example in labour market. The right side of the Figure illustrates the supply and demand for labour where the quantity of origin labour is L_0. The gross wage is represented by *Wg* and the net wage is *Wn.* The excess burden due to the labour tax represents the area C. After increasing tax, the gross wage rises to the *Wg´* creating the area D, i.e. marginal excess burden.

Figure 8: Taxation of Polluting Good Accompanied by Cuts in Labour Tax Rate



Source: Fullerton, Leicester and Smith (2008)

The hypothesis of double dividend is supported by the following example. If collected revenues are recycled by cutting wage tax, it may lead to the welfare gain B (the right side of the Figure 8), thus fixing the pollution problem, and simultaneously to the reduction of welfare cost C due to rise in net wage. This is the implication of the reduced the real net wage *Wn´*, since a new tax on pollution good higher its price and hence the overall consumption costs. Besides, on of the conclusion of the study by Bovenberg and de Mooij (1994) is that labour supply depends on this *real* net wage.

6.4 The Model of Optimal Environmental Taxation

To simply assess optimal taxation I employ the model of Bovenberg and de Mooij (1994) where the linear production function is described as following:

$$N\iota L = NC + ND + G \tag{13}$$

With the input labour, L, which produce a clean good, C, a dirty good, *D,* and government services, G. Whereas each private good is expressed per capita, there are N identical households in the economy. The constant term ι is a labour productivity. Household utility, *U*, is a function of the private goods, C, *D*, and leisure, V, and the public goods G and environmental quality, E:

$$U = u(C, D, V, G, E) \tag{14}$$

The supply of both public goods is given. The environmental quality is a function of the aggregate production of the dirty good: $E = e(ND)$, where $e' < 0$. Households maximize utility with a budget constraint:

$$C + D(1 + t_d) = \iota(1 - t_l)(1 - V) \tag{15}$$

where t_d denotes the pollution tax on consumption of a dirty good and t_l is a tax rate (ad valorem) on labour income. This tax causes distortions on labour market. Besides budget constraint, households are subjected to a time endowment $V + L = 1$. The government budget constraint is given by Walras law as a combination of the household budget constraint (15) and market equilibrium (13):

$$G = t_d ND + t_l \iota NL \tag{16}$$

If employing a revenue-neutral tax reform, thus $G' = 0$. Its effects on welfare are derived from:

$$dU = -\frac{\partial u}{\partial V} dL + \frac{\partial u}{\partial C} dC + \frac{\partial u}{\partial D} dD + \frac{\partial u}{\partial E}\left(\frac{de}{d(ND)}\right) NdD \qquad 17)$$

Optimizing household's behaviour, I use the first-order conditions and together with equation (13), I get:

$$\frac{dU}{\lambda} = \iota t_l dL + \left[t_d - N\frac{\partial u}{\partial E}\left(-\frac{de}{d(ND)}\right) / \lambda \right] dD \tag{18}$$

where λ is a marginal utility of income, the first term on the right side presents the effect on the labour market distortion and the second denotes the environmental distortion effect.

As mentioned above, the first-best world corresponds to a case without other distortion taxation, i.e. $t_l = 0$. Thus, the optimal value of t_d is:

$$t_d^{\ *} = N\frac{\partial u}{\partial E}(-\frac{de}{d(ND)})/\lambda \tag{19}$$

where $t_d^{\ *}$ is the Pigovian tax. In such case, the consuming less dirty goods leads to beneficiary impacts on environment which would offset adverse impacts on welfare caused by a reduction of the tax base. Since there is no tax on labour income, the social benefits would be offset by the social opportunity costs of additional employment, thus there would be no impact on welfare due to changes in employment.

However, other case occurs with the presence of labour-income taxation, i.e. with the distortion $t_l > 0$. Hence, the optimal environmental tax needs to be assessed along with employment response to a change in the tax base. First, assume that public consumption does not change i.e. $\hat{G} = 0$. As Bovenberg and de Mooij (1994) pointed out, the model is log-linearized[69], which leads to a government budget constraint, divided by $(1-t_l)\iota NL$, in a new form:

$$\hat{b}' = -\hat{t}_l - \Phi_d \hat{t}_d \tag{20}$$

where $\Phi_d = D(1+t_d)/\left[C + D(1+t_d)\right]$ stands for the share of D in household's consumption.[70] Hence, the effect of the tax base can be defined:

$$\hat{b}' \equiv \frac{t_l \hat{L} + t_d a_d \hat{D}}{1-t_l} \tag{21}$$

where $a_d = (D/\iota L) = (1-t_l)\Phi_d/(1+t_d)$ denotes the share of D in the output, $t_l \hat{L}$ is the effect of the labour tax on the tax base and $t_d a_d \hat{D}$ then the effect of the tax on pollution. Let the real wage after tax be $w = \iota(1-t_l)/p$ where ι denotes wage before tax and p denotes the consumption price index. Hence:

[69] Log-linearization approach can be found in prior research papers.

[70] $\hat{t}_l = dt_l/(1-t_l)$; $\hat{t}_d = dt_d/(1-t_d)$

$$\hat{w} = -\hat{t}_l - \Phi_d \hat{t}_d \qquad 22)$$

If $\hat{b}' < 0$ in the equation (20), where right side of the equation presents the relative change in the wage after tax,....Assume that household utility is the following function where *Q* which is here the function aggregating consumption of clean and dirty goods[71]:

$$U = u(G, E, H(V; Q(C, D))) \qquad (23)$$

Public consumption and environmental quality do not have direct impact on private demand.[72] If there are no environmental externalities, thus a uniform tax on Q will be optimal (Bovenberg, de Mooij, 1994). To define labour supply, let's optimize household utility (23) under constraint (14). Hence, the labour supply is generated by the real wage after tax.[73]

$$\hat{L} = \theta_l \hat{w} \qquad (24)$$

where θ_l means the uncompensated wage elasticity of labour supply. Let σ_V be the elasticity of substitution between *Q* and *V*, thus $\theta_l = V(\sigma_V - 1)$. If σ_V exceeds unity, hence the substitution effect outweighs the income effect. Household's consumption of dirty goods is:

$$\hat{D} = \hat{L} + \hat{w} - (1 - \Phi_d)\sigma \hat{t}_d \qquad (25)$$

where the elasticity of substitution between C and D in Q is indicated by σ. To express change in employment, the equations (21), (22), (24) and (25) into the government constraint in the form of (20) resulting in:

$$\Delta \hat{L} = -\theta_l t_d a_d (1 - \Phi_d)\sigma \hat{t}_d \qquad (26)$$

where $\Delta \equiv 1 - (t_l + a_d t_d)(1 + \theta_l) > 0$. The equation shows that if $\theta_l > 0$, an increase in t_d will negatively affect employment. The reduction in labour supply is caused by decline in the real wage after tax.[74] Since the environmental tax causes distortion in composition of the

[71] Q is homothetic function.
[72] *G,E* are separable from private good, i.e. *C, D*.
[73] The labour supply does not depend on the price of *D* or *E*.
[74] This is due to the fact that the reducing labour income tax does not fully offset the effect of pollution tax in consumers´ real wage (Bovenberg and de Mooij, 1994).

consumer consumption, obviously, the tax on labour income seems to be more efficient to finance public expenditures. Despite environmental quality improving, the distortions negatively influence real labour income. Since the supply of collective goods is higher due to better environment, the consumers may supply less labour as the costs of such goods are paid by labour.

To define the optimal tax on pollution, the welfare effects of marginal changes in taxes should be assessed. The equation (18) shows that if there is an initial positive tax on labour, i.e. the second best world with pre-existing distortions, the welfare will increase. Specifically, in such case the second term on the right side of the equation is equal zero, the labour increases due to the lower environmental tax which implies the positive first term on the right side. Contrary, in the first-best world, where $t_l = 0$, the marginal reduction in pollution tax below Pigovian level does not have effect on welfare. Hence, as it is the main conclusion of this analysis, with pre-existing distortion taxes, the optimal environmental tax is lower than social damage from pollution.

Regarding the compensation, the more convenient measure for revenue recycling seems to be cuts in distortion taxes rather than lump-sum transfers. More distortions due to the higher tax burden negatively affect employment, thus, lowering the labour taxes has probably less adverse impact on employment. Since the additional revenues from environmental taxes recycled through the cuts in existing taxes reduce costs, this confirms the existence of the double dividend hypothesis.

A little bit different viewpoint has Metcalf (2000) who promotes the deeper understanding of impacts on environmental quality. He suggests focusing more on how a level of tax distortions is related to environment improvement rather than changes in optimal tax rates.

7. Economic and Social Impacts of Energy Taxation

In this part I apply general equilibrium model to assess impacts of energy taxes on an economy. First, I introduce the basis characteristic of general equilibrium model used to evaluate an environmental policy. In the next part I solve numerical model adapted on the Czech economy. Energy taxes implemented in the Czech tax system have already been discussed in the Chapter 5. Since they are rather specific taxes than ad-valorem, I imply conception tax rates in the model.

7.1 General Equilibrium Approach to Policy Assessment

With constantly growing concerns about environment, some alterations have been implemented in national policies. Nevertheless, any decision-making to introduce a new environmental tool need to be assessed from its implication aspects. Energy taxes have broad impacts on an economy because of their enormous use as inputs in industry production or simply for households' consumption. To find out effects of an individual environmental policy, the most common tools are computable general equilibrium models (CGE) which on the basis of equilibrium across a set of markets employ concrete data to investigate changes in key economic indicators. However, the relations between actors affected by environmental measurements are too complicated and CGE models simplify the reality. Assumptions of the models, which I will discussed below, are, indeed, sometimes far from real situations, thus, the solving of the model should be taken with some respect. In particular, ascertained results are very depending on input data and chosen procedure.

The very foundation of the modelling economic impacts of policies to protect environment can be found in the beginning of 1980s. The first surveyed questions of GHG emission abatement used to be assessed mostly via input-output analysis and Keynesian macroeconomic models. Whereas the latter focus on investigation of crucial macroeconomic indicators and reflect economic behaviour as a whole, the first, based on I-O tables for a specific national production, have microeconomic backgrounds. With progress of time, researchers started to develop CGE models which apply I-O tables too but are more complex.

To outline basic features, the CGE models analyse efficient allocation of resources from the microeconomic viewpoint. They work with utility functions of consumers and design an optimization problem. The crucial assumption of the models is that each market gets into equilibrium which is shown through equations proceeding from the theory of Walras, followed by Arrow and Debreu, for example.

Data used in CGE models reflect system on national accounts in form of social account matrix (SAM) which proceeds from national I-O tables. SAM consists of a specific number of sectors which are aggregated or disaggregated in accordance to available data and convenient structure. The other required data are elasticity of substitution between individual inputs which are estimated. The calibration of the model provides shares of inputs adequate to data in SAM. Regarding financial flows, the CGE model can work without money as a unit of account; mostly just barter trade is used. Hence, there is a fix price, i.e. numeraire, and relative prices.

The general equilibrium approach to model policy scenario has been used widely in many research papers. It has become quite prestigious between policy analysts, theorists or other researchers. One of the reasons is its complexity and the inherent potential to respond to broad requirements. As the models have been developed from the basic to the more extent ones, the initial assumptions of ideal cases have been reassessed and some key limitations detected. In particular, model outcomes were often found not corresponding to the expectations, thus, the necessity to new applications emerged.

The discussed approach, as mentioned above, has some significant contribution to assessing the environmental policy. The important strength steams from its microeconomic basis enabling to analyse behaviour of economic agents. The principle of optimisation and decision-making are instrumental towards integrating all behaviours together and describing how it would be if the markets are in equilibrium. The theoretical foundations of the models enable to find crucial factors explaining the simulation results which might not be easily predictable. *Moreover, the embodied theory also provides a precise check on the validity of the results, since it is impossible - except for errors - that the model will lead to results which are contrary to what the underlying theory predicts* (Borges, 2008, p.16*).*

The major benefit of the CGE models is that they can simulate complex interrelationships with all considered agents and markets, even allowing for many related factors. The whole bunch of effects may be embodied in a relatively simple structure.

Moreover, the general equilibrium method is useful by assessing policy with broad distension because of its feature to make an analysis internal consistent.

The models are practically useful acknowledges also their highly disaggregated structures which have been recently formed. Such kinds of the models allow considering many structural issues related to inefficiencies on the market, as for example taxes, which might not be possible in the aggregated forms. That is, sometimes very detailed of sectors are needed. According to the theory of the second best world, the overall allocation of resources is not automatically improved by mitigating single inefficiency on the market. If there are other distortions, the even deterioration can occur in such case because so much inefficiency on the market may cancel out. An undoubted strength of the CGE models is the computable part, that is, they can numerically solve policy with substantial changes in relative or absolute terms.[75] The important advantage is also the greater possibility to assess welfare changes under a new policy measures. The policy impacts, whether structural or distributional, need to be analysed not only by rough estimates of income or gross national product but also by other consequences has to be found. Such example may illustrate energy taxation as a form of indirect tax is likely to have, by changes in relative prices of energy commodity, significant impact on the consumers demand and their welfare. *In particular, explicit welfare measures embodied in these models help explain how the situation of a consumer or group of consumers as changed, what factors contributed to improve or worsen it, and what is the relative weight of each one* (Borges, 2008, p.19).

Contrary to indisputable advantages of the general equilibrium approach, it has some lacks declining its capability if not even discouraging from its use. The complex structure including many parameters leads us to acknowledge one of the most substantial weaknesses of the method, that is, the empirical validation. Choice of the form of the model and its parameters is the crucial step. The parameters are not here estimated in econometric analysis but rather independently or obtained from literature. Hence, the models are rather able to show a tendency of the economy than forecast real facts.

The assumptions of the CGE models may vary across their structures. However, there is a fundamental assumption of market equilibrium which have to be reached. Otherwise, economic agents' behaviour cannot be asses until the markets get into

[75] The general equilibrium model may not depend on assumption of a small change as some other mathematical models based on differential calculus which is applicable only for small contemplated policy ganges (Borges, 2008).

equilibrium. This might be disputable in case of some policy for which the state of persistent disequilibrium is important. The other weaknesses can be found in a specific type of the models. As mentioned above, the models were developed and their structure notably changed since the first ones. More inter-temporal analysis started to be considered replacing static aspects to dynamic ones. However, still the static approach is often used for its simplicity so the problem arises in treatment of expectations and investment decisions.

7.2 The CGE Model

In this part of the thesis I employ a CGE model to study the effects of energy taxes and some of its main distributional consequences. Generally, taxes on goods and services have many direct and indirect effects influencing interrelated sectors. A general equilibrium framework is used to capture possible interactions and changes in prices, consumption, production and social welfare. In the first place, I analyse how an implementation of new energy tax affect these variables. The questions asked here are whether tax on energy good changes consumer and producer behaviour in favour of lower energy demand and whether it leads to actions which may lead to environmental quality improving. However, the aim of the thesis is not assess all environmental consequences, which would require more complex analysis, thus, the real impact on amount of emissions produced is not captured here.

7.2.1 The Model Structure

To demonstrate likely implications of energy taxation, I follow Shoven and Whalley (1984) CGE model for tax policy evaluation.[76] This is a simple general equilibrium interpretation in the case of a closed economy; however, as one of the fundamental model structure it can easily demonstrate target policy impacts. Since the model is based on Walrasian general equilibrium, the three market clearance conditions must be satisfied which I will denote later. First, let's specify the structure of the economy. There are two final goods produced, energy and non-energy. Firms rent two factors of production, capital and labour, owned by households; households consume produced goods

[76] The origin of the model comes from Arrow-Debreu interpretation and can be found in Arrow and Hahn (1971).

and services and have initial endowments of the factors but no initial endowment of goods. Since energy taxes are likely to have greater negative impact on low-income households, I keep two types of consumer in the model as in Shoven and Whalley (1984). High-income households are represented by a rich consumer who owns the capital. Contrary, low-income group represented here by a poor consumer owns the labour. The consumers do not demand the factors which mean that there is no choice between labour and leisure. For the simplicity, I consider government only as a collector of taxes, thus while imposing taxes, the revenue is directly distributed to the consumers.

Consumer's Behaviour:

The consumers maximize their utility under the budget constraint. The utility is the CES function, with technical coefficients of the function α_i, and elasticity of substitution σ, followed by:

$$u = \left(\sum_{i=1}^{2} \alpha_{i,c}{}^{1/\sigma} X_{i,C}^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)} . \tag{7.1}$$

The household's optimization problem is expressed:

$$\max_{X_{i,C}} u(X_{1,C}, X_{2,C}) \text{ s.t. } \mu = \sum_{i=1}^{2} p_i X_{i,C} \quad , \tag{7.2}$$

which is subjected to the budget constraint:

$$p_1 X_{1,C} + p_2 X_{2,C} \leq p_L L + p_K K = I_C \ , \tag{7.3}$$

where *L* and *K* are the factors of production with prices $p_{L,} p_K$.

By maximizing the utility function subjected to the budget constraint, the final product demands are, hence, expressed as:

$$X_{i,C} = \frac{\alpha_{i,C} I_C}{p_i{}^{\sigma} (\alpha_{1,C} p_1^{(1-\sigma)} + \alpha_{2,C} p_2^{(1-\sigma)})} \quad , \tag{7.4}$$

where $i = \{1,2\}$ and $c = \{1,2\}$. The exact expression of the demand functions deriving from the optimization problem is shown in Appendix 6.

Producer's Behaviour:

The production function is the CES technology with the assumption of constant-return-to scale.[77] For two factor of production follows:[78]

$$Q_i = \phi_i \left(\delta_i L_i^{(\sigma_i - 1)/\sigma_i} + (1-\delta_i) K_i^{(\sigma_i - 1)/\sigma_i} \right)^{\sigma_j/(\sigma_j - 1)}, \tag{7.5}$$

where Qi denotes output of the i[th] industry sector and ϕ_i is the scale parameter, σi is the elasticity of factor substitution, $i = \{1,2\}$.

The optimization problem is solved by minimizing production costs subjected to the production technology:

$$\min p_L L + p_K K$$

$$\text{s.t. } f(K,L) = \phi \left(\delta_i L_i^{(\sigma_i - 1)/\sigma_i} + (1-\delta_i) K_i^{(\sigma_i - 1)/\sigma_i} \right)^{\sigma_j/(\sigma_j - 1)} = Q. \qquad 7.6)$$

Hence, factor demands can be derived as:

$$L_i = \phi_i^{-1} Q_i \left(\delta_i + (1-\delta_i) \left(\frac{\delta_i p_K}{(1-\delta_i) p_L} \right)^{(1-\sigma_i)} \right)^{\sigma_i/(1-\sigma_i)}, \tag{7.7}$$

and

$$K_i = \phi_i^{-1} Q_i \left((1-\delta_i) + \delta_i \left(\frac{(1-\delta_i) p_L}{\delta_i p_K} \right)^{(1-\sigma_i)} \right)^{\sigma_i/(1-\sigma_i)}. \qquad 7.8)$$

Market Clearing Conditions:

The first of the general equilibrium conditions is the commodity market clearance, given by:

$$Q_1 = X_1^1(p_1, p_2, p_L, p_K) + X_1^2(p_1, p_2, p_L, p_K), \qquad 7.9)$$

$$Q_2 = X_2^1(p_1, p_2, p_L, p_K) + X_2^2(p_1, p_2, p_L, p_K). \tag{7.10}$$

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77 A production function f (K; L) refers to constant returns to scale if $f(\lambda K, \lambda L) = \lambda f(K,L)$ for $\lambda > 0$.

78 Since output Q is determined by the market (not by the firm) and conditionally on the activity level of the associated sector , it is rather convenient to call the demand functions „conditional".

The similar conditions must satisfy market of factors:

$$\overline{K} = K_1(p_{L,}p_{K,}Q_1) + K_2(p_{L,}p_{K,}Q_2), \quad (7.11)$$

$$\overline{L} = L_1(p_L, p_K, Q_1) + L_2(p_L, p_K, Q_2). \quad 7.12)$$

where $\overline{K}$ and $\overline{L}$ represents fixed amounts of capital and labour, respectively.

The zero profit conditions in our economy are met by the following equations where total revenues equal to total costs:

$$p_1 Q_1 = p_K K_1(p_L, p_K, Q_1) + p_L L_1(p_L, p_K, Q_1), \quad (7.13)$$

$$p_2 Q_2 = p_K K_2(p_L, p_K, Q_2) + p_L L_2(p_L, p_K, Q_2). \quad (7.14)$$

To have the CGE complete to solve, production and demand parameters have to be specified. I also have to set origin endowment of the production factor which are fully employed. Behaviour in general equilibrium model is affected only by relative prices, thus, price of the labour is chosen as numeraire. The Table 8 demonstrates chosen parameters. For the overview of the parameters see the Appendix 6.

Table 8: Model Parameters

Demand Parameters				**Endowments**	
	$\alpha_{1,C}$	$\alpha_{2,C}$	σ_C	K_C	L_C
Rich Consumer	0,5	0,5	0,5	30	0
Poor Consumer	0,3	0,7	0,5	0	60
Production Parameters					
	φ_i	δ_i	σ_i		
Energy	1,5	0,6	0,8		
Non-energy	2	0,7	0,8		

Although choosing the convenient value of parameters seems to be crucial part of the setting the model, there is always lack of the information and many research papers use the parameter values from previous analyses. As estimating of elasticity parameters is not an objective of the thesis I take the elasticity of substitution between energy goods and non-energy goods from Böhringer, Welsch and Löschel (2001) as 0.5 for both consumers and elasticity between factors as 0.8. I keep the same values as in Shoven and Whalley (1984) for other parameters. Endowment of capital and labour are set as 30 and 60, respectively.

Now, with all the parameters and general equilibrium conditions set, I can solve the problem as minimizing the sum of square errors of three given conditions while changing variables, i.e. prices and quantities. Since p_L is standardized to 1, leaving us with the five solution variables, the final number of market clearing equations identifying the model is five. To get the initial values of variables fitting to the model, I need to set starting value of quantities. Here, I choose the similar approach as in Peng (2007) which is setting the initial value only for one quantity produced. Thus, I set Q_1 as 75 units and Q2 as zero.[79] When the model is calibrated to the given parameter data, I can simulate the several scenarios to assess various tax policies.

7.2.2 The CGE Model with Taxes

To incorporate tax policy to the model structure, tax parameters are introduced. Hence, demand function is modified:

$$X_{i,C} = \frac{\alpha_{i,C} I_C}{p_i^{\sigma}\left(\alpha_{1,C}(t_1+p_1)^{(1-\sigma)} + \alpha_{2,C}(t_2+p_2)^{(1-\sigma)}\right)} \quad , \qquad 7.15)$$

where t_1 and t_2 are taxes imposed on energy and non-energy goods, respectively. Consumer's income with taxes on labour and capital is:

$$I_C = (1-t_L)p_L L + (1-t_K)p_K K \; . \qquad (7.16)$$

Factor demands changes to:

$$L_i = \phi_i^{-1} Q_i \left(\delta_i + (1-\delta_i)\left(\frac{\delta_i (p_K + \tau_{K_i})}{(1-\delta_i)p_L}\right)^{(1-\sigma_i)} \right)^{\sigma_i/(1-\sigma_i)} \quad , \qquad 7.17)$$

and

$$K_i = \phi_i^{-1} Q_i \left((1-\delta_i) + \delta_i \left(\frac{(1-\delta_i)p_L}{\delta_i (p_K + \tau_{K_i})}\right)^{(1-\sigma_i)} \right)^{\sigma_i/(1-\sigma_i)} \quad , \qquad (7.18)$$

[79] It is convenient to set initial values of price variables equal to unity and the quantity variables equeal to the corresponding values in the SAM (Sue Wing, 2004).

where τ_{K_i} is the tax on imposed on capital income in i[th] product sector. The industry output is taxed by τ generating total revenue and total cost function of both sectors as following:

$$(1-\tau)p_1Q_1 = (1+\tau_{K_i})p_K K_1 + p_L L_1 \quad , \tag{7.19}$$

$$(1-\tau)p_2Q_2 = (1+\tau_{K_2})p_K K_2 + p_L L_2 \quad . \tag{7.20}$$

In order to assess tax policy in the model, the new solution variable is T is added, denoting the total tax revenue collected by government from the consumers and producers. The sums of revenue are represented by two following equations:

$$T_C = \sum(t_i p_i X_{i,C}) + t_L p_L L + t_K p_K K \quad , \tag{7.21}$$

$$T_S = \sum(\tau p_i Q_i + \tau_{K_i} p_k K_i) \quad . \tag{7.22}$$

Following Shoven and Whalley (1984) I assume that tax revenue are distributed between households unequally, 60 percent of revenue to the representative poor consumer and 40 percent to the rich consumer.

7.3 Tax Policy Scenarios

To investigate the effect of energy taxation, I compare the baseline scenario without taxes (the Benchmark Scenario) with three alternatives. The first alternative scenario is the situation in which there is tax on energy good without other distorting taxes; in the second other additional taxes are imposed. The third alternative scenario implies higher energy tax while some of the factor taxes are lowered. The aim of such scenarios is to compare social and welfare changes taking account different tax policies. Although the introduced CGE model is quite simple and distant from the reality, it may show the likely effects caused by new tax policy implementation.

7.3.1 Benchmark scenario

In the baseline scenario, there are no taxes, thus $t_1, t_2, \tau_{K_i}, \tau = 0$. For the benchmark performance the price and quantity variables have been set (see above) generating the equilibrium solution which is summarized in the Table 9.

Table 9: Equilibrium Solution in Benchmark Scenario

	Energy	Non-energy	Capital	Labour
Equilibrium Prices	1,4158	0,9753	1,1872	1,0000
	Energy	Non-energy	Total	
Factor Demand				
Capital	14,243	16,450	30,693	
Labour	22,601	37,170	59,771	
Product Supply				
Qi	28,004	57,180		
Profit Maximization				
Total Revenue	39,648	55,765		
Total Costs	39,511	56,700		
	Rich Consumer	Poor Consumer	Total	
Factor Supply				
Capital	30	0	30	
Labour	0	60	60	
Product Demand				
Energy	13,747	14,431	28,178	
Non-energy	16,564	40,572	57,136	
Other Variables				
Income	35,617	60,000	95,617	
Utility	30,049	54,603		

Source: own calculations

7.3.2 Alternative Scenario 1

The first alternative scenario reflects the situation where only tax on the energy good is implied, i.e. $t_1 > 0$ while other taxes are kept zero. The tax is regarded as lump-sum tax. I chose the two different values for the tax, 10 % and 20 % to see the size of the changes while implemented different tax rates. The results are summarized in the Table 10.

Table 10: Equilibrium Solution with 10 % tax on energy good

	Energy	Non-energy	Capital	Labour
Equilibrium Prices	1,4891	0,9582	1,1879	1,0000
	Energy	Non-energy	Total	
Factor Demand				
Capital	14,239	16,445	31	
Labour	22,604	37,174	59	
Product Supply				
Qi	28,003	57,177		
Profit Maximization				
Total Revenue	39,222	54,804		
Total Costs	39,519	56,709		
	Rich Consumer	Poor Consumer	Total	
Factor Supply				
Capital	30	0	30	
Labour	0	60	60	
Product Demand				
Energy	13,662	14,446	28,108	
Non-energy	16,515	40,747	57,262	
Other Variables				
Income	35,637	60,000	95,637	
Utility	29,907	54,778		

Source: own calculation

After a 10 % tax on energy good is imposed, the marginal cost of the good increases which leads to new higher price (1.4891 vs. 1.4158). Simultaneously, the price for non-energy goods decreases (0.9582 vs. 0.9753). The changes by consumer demands are as presumed. Total demand for energy goods decreases (28.108 vs. 28.187) while total demand for non-energy good increases (57.262 vs. 57.136). If we look on each consumer separately, the simulation leads to the following results: the rich consumer demands higher amount of energy good (13.662 vs. 13.747) and lower amount of non-energy good (16.515 vs. 16.564). The behaviour of the poor consumer is the same for non-energy good (40.747 vs. 40.572), however, his energy good demand increases as well (14.446 vs. 14.431).

Imposing higher energy tax at rate 20 % will cause little changes (see Table 11) as expected, i.e. higher energy price (1.5119 vs. 1.4891) and decreased demand for energy goods (27.962 vs. 28.108).

Table 11: Equilibrium Solution with 20 % tax on energy good

	Energy	Non-energy	Capital	Labour
Equilibrium Prices	1,5116	0,94322	1,17974	1,0000
	Energy	Non-energy	Total	
Factor Demand				
Capital	14,283	16,504	31	
Labour	22,549	37,103	59	
Product Supply				
Qi	28,000	57,177		
Profit Maximization				
Total Revenue	38,751	53,931		
Total Costs	39,392	56,573		
	Rich Consumer	Poor Consumer	Total	
Factor Supply				
Capital	30	0	30	
Labour	0	60	60	
Product Demand				
Energy	13,492	14,470	27,962	
Non-energy	16,343	40,898	57,241	
Other Variables				
Income	35,392	60,000	95,637	
Utility	29,563	54,943		

Source: own calculation

7.3.3 Alternative Scenario 2

In this scenario I include also other taxes into the model to observe behaviour of variables in the presence of other distorting taxes. I impose only some additional taxes as tax on labour and capital at rate 15 % and output tax at rate 20 %. I keep the 20 % tax on energy good, other taxes still equal zero. The results are summarized in the Table 12.

Table 12: Solution with 20 % tax on energy good and other taxes

	Energy	Non-energy	Capital	Labour
Equilibrium Prices	1,1278	0,9011	0,8671	1,0000
	Energy	Non-energy	Total	
Factor Demand				
Capital	16,452	19,454	36	
Labour	20,308	34,204	55	
Product Supply				
Qi	27,967	57,275		
Profit Maximization				
Total Revenue	31,541	51,611		
Total Costs	34,577	51,081		
	Rich Consumer	Poor Consumer	Total	
Factor Supply				
Capital	30	0	30	
Labour	0	60	60	
Product Demand				
Energy	9,907	16,779	26,686	
Non-energy	11,084	43,7798	54,883	
Other Variables				
Income	22,111	60,000	82,112	
Utility	20,925	60,418		

Source: own calculation

Surprisingly, both sector prices decrease in comparison to the benchmark set. Since the price of capital falls, the factor demand increases in both sectors. Supply of energy sector increases, while slightly decreasing in non-energy sector. Similarly, in this scenario, the product demand increases only by poor consumer despite the opposite path in case of rich consumer and total demand. Thus, the relevant utility function follows the direction of the demand shift.

7.3.4 Alternative Scenario 3:

The final assessment refers to the situation when some of the distorting taxes are lower as for example labour or corporate tax. I keep all taxes the same as in the previous scenario except of taxes on labour and capital which decreased to 10 %. The Table 13 shows the solution.

Table 13: Solution with 20 % tax on energy and decreased tax burden

	Energy	Non-energy	Capital	Labour
Equilibrium Prices	1,1713	0,9092	0,9218	1,0000
	Energy	Non-energy	Total	
Factor Demand				
Capital	15,997	18,841	35	
Labour	20,731	34,769	56	
Product Supply				
Qi	27,976	57,282		
Profit Maximization				
Total Revenue	32,770	52,084		
Total Costs	35,477	52,136		
	Rich Consumer	Poor Consumer	Total	
Factor Supply				
Capital	30	0	30	
Labour	0	60	60	
Product Demand				
Energy	10,8247	16,325	27,149	
Non-energy	12,285	43,234	55,519	
Other Variables				
Income	24,888	60,000	84,889	
Utility	23,016	59,358		

Source: own calculations

7.3.5 Social Welfare Analysis

The important question in this field is whether such proposed policy has significant effect on social welfare. One of the simple approaches often used is a welfare analysis based on Hicksian compensating variation (CV) and equivalent variation (EV) associated with the consumer incomes and utilities.[80] The principle is to compare their incomes and utilities in equilibrium solutions before and after implementation of a tax policy. The CV and EV are denoted as:

$$CV = I^A \frac{U^A - U^B}{U^A}, \qquad (7.23)$$

$$EV = I^B \frac{U^A - U^B}{U^B}, \qquad (7.23)$$

where I^A denotes income of the consumer in alternative scenario, i.e. with 10 % tax on energy good, I^B denotes income in benchmark scenario. Similarly, U^A is the utility after implementing tax and U^B is the utility before the taxation. As shown in the Table 15, both

[80] Such approach can be found for example in Shoven and Whalley (1984) or in Peng (2007).

total CV and EV are negative which means that the welfare deteriorates in the case of introducing 10 % tax on energy goods. The same generates the Alternative Scenario 2.

Table 15: Welfare Analysis for Alternative Scenario 1

Welfare Analysis			
	Benchmark	Alternative	Difference
Urich	30,0491	29,9073	-0,1418
Upoor	54,6035	54,7779	0,1745
Irich	35,6175	35,6372	0,0197
Ipoor	60,0000	60,0000	0,0000
	CV	EV	
Rich	-0,1690	-0,1681	
Poor	0,1911	0,1917	
Total	-0,3601	-0,3598	

Source: own calculations

Table 16: Welfare Analysis for Alternative Scenario 2

Welfare Analysis			
	Benchmark	Alternative	Difference
Urich	30,0491	29,5626	-0,4865
Upoor	54,6035	54,9427	0,3392
Irich	35,6175	35,3922	-0,2253
Ipoor	60,0000	60,0000	0,0000
	CV	EV	
Rich	-0,5825	-0,5767	
Poor	0,3704	0,3727	
Total	-0,9529	-0,9494	

Source: own calculations

8. Conclusion

In the first part of the thesis I analyse effectiveness of individual environmental policy instruments. The most common instruments with incentive characteristic are emission taxes and tradable emissions allowances. In comparative study of cost-effectiveness of alternative instruments of environmental policy I found the most suitable instrument to be taxes on emissions and tradable allowances, i.e. the instruments where emissions are reduced by pricing the pollution externality. The other incentive-based instruments are unlikely to optimally engage all major ways to reduce emissions as well as the direct regulatory measurements which also fail to ensure the same marginal costs of reducing emissions across heterogeneous firms. Nevertheless, from the fiscal point of view, the more valuable are taxes than tradable allowances because they generate greater additional revenues for government and thus possible recycling through cutting other distorting taxation.

However, there are some cases where the cost advantage of the incentive-based instruments is scaled down. For example, if emissions taxes have no significant effect on product prices, their ability to exploit the output reduction will be doubted. Thus, the relative differences in cost-effectiveness between the instruments may become marginal. Reallocation of abatement is another argument in favour of the taxes because they are supposed to minimize costs of pollution abatement if the costs differ across polluters. Nevertheless, there are some disadvantages of the taxes. Besides uncertainty about their impacts on environment which are not simply identified, they may represent really substantial burden for economic actors since they have a potential to raise a commodity price the most. Negative impact can be found in decreased competitiveness of the affected industries on international market caused by the taxes implementation.

The first likely effects of the implementation of a new environmental policy have been discussed as the increase of energy products prices after introducing or enhancing energy tax rates as a result of additional production costs. The ecological tax reform affects the competitiveness of the production sector or even the whole economy. These spill-over effects occur for instance when measures to reduce carbon emissions leads to higher carbon emissions in other countries because of decreased competitiveness. Moreover, the effort of the producers to reduce energy consumption can lead to investing to the new technologies and intermediates more energy-efficient. Besides, greater production of energy-efficient companies may offset possible decrease in production due to higher energy taxation. The fact that costs of environmental policies are passed fully or to some extent to the consumers through higher market prices is evident. In particular, the way how the involved groups are affected depends on the revenues from different use of policies. The additional revenues from carbon taxes or emissions permits are supposed to be recycled and thus lower the burden of the participants.

Introducing exemptions in applied policy instruments causes structural changes in an economy. One good example is exemptions for the energy-intensive sector within the framework of an energy tax reform. Here the results differ across research literature. Some positive output effect on energy use can be found because of discrimination in redistributed revenues.

To investigate the effect of energy taxation with emphasis on specific economy, I employ computable general equilibrium model. I compare the baseline scenario without taxes with three alternatives. The first alternative scenario is the situation in which there is tax on energy good without other distorting taxes; in the second other additional taxes are imposed. The third alternative scenario implies higher energy tax while some of the factor taxes are lowered. The aim of such scenarios is to compare social and welfare changes taking account different tax policies. Although the introduced CGE model is quite simple and distant from the reality, it may show the likely effects caused by new tax policy implementation.

My results are following: after a 10 % tax on energy good is imposed, the marginal cost of the good increases which leads to new higher price. Total demand for energy goods decreases while total demand for non-energy good increases. Looking on each consumer separately (rich and poor consumer), the simulation leads to the following results: the rich consumer demands higher amount of energy good and lower amount of non-energy good. The behaviour of the poor consumer is the same for non-energy good; however, I found his energy good demand increasing too. Imposing higher energy tax at rate 20 % will cause little changes with the same path as in the previous case. In other scenario I include also other taxes into the model to observe behaviour of variables in the presence of other distorting taxes. The final assessment refers to the situation when some of the distorting taxes are lower as for example labour or corporate tax. The important question in this field is whether such proposed policy has significant effect on social welfare. I found both negative welfare impacts in the case of introducing new tax at 10 % and 20 % on energy goods.

By means of general equilibrium analysis I confirm the most significant effects of energy taxation in term of likely changes in energy prices, consumer and producer behaviour and social welfare. Since the analysis in this thesis is not complex and can be extended to other relevant policy scenarios, major questions of energy taxation have been discussed and their consequences shown. The further extension may refer for example to investigating emission abatement or employment effects as possible double dividend in case of recycling revenues from energy taxation.

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Appendix 1:

Tax increase (in %) from minimum tax implementation compared to the tax rates in 2003

	AT	BE	DE	DK	FI	FR	EL	IE	IT	NL	PT
Industry											
Coal	Min	Min	Min	-	-	Min	Min	Min	Min	-	Min
reduced rate	Min	Min	Min	-	-	Min	Min	Min	Min	Min	Min
Heavy Fuel	-	15%	-	-	-	-	-	10%	-	-	15%
reduced rate	Min	Min	Min	36%	-	Min	Min	Min	Min	Min	Min
Light Fuel	-	56%	-	-	-	-	-	-	-	-	-
Electricity	-	Min	-	-	-	-	Min	Min	-	-	Min
reduced rate	Min	Min	Min	-	-	Min	Min	Min	-	-	Min
Natural Gas	-	-	-	-	-	-	Min	Min	-	-	Min
reduced rate	Min	Min	Min	-	-	-	Min	Min	-	131%	Min
Transport											
Diesel	4%	4%	-	-	-	-	23%	-	-	-	1%
Gasoline (95ron)	-	-	-	-	-	-	21%	-	-	-	-
Domestic/Household											
Coal	Min	Min	Min	-	-	Min	Min	Min	Min	-	Min
Light Fuel	-	14%	-	-	-	-	-	-	-	-	-
Electricity	-	-	-	-	-	-	Min	Min	-	-	Min
Natural Gas	-	-	-	-	-	Min	Min	Min	-	-	Min

	ES	SE	UK	HU	PL	SI	CZ	SK	EE	LT	LV
Industry											
Coal	Min	-	-	Min	Min	Min	Min	Min	Min	Min	Min
reduced rate	Min	-	10%	Min	Min	Min	Min	Min	Min	Min	Min
Heavy Fuel	4%	-	-	-	Min	3%	Min	-	Min	15%	28%
reduced rate	Min	-	26%	Min	Min	Min	Min	Min	Min	Min	Min
Light Fuel	-	-	-	-	-	-	Min	-	-	7%	Min
Electricity	-	Min	-	Min	Min	Min	Min	Min	Min	Min	Min
reduced rate	Min	Min	-	Min	Min	Min	Min	Min	Min	Min	Min
Natural Gas	Min	-	-	Min	Min	-	Min	Min	Min	Min	Min
reduced rate	Min	-	14%	Min	Min	Min	Min	Min	Min	Min	Min
Transport											
Diesel	3%	-	-	-	21%	-	32%	9%	85%	44%	80%
Gasoline (95ron)	-	-	-	-	-	-	18%	23%	60%	32%	34%
Domestic/Household											
Coal	Min	-	Min	Min	Min	Min	Min	Min	Min	Min	Min
Light Fuel	-	-	-	-	-	-	Min	23%	-	7%	-
Electricity	-	-	Min	Min	Min	Min	Min	Min	Min	Min	Min
Natural Gas	Min	-	Min	Min	Min	14%	Min	Min	Min	Min	Min

Source: Kouvaritakis et. all (2005)
Notes : MIN means that there were no tax and the minimum tax will be applied, % is the tax increase through the minimum tax, - the existing taxes are higher that the minimum tax.

Ex-ante Price Increase through Minimum Tax
(for average energy prices of 2000, incl. existing taxes)

		AT	BE	DE	DK	FI	FR	EL	IE	IT	NL	PT
Coal	Energy Intensive	8.0%	8.2%	6.5%	0.0%	0.0%	4.2%	6.2%	11.7%	10.3%	0.0%	11.7%
	Other	8.0%	8.2%	6.5%	0.0%	0.0%	4.2%	6.2%	11.7%	10.3%	0.0%	11.7%
Oil	Energy Intensive	0.0%	1.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.8%
	Other	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gas	Energy Intensive	4.5%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%	5.1%	0.0%	2.1%	2.4%
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%	5.1%	0.0%	0.0%	2.4%
Electricity	Energy Intensive	1.2%	1.0%	0.0%	0.0%	0.0%	1.3%	1.1%	0.9%	0.0%	0.0%	0.7%
	Other	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	1.1%	0.9%	0.0%	0.0%	0.7%
Oil for transport	Industry	6.2%	6.2%	0.0%	0.0%	1.5%	0.0%	15.1%	0.0%	0.0%	0.0%	5.0%
Coal	Household	3.3%	3.2%	2.7%	0.0%	0.0%	3.7%	4.1%	4.4%	8.5%	0.0%	9.2%
Oil	Household	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gas	Household	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	4.4%	3.8%	0.0%	0.0%	1.9%
Electricity	Household	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	1.0%	0.0%	0.0%	0.8%
Oil for transport	Household	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.8%	0.0%	0.0%	0.0%	0.0%
		ES	SV	UK	HU	PL	SL	CZ	LV	LT	EE	SK
Coal	Energy Intensive	7.1%	0.0%	0.6%	11.5%	10.1%	16.0%	16.0%	16.0%	16.0%	16.0%	15.6%
	Other	7.1%	0.0%	0.0%	11.5%	10.1%	13.9%	26.9%	13.9%	13.9%	13.9%	15.6%
Oil	Energy Intensive	0.2%	0.0%	1.7%	0.0%	12.2%	0.3%	12.3%	2.4%	1.4%	12.4%	0.0%
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.0%	6.0%	0.8%	1.9%	0.0%
Gas	Energy Intensive	3.3%	0.0%	0.7%	4.6%	4.4%	0.0%	3.9%	4.6%	4.6%	4.6%	5.7%
	Other	3.3%	0.0%	0.0%	4.6%	4.4%	0.0%	3.9%	4.6%	4.6%	4.6%	5.7%
Electricity	Energy Intensive	0.0%	1.6%	0.0%	1.0%	1.3%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%
	Other	0.0%	1.6%	0.0%	1.0%	1.3%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%
Oil for transport	Industry	5.8%	0.0%	0.0%	0.5%	14.6%	3.7%	17.9%	32.6%	22.3%	33.9%	8.9%
Coal	Household	11.9%	0.0%	3.9%	14.5%	10.2%	17.7%	36.8%	17.7%	17.7%	17.7%	30.7%
Oil	Household	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.5%	0.0%	0.5%	0.0%	2.2%
Gas	Household	2.7%	0.0%	4.2%	7.8%	5.7%	0.9%	6.6%	7.4%	7.4%	7.4%	11.8%
Electricity	Household	0.0%	0.0%	0.9%	1.6%	1.7%	1.8%	2.1%	1.8%	1.8%	1.8%	2.1%
Oil for transport	Household	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%	15.9%	14.6%	24.3%	10.3%

Source: Kouvaritakis et. all (2005)

Appendix 2:

Energy and transport fuel taxes as a share of GDP and total taxation, 2007

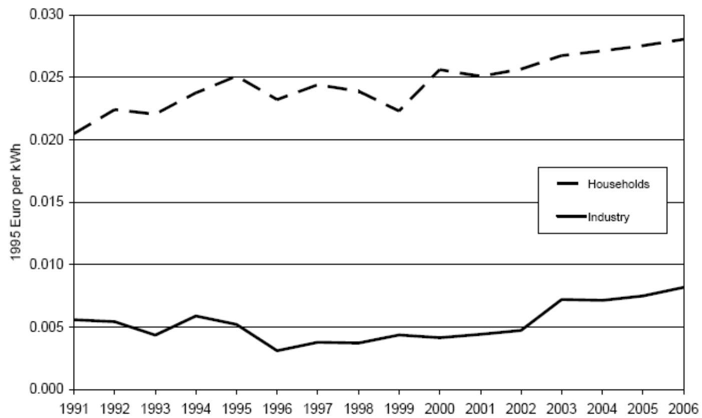
	Energy taxes		Transport fuel taxes	
	% of GDP	% of total taxation	% of GDP	% of energy taxes
EU27*	1.8	4.5	1.4	81
EA16**	1.7	4.2	1.4	80
Belgium	1.3	3.0	1.2	88
Bulgaria	3.0	8.9	-	-
Czech Republic	2.3	6.3	2.2	94
Denmark	2.3	4.6	1.2	52
Germany	1.9	4.7	1.4	78
Estonia	1.9	5.7	1.8	96
Ireland	1.2	3.8	1.1	94
Greece	1.2	3.7	1.1	92
Spain	1.4	3.8	1.2	86
France	1.4	3.3	1.3	87
Italy	2.1	4.8	1.5	75
Cyprus	1.8	4.3	1.4	79
Latvia	1.7	5.6	1.7	100
Lithuania	1.6	5.4	1.6	98
Luxembourg	2.4	6.7	2.4	98
Hungary	2.1	5.2	1.9	93
Malta	1.8	5.2	1.7	95
Netherlands	1.8	4.7	1.2	68
Austria	1.6	3.9	1.3	78
Poland	2.4	6.9	1.9	81
Portugal	2.0	5.6	1.9	94
Romania	1.7	5.8	-	-
Slovenia	2.3	6.1	2.2	92
Slovakia	1.8	6.2	1.8	96
Finland	1.7	3.9	1.3	77
Sweden	2.2	4.6	1.2	56
United Kingdom	1.8	5.0	1.7	94
Norway	1.3	2.9	0.8	61

Source: Eurostat, 2009
*Notes: *GDP - weighted average of the MS for which the data are available*
***Euro area (EA16): Belgium, Germany, Ireland, Greece, Spain, France, Italy, Cyprus, Luxembourg, Malta, the Netherlands, Austria, Portugal, Slovenia, Slovakia and Finland.*

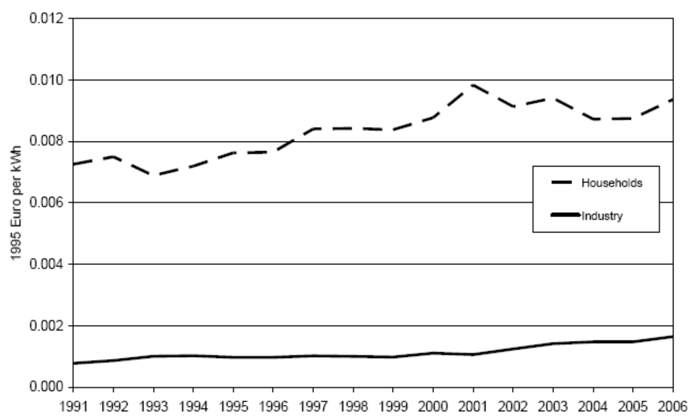
Appendix 3:

Trends in the Average Tax Component (in real terms, in final energy prices in EU-15)

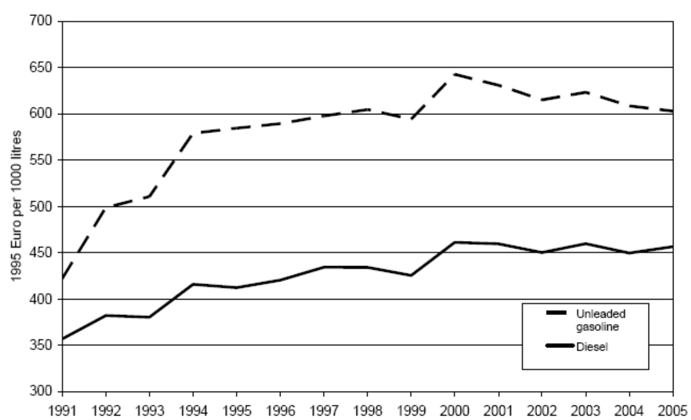
a) electricity



b) natural gas



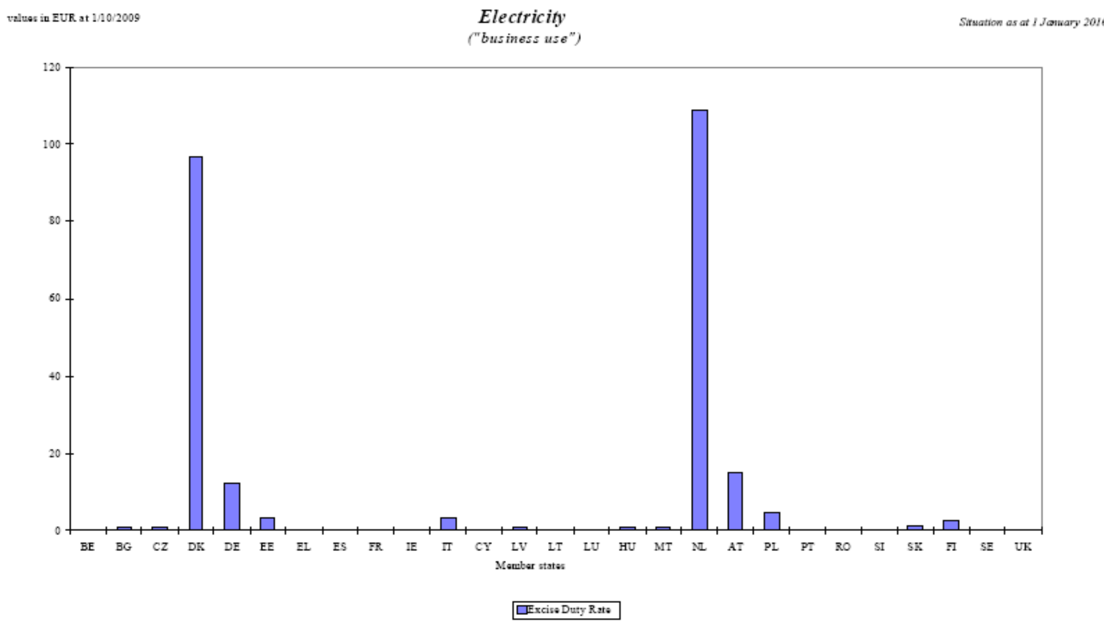
c) transport fuels



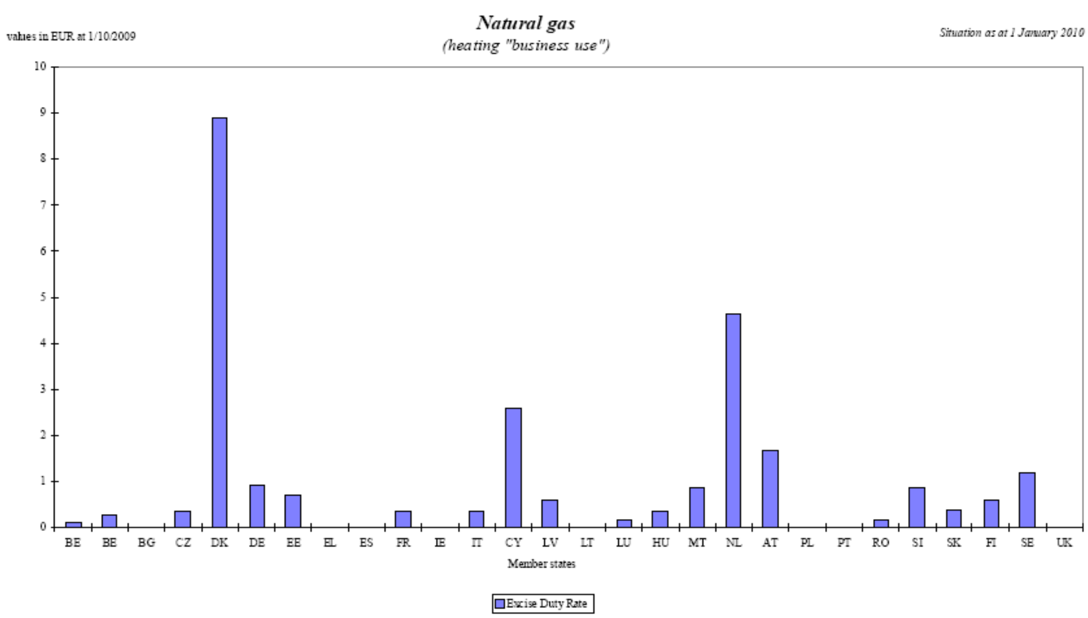
Source: EN32 Energy Taxes, 2007

Appendix 4:

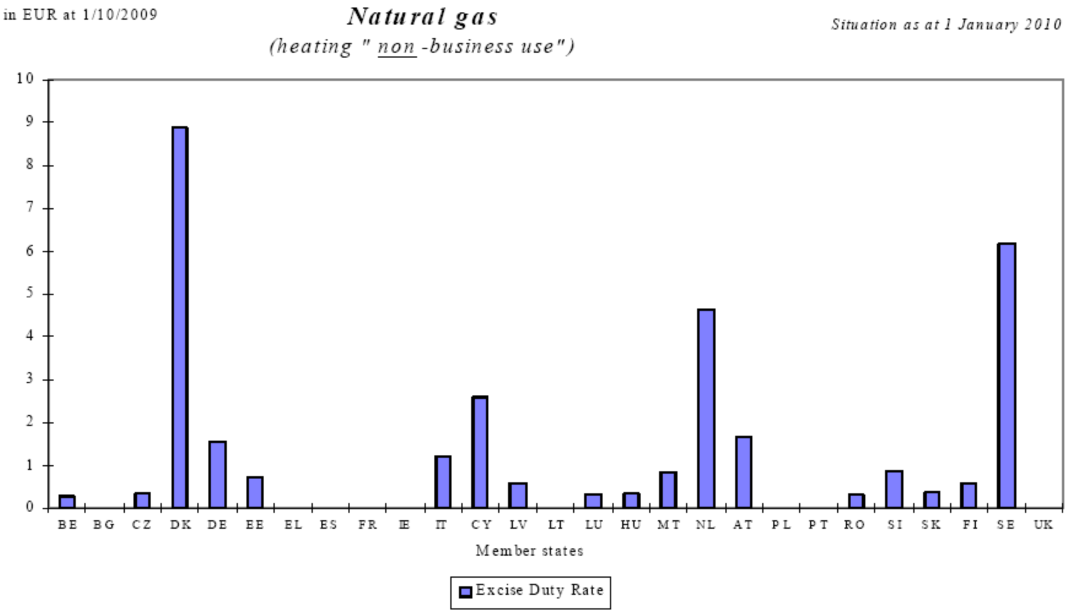
Minimum Excise Duties by Energy Products and Electricity in the EU MS



Minimum excise duty: 0,5 EUR per MWh

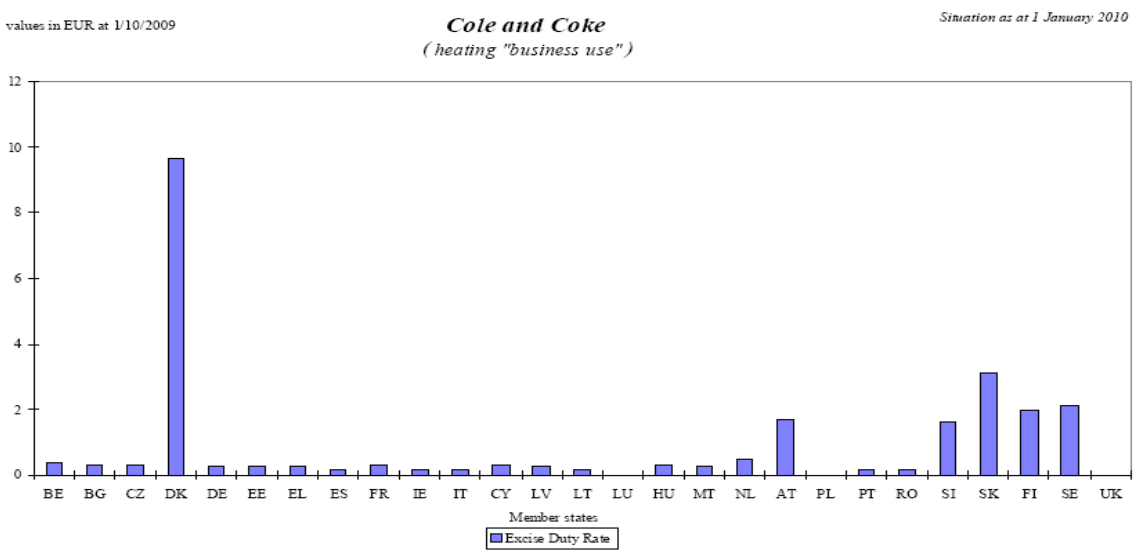


Minimum excise duty: 0,15 EUR per gigajoule values in EUR at 1/10/2009

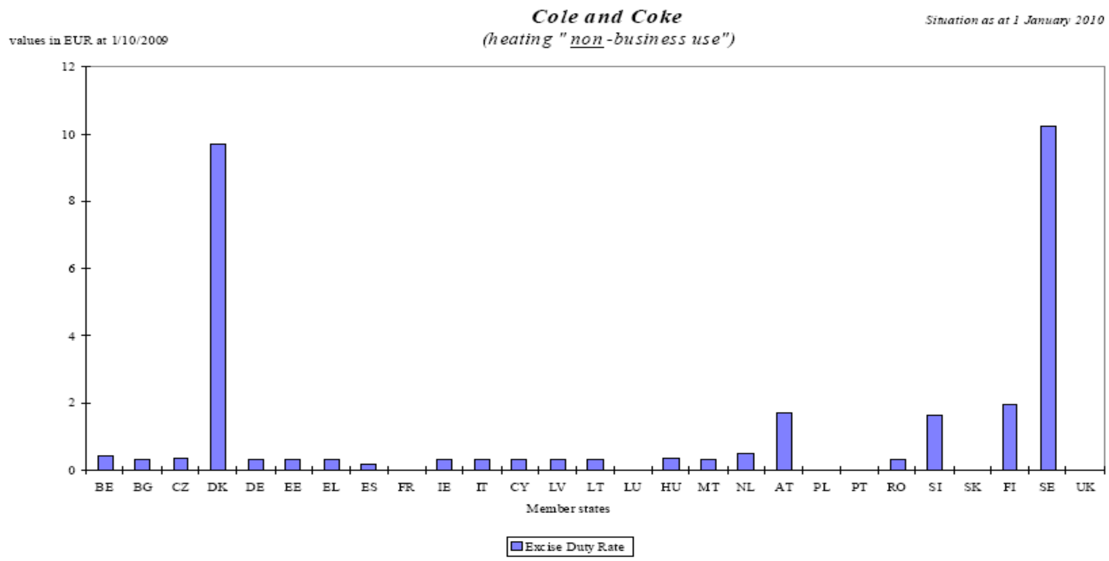


Minimum excise duty: 0,3 EUR per gigajoule

values in EUR at 1/10/2009



Minimum excise duty: 0,15 EUR per gigajoule our



Minimum excise duty: 0,3 EUR per gigajoule

Source: Excice Duty Tables, European Commission, 2009

Appendix 5:

CZECH REPUBLIC
Table 4 - Indices of energy prices

	Oil products		Electricity		Natural gas		Coal	
	Wholesale	Retail 2000 = 100	Wholesale 2000 = 100	Retail 2000 = 100	Wholesale 1995 = 100	Retail 2000 = 100	Wholesale 2000 = 100	Retail 2000 = 100
1989	..	27.7	25.1	20.9	28.6	14.8	50.2	13.3
1990	..	37.3	29.0	20.9	33.1	14.8	48.8	13.3
1991	..	57.0	66.8	23.8	76.2	28.1	71.4	30.4
1992	..	57.6	79.9	35.5	91.1	34.7	77.9	38.7
1993	..	65.4	82.3	37.4	93.8	36.4	84.6	45.2
1994	..	67.3	87.4	39.3	99.6	38.6	82.6	48.2
1995	..	67.0	87.7	43.5	100.0	42.6	83.1	57.7
1996	..	70.5	89.1	48.4	..	47.2	86.3	62.8
1997	..	75.8	90.4	56.3	..	55.0	92.9	71.5
1998	..	75.7	94.3	78.4	..	77.8	98.2	91.5
1999	..	80.1	96.7	86.8	..	87.0	104.9	97.7
2000	..	100.0	100.0	100.0	..	100.0	100.0	100.0
2001	..	94.9	105.9	114.8	..	131.1	102.2	102.4
2002	..	85.9	110.8	125.6	..	133.1	101.9	105.3
2003	..	87.1	107.4	119.8	..	134.6	102.2	107.5
2004	..	94.2	112.6	121.9	..	135.9	107.8	112.1
2005	..	100.9	122.5	126.8	..	153.4	126.4	116.0
2006	..	103.9	133.4	138.1	..	182.8	125.6	124.7
2007	..	103.6	145.7	149.0	..	173.7	..	146.0
2008	..	107.7	162.3	163.2	..	216.0	..	173.4
2009	..	..	..	..	..	..	..	..

Source: IEA, 2009

Appendix 6:

1) A list of parameters used in the CGE model

$\alpha_{i,C}$ Share parameters, $i = 1,2$

ϕ_i Scale parameter, $i = 1,2$

σ_C Elasticity of substitution between products

σ_i Elasticity of factor substitution, $i = 1,2$

δ_i Distribution parameter, $i = 1,2$

L, K Consumer's endowment of labour and capital

2) Producer's optimization problem

$$\min p_L L + p_K K \text{ s.t. } f(K,L) = \phi\left(\delta_i L_i^{(\sigma_i-1)/\sigma_i} + (1-\delta_i)K_i^{(\sigma_i-1)/\sigma_i}\right)^{\sigma_j/(\sigma_j-1)} = Q$$

Let ρ denotes $(\sigma-1)/\sigma$, and by omitting the subscript *i,* the production function is simplified. The equations with three unknowns, labour demand, L, capital demand, K, and the Lagrange multiplier, *μ,* are subjects to cost-minimizing problem:

$$f(K,L) = \phi\left(\delta L^{\rho} + (1-\delta)K^{\rho}\right)^{1/\rho} = Q$$

Optimality of *L* and *K*:

$$p_L = \mu \frac{\partial f(K,L)}{\partial L}$$

$$p_K = \mu \frac{\partial f(K,L)}{\partial K}$$

By deriving production function according to labour:

$$\frac{\partial f(K,L)}{\partial L} = \delta L^{\rho-1}\phi\left(\delta L^{\rho} + (1-\delta)K\right)^{1/\rho-1}$$

By substituting $Q = f(K,L)$:

$$\frac{\partial f(K,L)}{\partial L} = \delta\left(\frac{L}{Q}\right)^{\rho-1}\phi^{\rho}$$

$$\frac{\partial f(K,L)}{\partial K} = (1-\delta)\left(\frac{K}{Q}\right)^{\rho-1}\phi^{\rho}$$

By substituting for L and K into the optimality conditions:

$$\frac{L}{K} = \left(\frac{(1-\delta)p_L}{\delta p_K}\right)^{1/(\rho-1)}$$

By substituting for K in the equation....:

$$Q = \phi\left(\delta L^{\rho} + (1-\delta)L^{\rho}\left(\frac{\delta p_K}{(1-\delta)p_L}\right)\right)^{1/(\rho-1)}$$

The optimal value of Lagrange multiplier as a function of the prices p_L and p_K :

$$\mu = \left(\delta\left(\frac{p_L}{\delta}\right)^{1-\sigma} + (1-\delta)\left(\frac{p_K}{1-\delta}\right)^{1-\sigma}\right)^{1/(1-\sigma)}$$

Conditional factor demands:

$$L = \frac{Q}{\phi}\left(\frac{\delta\mu}{p_L}\right)^{\sigma},\ K = \frac{Q}{\phi}\left(\frac{(1-\delta)\mu}{p_K}\right)^{\sigma}$$

3) Consumer's optimization problem

$$\max u(X_{1,}X_2) = \left(\alpha_1^{1/\rho}X_1^{\rho} + \alpha_2^{1/\rho}X_2^{\rho}\right)^{1/\rho} \text{ s.t. } p_1X_1 + p_2X_2 = I$$

The right side of the equation arrives from substituting ρ to $(\sigma-1)/\sigma$, and by omitting the subscript c in the CES utility function:

$$u(X_{1,}X_2) = \left(\sum_{i=1}^{2}\alpha_{i,c}{}^{1/\sigma}X_{i,C}^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)}$$

Optimality of X_1 and X_2:

$$\lambda p_1 = \frac{\partial u(X_1,X_2)}{\delta X_1}$$

$$\lambda p_2 = \frac{\partial u(X_1, X_2)}{\delta X_2}$$

By deriving the utility function according to energy good and non-energy good:

$$\frac{\partial u}{\partial X_1} = \alpha_1^{1/\sigma} X_1^{\rho-1} \left(\left(\alpha_1^{1/\rho} X_1^{\rho} + \alpha_2^{1/\rho} X_2^{\rho} \right)^{1/\rho} \right)^{1/\rho-1}$$

$$\frac{\partial u}{\partial X_2} = \alpha_2^{1/\sigma} X_2^{\rho-1} \left(\left(\alpha_1^{1/\rho} X_1^{\rho} + \alpha_2^{1/\rho} X_2^{\rho} \right)^{1/\rho} \right)^{1/\rho-1}$$

By substituting into the optimality conditions and dividing:

$$\frac{p_1}{p_2} = \left(\frac{\alpha_1}{\alpha_2} \right)^{1/\sigma} \left(\frac{X_1}{X_2} \right)^{\rho-1}$$

Where $\rho - 1 = -1/\sigma$, thus we can write:

$$\frac{X_1}{X_2} = \left(\frac{p_1}{p_2} \right)^{1/\sigma} \left(\frac{\alpha_1}{\alpha_2} \right)$$

By substituting for X_2 into the equation of budget constraint:

$$I = X_1 \left(p_1 + p_2 \left(\frac{p_2}{p_1} \right)^{\sigma-1} \left(\frac{\alpha_2}{\alpha_1} \right) \right)$$

By rewriting the equation, we get the demand functions:

$$X_1 = \frac{\alpha_1 I}{p_1^{\sigma} (\alpha_1 p_1^{1-\sigma} + \alpha_2 p_2^{1-\sigma})}$$

$$X_2 = \frac{\alpha_2 I}{p_2^{\sigma} (\alpha_1 p_1^{1-\sigma} + \alpha_2 p_2^{1-\sigma})}$$