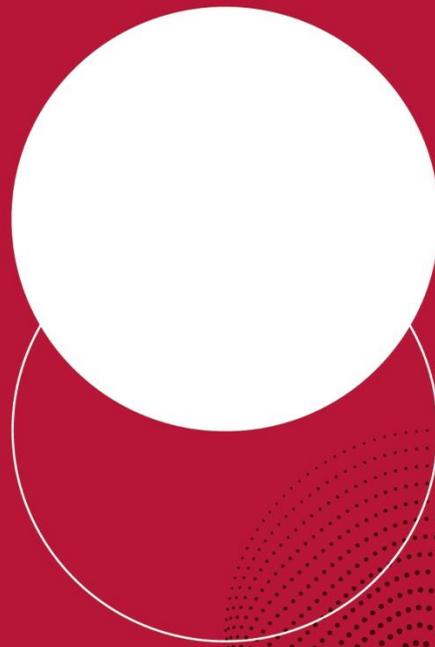




instytut
badań
strukturalnych



IBS WORKING PAPER 02/2016
FEBRUARY 2016

INPUT VS. OUTPUT TAXATION – A DSGE APPROACH TO MODELLING RESOURCE DECOUPLING

Marek Antosiewicz
Piotr Lewandowski
Jan Witajewski-Baltvilks



INPUT VS. OUTPUT TAXATION – A DSGE APPROACH TO MODELLING RESOURCE DECOUPLING*

Marek Antosiewicz[♣], Piotr Lewandowski^{♣*}, Jan Witajewski-Baltvilks^{♣♦}

Abstract

Environmental taxes are a crucial instrument aimed at reducing resource use through lower production losses, resource-leaner products and more resource-efficient production processes. In this paper we focus on material use and apply a multisector DSGE model to study two types of taxation: tax on material inputs used by industry, energy, construction and transport sectors, and tax on output of these sectors. We allow for endogenous adaption of resource saving technologies. We calibrate the model for the EU27 area using IO matrix. We consider taxation introduced from 2021 and simulate its impact until 2050. We compare the taxes along their ability to induce reduction in material use and raise revenue. We consider the effect of spending this revenue on reduction of labour taxation. We find that input and output taxation create contrasting incentives and have opposite effects on resource efficiency. The material input tax induces investment in efficiency improving technology which in the long term results in GDP and employment by 15-20% higher in comparison to comparable output tax. We also find that using revenues to reduce taxes on labour has stronger beneficial effects for the input tax.

Keywords: DSGE model; resource decoupling; technological change; environmental taxes; environmental policy; double dividend

JEL: C68, Q32, Q43

©Institute for Structural Research (IBS), Warsaw, 2016

All rights reserved.

ISSN: 2451-4373

* The paper has received funding from the European Union's Seventh Framework Programme under grant agreement no. 308674 and from the scientific budget for the years 2012-2015 for supporting co-financed projects. Usual disclaimers apply. All errors are ours.

♣ Institute for Structural Research (IBS), Warsaw, Poland and Warsaw School of Economics. Corresponding author. E-mail: marek.antosiewicz@ibs.org.pl.

♣* Institute for Structural Research (IBS), Warsaw, Poland. E-mail: piotr.lewandowski@ibs.org.pl.

♣♦ Institute for Structural Research (IBS), Warsaw, Poland. E-mail: jan.witajewski@ibs.org.pl.

Introduction

A need to limit the use of natural resources is becoming one of the most pressing issues for policy-makers. On the one hand, exhaustive use of resources, which are available only in limited supply, can potentially limit the production possibilities and welfare of future generations. On the other hand, use of resources such as fossil fuels, increases air-pollution and releases carbon to atmosphere causing the greenhouse effect. The importance of the problem has been recognised by, among others, policy makers in the European Union (EC 2012), US (USEPA2012) and China in its 12th five-year plan for years 2011-2015 (Su, Heshmati and Geng (2013)).

There are several policy options for resolving the problem of excessive resource use. If one thinks that today's production puts a burden on future generations, a tax on today's output constitutes a solution. If one thinks that the current market prices of resources do not reflect their true social costs (e.g. due to atmospheric pollution), then a tax on inputs constitutes a solution (Eckermann et al.). Other options include performance standards, which require firms to limit the use of resources per unit of output and incentivise firms to adopt of more efficient technologies, or R&D or deployment subsidies which support development and adoption of cleaner technologies. In this paper we limit our attention to the first two policy options: a tax on input and a tax on output. We use a multisector DSGE model of the EU27 area to simulate impact of these taxes levied on industry, energy, construction and transport sectors, starting in 2021 and till 2050. We allow for endogenous investment in efficiency improving and account for labour market adjustments. We find that input and output taxation create contrasting incentives and have an opposite effect on resource efficiency which implies different dynamics of material use and macroeconomic outcomes. Simulating tax rates which lead to an equal drop in material use, we find that the material input tax results in GDP and employment that is 15-20% higher comparing to the scenario with output tax. Simulating tax rates that equate the tax revenue, we find that the output tax results in a much smaller drop in material use. Additionally, we find that using the tax revenue to reduce labour taxation is much more efficient in the case of input tax. Thus, input tax implies smaller macroeconomic costs and better resource-efficiency outcomes than output tax in all variants of the simulations considered. This leads us to the conclusion that material input tax is a more efficient instrument to achieve resource decoupling.

In the paper we highlight and discuss one reason for the differential effects of input and output tax: material tax incentivise firms to substitute materials with material-saving technologies. Thus a given reduction in material use is associated with a smaller reduction in production. Indeed, as we demonstrate in the sensitivity analysis, larger substitutability between materials and material-saving technologies is associated with lower GDP loss upon introduction of material tax.

The ability of technology to substitute for the use of resources and energy has been documented in a range of empirical studies. Popp (2001) finds that an energy-related patent, on average, leads to long-run energy savings worth \$14.5 million . Sue Wing (2008) use industrial data on factor use and patent data to decompose changes in the US energy-intensity by industries into changes in industrial composition, factor substitution, technological change induced by changes in energy prices, and the disembodied technological change. He finds that induced technological change leads to energy savings, although its contribution is small relative to the other factors in the decomposition. Linn (2008) finds that a 10% increase in the energy price leads to technology adoption that results in 1% lower energy demand by new firms.

The paper contributes to the literature which studies the effectiveness of various policies aimed at reduction of resource and material use. There are numerous theoretical studies which examine the optimal policy mix for

reduction in the use of fossil fuels. Popp (2006) and Fischer and Newell (2008) find that a combination of carbon tax with R&D subsidies promoting efficient technologies brings more benefit than any of the single policies. Geralgh and van der Zwaan (2006) highlight the role of the efficiency standards, which, as they argue, promote both lower fuel consumption as well as adoption and development of more efficient technologies. More recently, the literature was extended by studies which analyse policies promoting material efficiency. Söderholm and Tilton (2012) argue that policies should correct the externalities directly but they should not set any targets of material efficiencies, as it is not clear what material efficiency target is socially optimal. In response to this argument, Allwood et al (2013) replied that although material efficiency may not be optimal from the economic perspective, it is going to face less political and social resistance than e.g. carbon tax. Skelton and Allwood (2013) examined the impact of carbon prices on efficiency in the use of steel. They find that substitution possibilities between material and labour matters for the policy effects. We extend the analysis of Skelton and Allwood (2013) by allowing for general equilibrium effects (e.g. adjustment of wages to changes in unemployment).

In contrast to the above papers, our paper does not suggest what the optimal policy mix is, but rather highlights what effects determine the success of the input tax when compared to the output tax. In addition, we extend the literature by analysing the impact of taxes not only on costs of policies in terms of GDP, but also in terms of employment.

In the next section we present our macroeconomic DSGE model which allows for endogenous adoption of material saving technologies. We discuss the calibration of model for the EU27 area, using Input Output matrix and literature findings. We lay out simulation strategy for taxation introduced from 2021. Although all model variables are simulated, we focus on taxation impact on GDP, national accounts, labour market, resource use, and public finances until 2050. In the third section, we present our results. Firstly, we compare the impact of input and output taxes which lead to the same total reduction in resource use in 2050. Secondly, we compare the impact of input and output taxes which raise the same revenue in 2050. Next, we check how sensitive the results are to the alternative uses of tax revenue – reducing taxation on labour instead of transferring it to household. The importance of tax recycling has been evidenced by the literature on double dividend hypothesis (e.g. Takeda (2007), Fæhn et al. (2009)) and our findings validate it. Lastly, we conduct sensitivity analysis and examine how our results change when we vary the parameter determining the substitutability between materials and material-saving technologies. In the final section we discuss our findings.

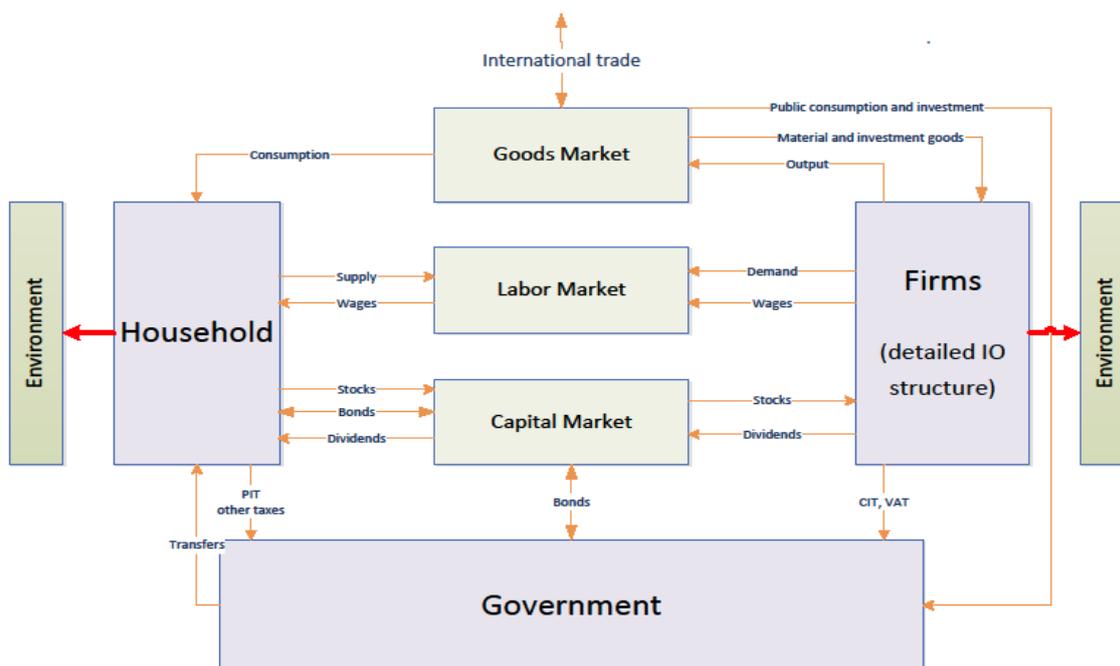
2. Materials and Methods

In this section we describe the model that we use for simulations and characterise them. Regarding the model description, we specify the production structure of firms that is crucial for modelling of firms response to input and output taxation which is the focus of the paper. A detailed description of the remaining agents of the model and the solution method can be found in Antosiewicz and Kowal (2016).

2.1. Model description

The model we use is a multi-sector, large-scale dynamic stochastic general equilibrium (DSGE) model which we calibrate and estimate for the EU27 area. The main economic agents in the model are: household, representative firm in each of the eight sectors and government. The basic scheme of the model is shown in Figure 1.

Figure 1. Scheme of model structure.



The model is disaggregated into the following sectors: Agriculture (AGR), Raw Material Production (RMP), Industry (IND), Energy (ENG), Construction (CONSTR), Transport (TRANS), Market Services (SERV) and Public Services (PBL). Table 1 summarises the sector structure of the model.

Table 1. Sector structure of model.

	Sector name	Sector abbrev.	Eurostat CPA sectors ¹
1	Agriculture	AGR	A01, A03, C10-C12
2	Raw Material Production	RMP	A02, B
3	Industry	IND	C except C10-C12
4	Energy	ENG	D, E
5	Construction	CONSTR	F
6	Transport	TRANS	H
8	Market Services	SERV	G, I, J, K, L, M, N

¹ Letter codes without numbers refer to all subsectors which begin with given letter.

In each sector $s \in S$ a representative firm maximises the expected, discounted profits:

$$\max E \sum_{t=0}^{\infty} \beta^t \Pi_t^s, \quad (1)$$

Where β is the discount factor and Π_t^s are the profits of the firm. The firm operates a multi-stage production technology using CES functions. In the first stage capital K_t^s is combined with energy intermediate material ENG_t^s in order to produce composite good KE_t^s :

$$KE_t^s = \left[(1 - \theta_E^s) (K_t^s)^{\frac{\epsilon_E^s - 1}{\epsilon_E^s}} + \theta_E^s (ENG_t^s)^{\frac{\epsilon_E^s - 1}{\epsilon_E^s}} \right]^{\frac{\epsilon_E^s}{\epsilon_E^s - 1}}, \quad (2)$$

where θ_E^s is a parameter determining the share of energy in the composite good and ϵ_E^s denotes the elasticity of substitution between capital and energy. In the second stage the composite good KE_t^s is combined with labour N_t^s in order to produce another composite good:

$$KLE_t^s = \left[\theta_{KE}^s (KE_t^s)^{\frac{\epsilon_{KE}^s - 1}{\epsilon_{KE}^s}} + (1 - \theta_{KE}^s) (N_t^s)^{\frac{\epsilon_{KE}^s - 1}{\epsilon_{KE}^s}} \right]^{\frac{\epsilon_{KE}^s}{\epsilon_{KE}^s - 1}}, \quad (3)$$

where parameter θ_{KE}^s sets the shares of the production factors, and ϵ_{KE}^s sets the elasticity of substitution. In the final stage of production the second composite good is combined with material good M_t^s

$$Y_t^s = \left[(1 - \theta_M^s) (KLE_t^s)^{\frac{\epsilon_M^s - 1}{\epsilon_M^s}} + \theta_M^s (M_t^s)^{\frac{\epsilon_M^s - 1}{\epsilon_M^s}} \right]^{\frac{\epsilon_M^s}{\epsilon_M^s - 1}}, \quad (4)$$

where θ_M^s is the share parameter of the production factors and ϵ_M^s sets the elasticity of substitution.

Aggregate intermediate material is produced using goods from all sectors of the model in a two-step procedure. Since we are mainly interested in assessing effects of policies on the Materials Production sector (A02 and B in Eurostat CPA) we proceed with the following approach. We assume that material good is composed of a material good of the Raw Material Production sector $M_t^{s,RMP}$ and a bundle of goods from remaining sectors MO_t^s with a CES function which also accommodates endogenous material efficiency. Then, the bundle of remaining material goods is produced using Leontief function. This can be summarised in the following equations:

$$M_t^s = \left[EFF_t^s \theta_{RMP}^s (M_t^{s,RMP})^{\frac{\epsilon_{RMP}^s - 1}{\epsilon_{RMP}^s}} + (1 - \theta_{RMP}^s) (MO_t^s)^{\frac{\epsilon_{RMP}^s - 1}{\epsilon_{RMP}^s}} \right]^{\frac{\epsilon_{RMP}^s}{\epsilon_{RMP}^s - 1}}, \quad (5)$$

$$\forall u \in S \quad M_t^{s,u} = \theta_u^s MO_t^s, \quad (6)$$

As usual, θ_{RMP}^s and ϵ_{RMP}^s set the share and elasticity in the CES composite, whereas parameters θ_u^s set the share of material good of sector u in the production function of sector s . The variable EFF_t^s sets the material efficiency of sector s and in the steady state it is normalised to unity. Each intermediate material use variable $M_t^{s,u}$ is a composite of home and foreign produced goods, which are additionally denoted by subscripts H and F :

$$M_t^{s,u} = \left[\theta_H^{s,u} (M_{t,H}^{s,u})^{\frac{\epsilon_H^s - 1}{\epsilon_H^s}} + (1 - \theta_H^{s,u}) (M_{t,F}^{s,u})^{\frac{\epsilon_H^s - 1}{\epsilon_H^s}} \right]^{\frac{\epsilon_H^s}{\epsilon_H^s - 1}}, \quad (7)$$

Endogeneity of technology choices means that firms are allowed to change the characteristics of technology parameters of production function under market incentives. For instance, an increase in energy prices incentivises firm to invest in the more costly, energy-saving technology. Effectively, this gives a firm a possibility to substitute inputs with capital. Importantly, this substitution possibilities are limited in the short-run: we assume that the efficiency of technology is the weighted average between past and today's technology choices. In particular we let EFF_t^s to be determined by:

$$EFF_t^s = EFF_{t-1}^s \frac{(1 - \delta)K_{t-1}^s}{K_t^s} + Z_t^s \frac{I_t^s}{K_t^s} \quad (8)$$

Where K_t^s is the stock of capital, I_t^s is the level of investment and Z_t^s is the firm's choice of technology at time t . The more efficient technology involves higher costs of capital good. Specifically, the cost of capital goods is given by:

$$IC_t^s = I_t^s (1 + (cZ_t^s)^\alpha). \quad (9)$$

Note that if $\alpha = \infty$, firms always choose $Z = 1$.

The profit of the firm is given by revenue from sales of good Y_t^s less the cost of labour, investment, intermediate material use cost, vacancy posting cost and taxes. Goods produced by the sector firms are aggregated by final goods firms, which produce consumption, public, investment and export good. The final goods production structure is given by the Input-Output matrix.

The consumer maximises utility from consumption subject to her income which is composed of labour income less taxes, dividends from firms, and transfers from the government. The government collects labour, VAT and environmental taxes and spends it on the purchase of the public good and on transfers to the household. Labour market is modelled according to the search and matching framework, similar to Mortensen (1999) and Pissarides (2000). Unemployment rate is determined endogenously and depends on the number of vacancies generated by firms, and the intensity of job search by job seekers. The decisions of firms on opening of vacancies depends on the current and future states of the economy.

The sector structure of the model is calibrated using the Nace Rev. 2 Input-Output matrices for the year 2010 available from Eurostat. The flows are determined by the share parameters θ which appear in equations determining the production structure. The elasticity parameters are set as follows:

- ϵ_E^s – elasticity between capital and energy. According to numerous studies the elasticity of substitution between these factors is very low (e.g. Okagawa and Ban (2008) and Kuper and Soest (2003)). We set this parameter at 0.1.

- ϵ_{KE}^S – elasticity between capital-energy composite and labour. The standard practice of DSGE models is to use the Cobb-Douglas specification, therefore we set a high elasticity at 0.95.
- ϵ_M^S - elasticity between capital-energy-labour composite and materials. We set this elasticity at 0.3 following CGE model in Bucher (2011).
- ϵ_{RMP}^S – elasticity between RMP material and other materials. Koschel (2000) shows that the elasticity of substitution between fuels and other raw materials goods is low. We also chose a small value of 0.1, although the RMP sector includes other materials apart from fuels.
- ϵ_H^S – elasticity between home and foreign goods. The literature regarding this elasticity shows that it can take a wide range of plausible values. For example, in Hooper et al. (2000) it is estimated that for G7 countries this elasticity is in the range between 0.1 and 2. Heathcote and Perri (2002) demonstrated that low values of this parameter result in a model that better reproduced business cycle properties of data. We set this value at 0.4.

2.2. Simulation setup

We use the model described in the previous subsection to compare the two tax schemes in their ability to reduce material use and their economic impact, measured among others in the in output, employment or sector shifts in the economy. We define the input tax as an excise-type tax on the purchase of the intermediate material of the Raw Material Production sector by the Industry, Energy, Construction and Transport sectors. We define the output tax as an excise (non-deductible) tax which is levied on the value added generated by these four sectors.

In order to assess the taxes along a possibly wide range of dimensions, we perform several simulation experiments. In the basic experiment we consider two simulations which differ in the basis for the comparison of the two taxes. In the first simulation we follow a material reduction approach. For each type of tax we simulate such a (roughly linear) path of tax rates that the resulting decrease of the RMP sector output is increasing linearly from 0% in 2021 to 20% in 2050. In the second simulation we follow a fiscal approach. For each type of tax we simulate such a linear path of tax rates that the revenue in 2050 reaches approximately 1% of GDP. For both of these simulations we assume that the revenues are used as a lump sum transfer to the household. Such fiscal closure allows us to analyse only the price incentives that the tax has for the behaviour of firms.

In the third simulation experiment we modify the fiscal closure. We follow the first simulation setup (material reduction approach) but we assume that 20% of the tax revenue is spent on lowering labour taxation. The main aim of this simulation is not to verify the double dividend hypothesis, but to compensate for the fact that the two taxes differ significantly in total revenue they generate (higher in the case of the output tax). The offsetting effect of lower labour tax reduction will therefore be stronger in the case of the output tax.

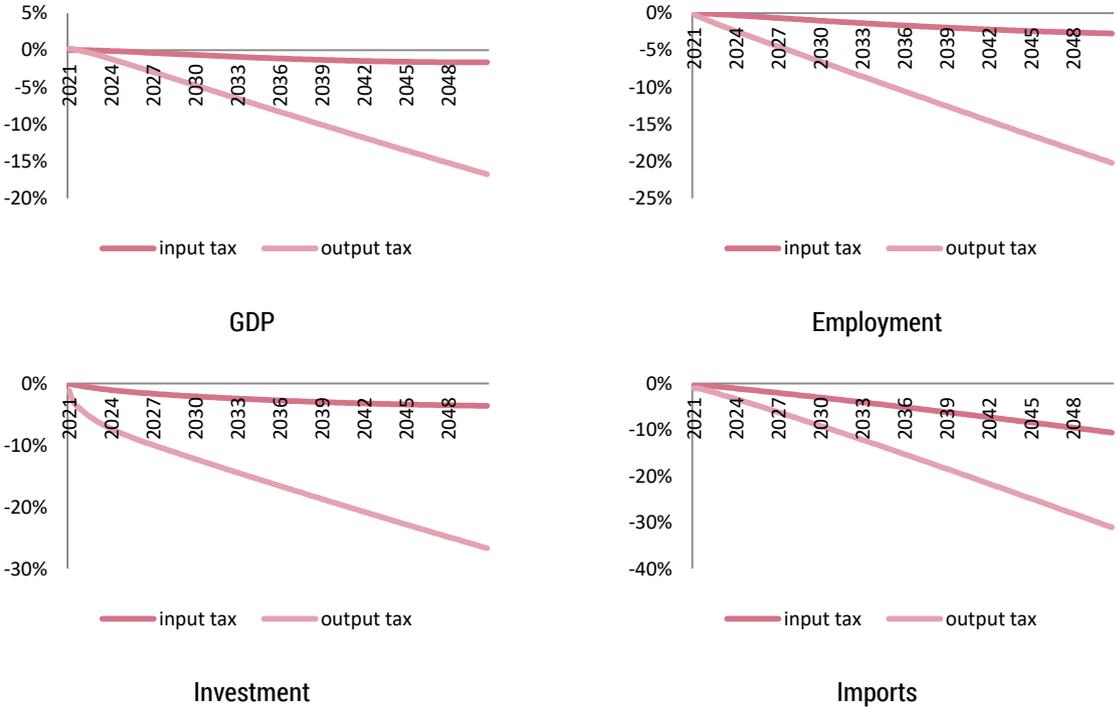
Lastly, we check robustness of our results. As they a large extent rely on the endogenous material efficiency mechanism, we perform sensitivity analysis with respect to the elasticity parameter which governs this mechanism. Again, we follow the material reduction approach as in the first simulation exercise. All simulations are performed using the Kalman filter [16]. Results are expressed as deviations from the steady state of the model, which we interpret as the baseline growth scenario for the EU27.

3. Discussion of results

3.1. Equalling material reduction

This subsection shows results for the first simulation approach in which we set tax rates as to achieve a material reduction of 20% at the end of the simulation horizon (2050). We start with discussing the basic macroeconomic impact of the two taxes as measured by the response of gross domestic product, employment, investment and imports, which is shown in Figure 1. Both taxes have a negative impact on all economic indicators, however the output tax causes a much stronger decline. The drop in GDP in 2050 is equal to 16.7% for the output tax, against 1.7% for the input tax. This is equivalent to a reduction of the yearly growth rate by 0.6 and 0.06 percentage points, respectively, between 2021 and 2050. For both taxes the impact on employment and investment is slightly stronger than on GDP: for the output tax amounts to 20.2% and 26.7% in 2050, respectively, whereas for the input tax to 2.8% and 3.6%, respectively. The decrease in international trade, measured by value of imports is most pronounced, leading to a more closed European economy – the drop is equal to 31.1% and 10.6% for the output tax and input tax, respectively, which is much stronger than the impact on GDP. It has to be noted, however, that the foreign trade in the model is the trade of the EU27 area with the rest of the world. It does not take into account trade between the EU member states. The relative impact on trade (relatively to GDP deviation) is much stronger in the case of the input tax, because input tax directly taxes imports of material goods, as opposed to the output tax, which decreases the competitiveness of home produced vs foreign goods.

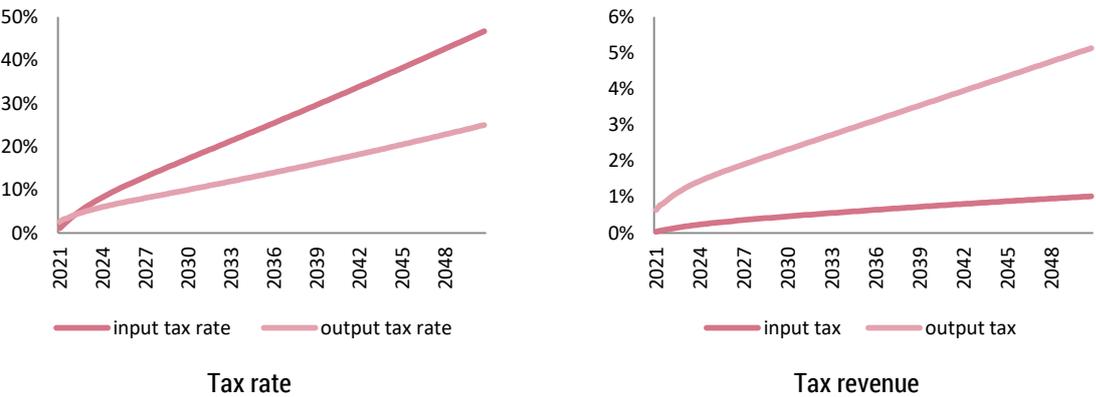
Figure 1. Basic macroeconomic impact of the input and output taxes on gross domestic product, employment, investment and imports. Results are shown as percent deviations from baseline scenario.



The left panel of Figure 2 shows the endogenously calculated tax rates which are necessary for achieving the assumed decrease of the output of the material production sector. Both tax rates increase roughly linearly from 2021 and in 2050 reach approximately 47% for the input tax and 25% for the output tax. However, the right panel

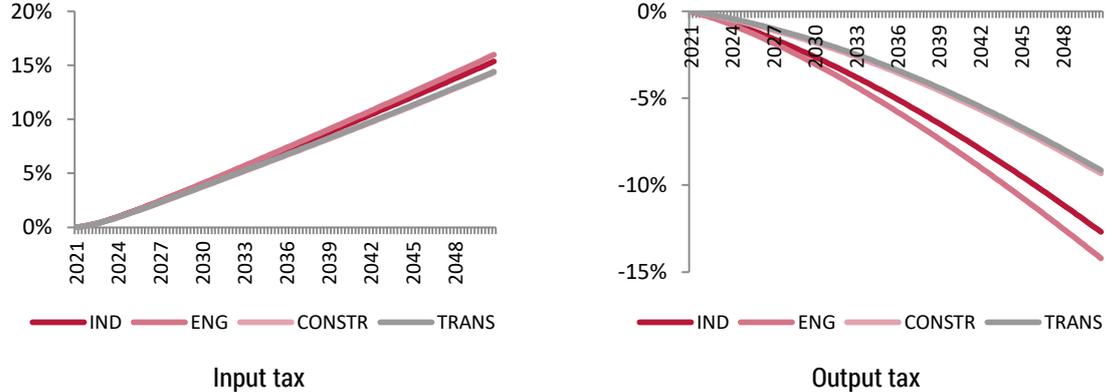
of Figure 2 shows that the output tax generates much higher revenue – it reaches 5% of baseline GDP in 2050 (6% of GDP if we take into account the endogenous fall of GDP resulting from the tax), which is slightly less than the revenue from value added tax in the European Union (according to Eurostat, 7% of GDP in 2014). Hence we think that the output tax should not be treated only as an measure aimed at reducing material use, but also as a source of additional, considerable tax revenue. The difference in total tax revenue generated by both taxes is mainly due to the size of the base on which they are levied – for the input tax it is approx. 3% of GDP, for the output tax – approx. 25% of GDP. Moreover, we find that the endogenous reduction of the tax base is considerably stronger in case of the input tax.

Figure 2. Tax rates (left panel) and tax revenue (right panel) which result in a 20% decrease in the output of the RMP sector. The tax revenue is presented as a percentage of the baseline GDP and does not take into account the endogenous drop in GDP.



The crucial difference between the two taxes is however in the endogenous response of firms concerning investment in material efficiency. Figure 3 shows effects of both taxes on investment in material efficiency in sectors on which the tax is levied (industry, energy, construction, transport). The input tax, which increases the price of intermediate material input in the production function, induces offsetting, endogenous additional firm investment in technology. Our model shows that in 2050, firms operating in these sectors are able to produce approximately 15% more goods from a unit of RMP intermediate material. In the case of output tax, the price signal works in the opposite direction. Firms do not see a direct link between the tax and their material efficiency and therefore invest less in cleaner, more resource efficient technologies. Due to the limited substitution possibilities between material input and other factors of production, the final result is a strong GDP contraction as reported in Figure 1.

Figure 3. Effect on material efficiency in selected sectors of the input and output tax.



Now we discuss adjustments in the sector structure of GDP and employment, as well as a potential of shifting towards a more service based economy as a result of taxation aimed at resource decoupling. Figures 4 and 5 show the impact of both taxes on GDP and employment sector structure in 2030 and 2050. The main finding is that none of the taxes brings about substantial sectoral shifts. Maximum changes reach approx. 1.75 percentage points of GDP for private and public service sectors, and 4 percentage points for employment in the public service sector. Overall, the output tax has a stronger effect on the sector structure of economy, especially for employment structure. Smaller sectoral shifts in the input tax simulation are primarily due to firms' investment in material efficiency, which imply that adjustments go through efficiency channel and not via sector reallocation. For the output tax, employment share decreases in sectors on which the tax is levied and increases in remaining sectors, primarily in the public service sector. What is more, the GDP share of this sector also increases the most. This is due to the fact that this sector has the smallest share of intermediate use in its value added, therefore the price increase of intermediate use in other sectors (brought about by the tax) increases the relative demand for the output of this sector.

Figure 4. Effect on structure of GDP in 2030 and 2050 shown in percentage points with respect to baseline.

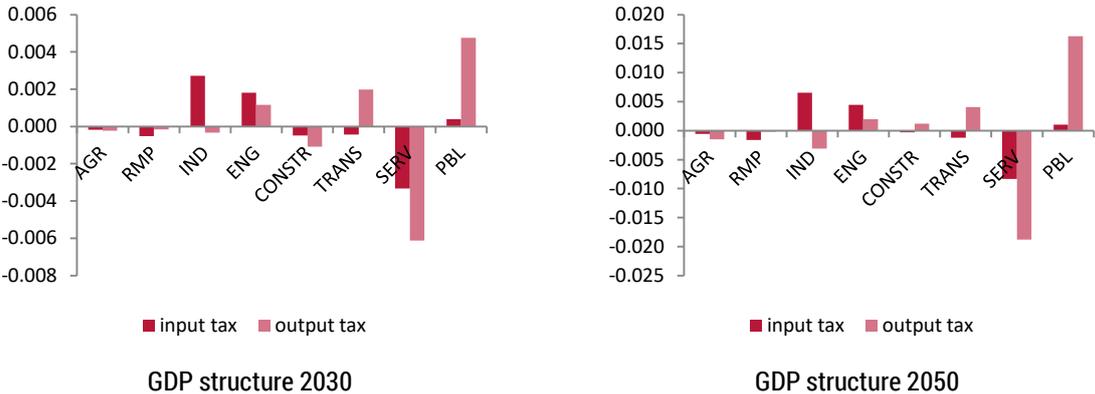
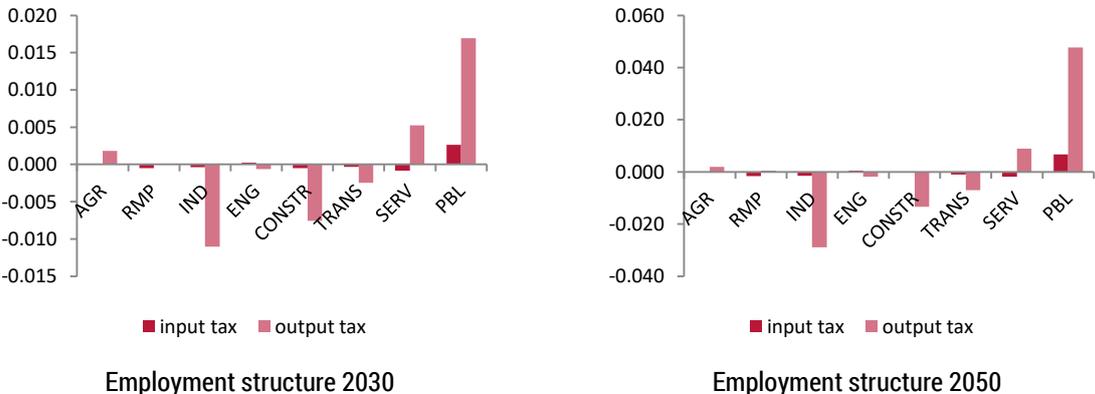


Figure 5. Effect on structure of employment in 2030 and 2050 shown in percentage points with respect to baseline.



3.2. Equalling tax revenue

This subsection shows the results for the fiscal approach simulation – we compare the two taxes along their ability to generate revenue. Since the bases of the two taxes react differently, we opt for a simulation in which we equate the revenue at approximately 1% of GDP in 2050. This simulation is important when considering the double dividend hypothesis and using the environmental tax revenue to decrease labour taxation. Conducting such a policy requires a stable source of government income to finance such a decrease. As can be expected, the left panel of Figure 6 shows that the required output tax rate is small in comparison to the input tax rate. The right panel of Figure 6 shows that the trajectory of the revenue from the input tax has higher curvature. That suggests that the base of this tax responds more strongly than that of the output tax. Lower responsiveness of the output tax base means that it is a more stable source of revenue and as such might better suited for combining it with labour tax reduction.

Figure 6. The tax rates (left) and the resulting revenue from the tax – set to approximately achieve 1% of GDP revenue in 2050.

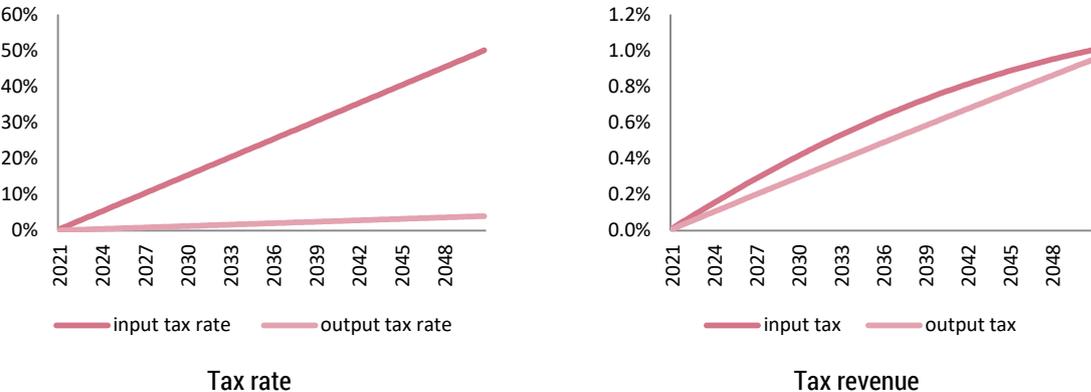
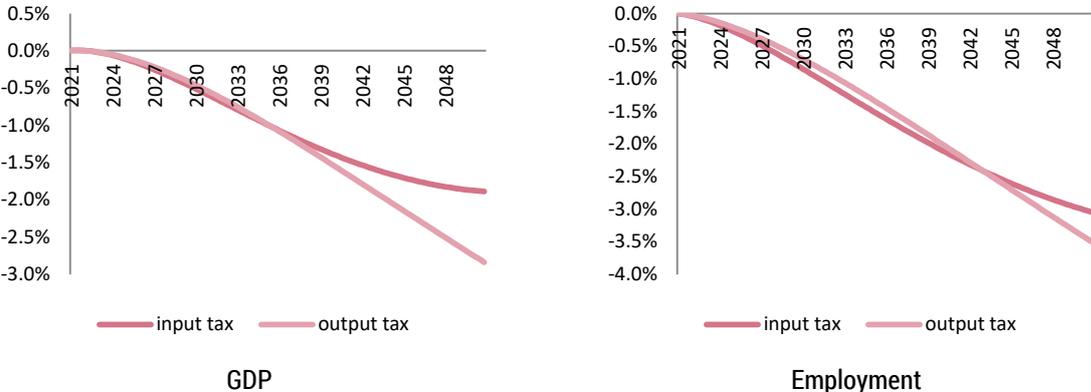


Figure 7 shows the impact of the two taxes on GDP and employment. The short term elasticity of these two macroeconomic indicators with respect to tax revenue is essentially the same. However, in the long-run the negative effect of the input tax is weaker, because firms are able to adapt to this tax with investment in material efficient technologies, therefore slowly reversing the economic decline.

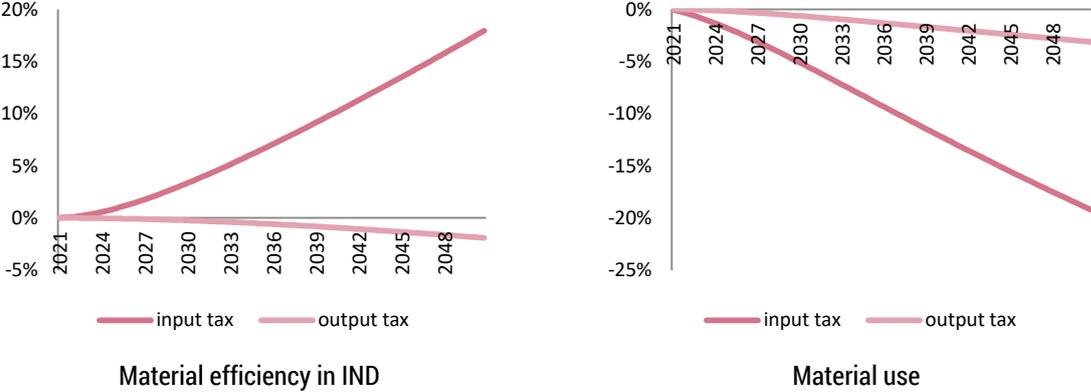
Figure 7. Impact on GDP and employment of environmental taxes when rates are set to equate tax revenue.



The left panel of Figure 8 shows the impact the two taxes have on the endogenous reaction of Industry sector firm regarding material efficiency. Improvement in material efficiency and reduction of material use are much stronger in the case of input tax. A relatively small output tax does not have a significant negative effect on

material efficiency, however, as can be seen from the right panel of Figure 8, its environmental impact is also very small. The strong revenue effect of the output tax is offset by its ability to promote environmentally friendly development.

Figure 8. Effect of environmental taxes on material efficiency in Industry sector and on material use.



3.3. Tax recycling

This subsection discusses the experiment of spending 20% of the environmental tax revenue (material reduction approach) on reducing labour taxation. The rationale behind this simulation is the following: policy makers believe that a large part of the negative economic effect of environmental policies can be avoided by creating incentives which could increase labour supply. Moreover, as shown in the previous subsections, environmental taxes can be a significant source of government revenue. Thus, it is important to not only discuss the price incentives that tax policies provide, but also deal with their implications for fiscal policy. This matters especially for the output tax.

Channelling environmental tax revenue for reduction of labour tax has at least two important effects. On the one hand, lower labour taxation increases labour supply, thus contributes to higher employment. On the other, the additional output brought about by increased employment has an offsetting effect on material use, especially if new jobs are created in resource-intensive sectors.

Figures 9 and 10 show effects of such tax recycling on GDP and employment in comparison to the effect of fiscal approach simulation with a standard lump sum closure, which we discussed in subsection 3.1. The negative effect of the input tax is clearly counterbalanced by the reduction in labour taxation. The maximum deviation from baseline scenario is much smaller for both GDP and employment. GDP even returns to the baseline at the end of the simulation horizon, implying only a transitory slowdown. However, the case of the output tax is completely different. Both GDP and employment are barely affected by the recycling of revenues. This is because the resulting increase in employment has a strong side effect on material use, which in turn requires much larger output tax rate in order to achieve the assumed 20% decrease in the output of the Raw Materials Production sector. The final tax rates for both scenarios are shown in Table 2.

Figure 9. Effect of input (left panel) and output tax (right panel) on GDP under the assumption of 20% revenue recycling to reduce wage tax or transfer closure.

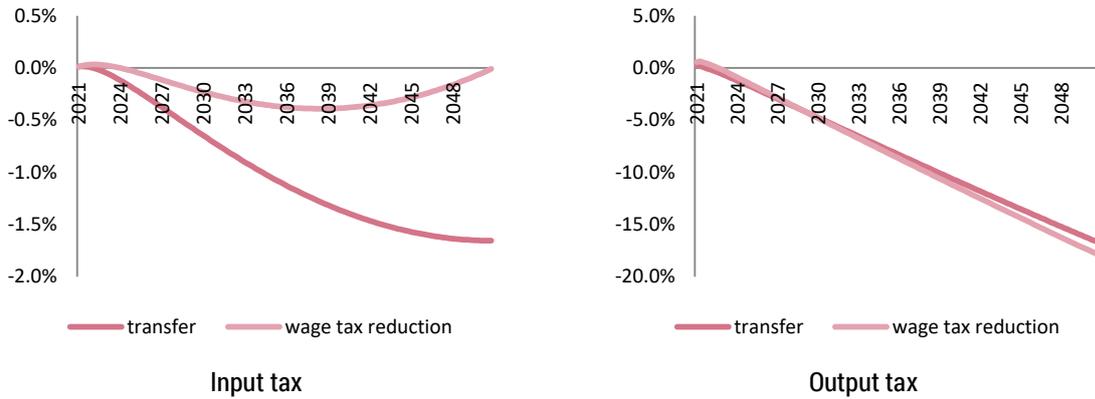


Figure 10. Effect of input (left panel) and output tax (right panel) on Employment under the assumption of 20% revenue recycling to reduce wage tax or transfer closure.

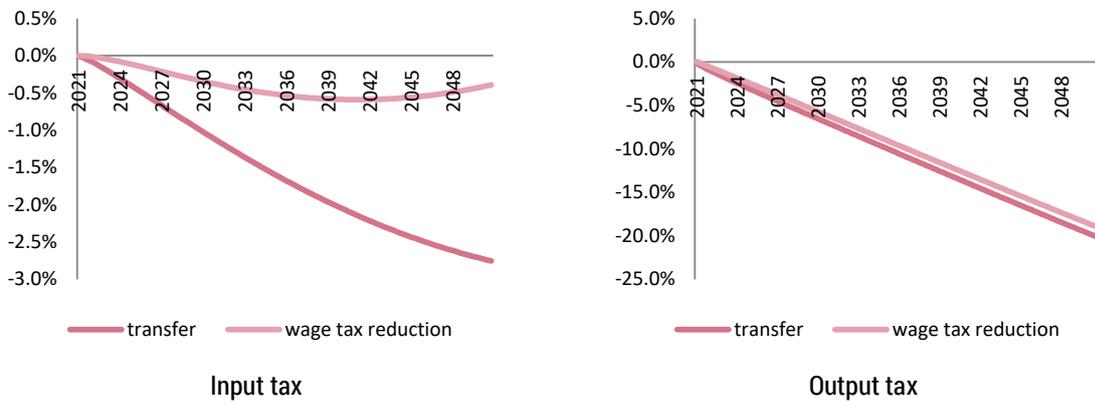


Table 2. Comparison of final tax rates (for 2050) for transfer and wage tax recycling scenario.

	transfer	wage tax reduction
input tax	46.7%	51.9%
output tax	25.0%	44.9%

3.4. Sensitivity analysis

In this subsection we perform a sensitivity analysis for parameter α which could be interpreted as the extent of the rigidity of changes in material efficiency with respect to additional spending. Alternatively, it could be understood as a parameter determining substitution possibilities between materials and material-saving technologies. Figure 11 shows the simulated path of GDP deviations for the two taxes and a wide range of parameter α values. The left panel shows that the technology rigidity parameter has a significant impact on the GDP response to the input tax. For the lower end of the parameter range, when firms have little possibilities to

substitute materials with the quality of technology, the drop in output in 2050 equals 1.2%, whereas for the higher end it is almost 4 times stronger – 4.7%.

The analysis of parameter sensitivity for the output tax yields seemingly contrasting results. The higher the technology rigidity parameter, the smaller the drop in GDP. The relative differences of the GDP changes in low- and high parameter value simulations are smaller, ranging from 18% to 12%. The output tax has a negative effect on investment in material efficiency for all levels of α . However, for high values of α , the decreasing investment leads to smaller losses in terms of material efficiency, and as a consequence to a shallower output decline. This can be seen from Figure 12, which shows the results for material efficiency. For high values of α , these changes are smaller than 1% (which for the 30 year horizon implies negligible yearly changes), although the directions of change are the same. Moreover, if we compare the decline in GDP for both taxes with a high value of parameter α , we see that it is still considerably smaller for the input tax (4.7%) than for the output tax (12.0%).

Figure 11. Sensitivity analysis for effect on GDP with respect to parameter α for input tax and output tax. Baseline value used in simulations is 1.5.

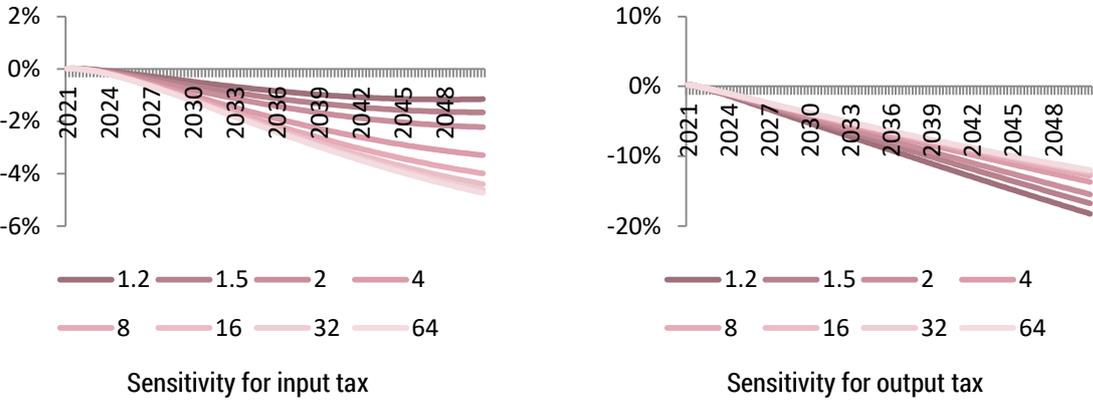
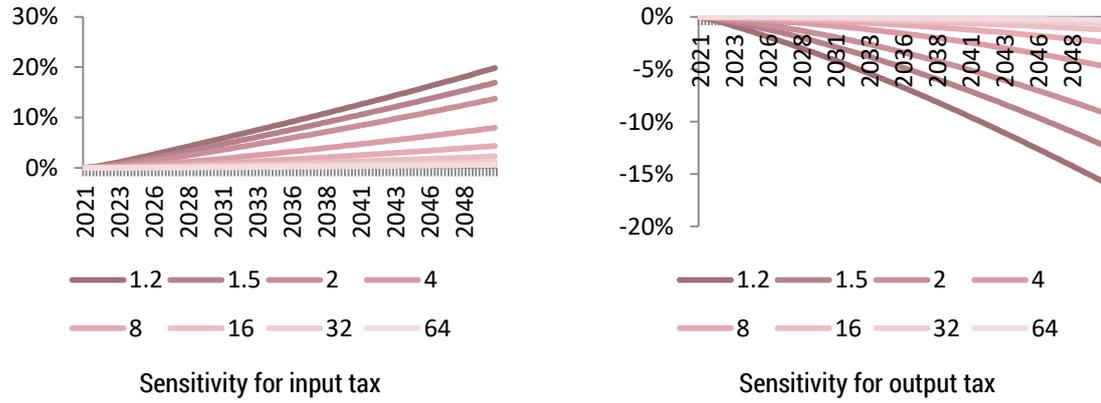


Figure 12. Sensitivity analysis for effect on material efficiency of Industry sector with respect to parameter α for input tax and output tax. Baseline value used in simulations is 1.5.



4. Conclusions

Our simulation results clearly indicate that the reduction of material use through the taxation of material input brings smaller economic costs than the same reduction achieved through the taxation of output in material-intensive sectors. In 2050, input tax levied on the EU27 from 2021 on encompasses by 16 percentage points smaller loss in GDP and by 17 percentage points smaller loss in employment in comparison to the output tax levied in the same period. Furthermore, input tax achieves the same material reduction target with smaller and less rapid changes in sectoral structure. Smaller structural change implies lower need for re-skilling of the workforce and therefore could potentially entail lower social costs of environmental policy.

We find that a significant part of the difference between macroeconomic effects of input and output tax could be traced down to the difference in technological adjustments induced by these taxes. Input tax incentivises firms in material-intensive sectors to invest in material-saving technologies. Since firms substitute materials with technology, they do not need a large cut in production in order to meet the material use reduction target. Indeed, the sensitivity analysis in section 3.4 shows that when firms do not have an option to invest in material-saving technology, the economic costs of input tax are much larger.

In contrast, the output tax creates no incentives for firms in material intensive industries to substitute materials with technology. A reduction in demand for firms' products is a direct effect of the output tax and firms respond with a reduction in use of all factors of production. Since material-saving technology could be viewed as one of the factors, the firm will look for cuts also in this domain. Indeed, figure 12 suggest that output tax leads to a reduction in material-efficiency. The sensitivity analysis in section 3.4 indicates that when the firm does not have a possibility to economise on a quality of technology, the reduction in material efficiency is smaller.

In addition to the material reduction approach, we have considered two alternative simulation setups. First, instead of targeting a given reduction in material use, we set a fiscal goal: we identified and simulated the output and input tax rate paths which result in the same budgetary revenue in 2050. We found that also in this fiscal approach simulation input tax involves smaller economic costs (in terms of GDP and employment) than output tax.

We also considered a scenario in which the tax revenue is partially used to reduce labour taxation. According to the double dividend hypothesis, this should reduce the negative economic effects of an environmental tax. Indeed, the hypothesis is supported in case of input tax. If the tax revenue is used on reduction of labour tax rate, the input tax has a negligible effect on GDP and employment in the long-run. In contrast, similar recycling of the output tax revenue barely affects the trajectory of GDP and employment loss implied by output tax and lump-sum transfer fiscal closure. The reason for this is that lowering labour taxes leads to more production and higher resource use. Thus, the output tax rate has to be even higher to meet the material reduction target, which in turn introduces even more distortion in the economy.

All in all, we find the input tax as a better tool to achieve resource decoupling than the output tax. However, output tax is superior in one regard – guaranteeing budgetary revenue. As input tax leads to much higher resource efficiency than output tax, it cuts down its own base to a higher extent than the output tax. Thus, if policy makers would treat these environmental taxes not only as an instrument to achieve resource decoupling, but also as an additional source of budget revenue per se, they would find the output tax more attractive than suggested by its poorer macroeconomic and resource-efficiency characteristics.

References

- EC 2012, Manifesto for a resource-efficient Europe. European Commission, Brussels, 17 December 2012, available online: http://europa.eu/rapid/press-release_MEMO-12-989_en.htm
- USEPA 2012, Beyond RCRA: Prospects for Waste and Materials Management in the Year 2020, United States Environmental Protection Agency, available online: <http://www3.epa.gov/epawaste/conservesmm/vision.htm>
- Su, B.; Heshmati, A.; Geng, Y.; Yu, X.. A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production* 2013, 42, 215–227.
- Eckermann, F.; Golde, M.; Herczeg, M.; Mazzanti, M.; Montini, A.; Zoboli, R. Resource taxation and resource efficiency along the value chain of mineral resources. European Environment Agency 2012, http://scp.eionet.europa.eu/wp/wp2012_3.
- Popp, D. The effect of new technology on energy consumption. *Resource and Energy Economics* 2001, 23(3), 215-239.
- Sue Wing, I. Explaining the declining energy intensity of the U.S. economy. *Resource and Energy Economics* 2008, 30(1), 21–49.
- Linn, J. Energy prices and the adoption of energy-saving technology. *Economic Journal* 2008, 118 (533), 1986-2012.
- Takeda, S. The double dividend from carbon regulations in Japan. *Journal of the Japanese and International Economies* 2007, 21(3), 336-364.
- Fæhn, T.; Gómez-Plana, A.G.; Kverndokk, S. Can a carbon permit system reduce Spanish unemployment? *Energy Economics* 2009, 31(4), 595-604.
- Popp, D. R&D subsidies and climate policy: Is there a ‘free lunch’?. *Climatic Change* 2006, 77(3-4), 311-341.
- Fischer, C.; Newell, R. Environmental and technology policies for climate mitigation. *Journal of Environmental Economics and Management* 2008, 55(2), 142-162.
- Gerlagh, R.; van der Zwaan, R. Options and instruments for a deep cut in CO₂ emissions: Carbon dioxide capture or renewables, taxes or subsidies? *The Energy Journal* 2006, 27(3), 25-48.
- Söderholm, P.; Tilton, J.E. Material efficiency: an economic perspective. *Resources, Conservation and Recycling* 2012, 61, 75–82.
- Allwood, J.M.; Ashby, M.F.; Gutowski, T.G.; Worrell, E. Material efficiency: providing material services with less material production. *Philosophical transactions Series A, Mathematical, physical, and engineering sciences* 2013, 371(1986).
- Skelton, A.C.H.; Allwood, J.M. The incentives for supply chain collaboration to improve material efficiency in the use of steel: An analysis using input output techniques. *Ecological Economics* 2013, 89, 33–42.
- Antosiewicz, M.; Kowal, P. Memo III – a large scale multi-sector DSGE model, IBS Research Report, 2016.
- Mortensen, D.T. Equilibrium unemployment dynamics. *International Economic Review* 1999, 40, 889-914.
- Pissarides, C.A. Equilibrium unemployment theory, Publisher: MIT Press, 2000.

Okagawa, A.; Ban, K. Estimation of substitution elasticities for CGE models. Discussion Papers in Economics and Business 2008.

Kuper, G.H.; Van Soest, D.P. Path-dependency and input substitution: implications for energy policy modelling. Energy Economics 2003, 25.4, 397-407.

Bucher, R. Mitigation, Adaptation, Technological Change and International Trade: Economic Aspects of Unilateral Climate Policies. Diss. PhD thesis, Universität Bern, 2011.

Koschel, H. Substitution elasticities between capital, labour, material, electricity and fossil fuels in German producing and service sectors. Center for European Economic Research in its series ZEW Discussion Papers no. 00-31 2000.

Hooper, P.; Johnson, K.; Marquez, J.R. Trade elasticities for the G-7 countries. Princeton Studies in International Economics No. 87 2000.

Heathcote, J.; Perri, F. Financial autarky and international business cycles. Journal of Monetary Economics 2002, 49.3, 601-627.



www.ibs.org.pl