Input vs. output taxation - a DSGE approach to modelling resource decoupling

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Abstract: Environmental taxes constitute 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 dynamic stochastic general equilibrium model of an open economy to study two types of taxation: tax on material inputs used by the industry, energy, construction and transport sectors, and tax on the output of these sectors. We allow for endogenous adaption of resource saving technologies by firms. We calibrate the model for the EU area using Input Output matrix. We consider taxation introduced from 2021 and simulate its impact on GDP, national accounts, labour market, resource use, and public finances until 2050. We compare the taxes along their ability to induce reduction in material use and the amount of tax income that they generate. We also consider several uses of tax revenue – standard transfer to household closure and reduction of labour taxation. 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. The material input tax induces investment in efficiency improving technology which in the long term results in GDP and employment that is 15-20% higher comparing to the scenario with output tax. The tax on output reduces industrial activity but also discourages investment in resource efficiency improving technology. We also find that using revenues for reducing taxes on labour has larger beneficial effects for the input tax. This leads us to the conclusion that material input tax being a more efficient instrument to achieve resource decoupling.

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

JEL: Q50, Q55, D57, D58, O10

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1. Introduction

A need to limit the use of natural resources becomes 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 the future generations. On the other hand, use of resources such as fossil fuels, releases carbon from the earth into atmosphere increasing air-pollution as well as causing the greenhouse effect. The importance of the problem has been recognized by, among others, policy makers in European Union (EC 2012), US (USEPA 2012) and China in its 12th five-year plan for years 2011-2015 (Su, Heshmati, Geng and Yu, 2013).

There are several policy options for resolving the problem of excessive resource use. The logic that today's production puts a burden on future generations justifies the taxation of today's output. If one believes that the current market prices of resources do not reflect their true social costs (e.g. due to atmospheric pollution), a solution is the tax on inputs. The imperfect adoption of more efficient technologies could be resolved with the performance standards, which require firms to limit the use of resources per unit of output. The development and adoption of cleaner technologies could be promoted also with R&D or deployment subsidies. In this paper we limit our attention to the first two policy options: tax on input and tax on output.

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. When simulating the tax rates that 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. On the other hand, when setting tax rates that equate the tax revenue, the output tax results in a much smaller drop in material use. Additionally, we find that the recycling tax revenue on reducing wage taxes is much more efficient in case of the input tax, however this is a tax that is a less stable source of government revenue. This leads us to the conclusion that material input tax being 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 smaller reduction in production. Indeed, as we demonstrate in the sensitivity analysis, larger substitutability between materials and material-saving technologies is associated with a 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 mln. Sue Wing (2008) use industrial data on factor use as well as patent data to decompose changes in US energy-intensity in US industries into changes in industrial composition, factor substitution, technological change induced by changes in energy prices and the disembodied technological change. He find that induced technological change does lead to energy savings, although its contribution is small relative to the other factors in the decomposition. Finally, Linn (2008) finds that a 10 percent increase in the price of energy leads to technology adoption that results in 1% lower energy demand by new firms.

We perform the simulation with a macroeconomic DSGE model which allows for endogenous adoption of material saving technologies. The model is calibrated for the EU area using Input Output matrix. We consider taxation introduced from 2020 and simulate its impact on GDP, national accounts, labour market, resource use, GHG emission and public finances until 2060. In order to compare the impact of the two taxes, we set the two tax rates in such a way that the total reduction in resource use is the same in both cases.

Next we supplement our analysis with three exercises. First, Second, as mentioned above, we examine how the outcome of taxation changes when we vary the parameter determining the substitutability between materials and material-saving technologies. Finally, we check how sensitive are the results to the alternative uses of tax revenue – reducing taxation on labour, subsidising investment in efficient technologies, transfers to household and reducing public debt. The importance of tax recycling has been evidenced by the literature on double dividend hypothesis (e.g. Takeda (2007) and Faehn et al. (2009)). Smaller macroeconomic costs of material tax relative to the costs of the output tax are observed in all variants of the simulations considered.

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 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. Gerlagh and van der Zwaan (2006) highlight the role of the efficiency standards, which, as they argue, promotes both, lower fuel consumption as well as adoption and development of more efficient technologies.

More recently, the literature was extended by the studies, which analyse policies promoting material efficiency. Söderholm and Tilton (2012) argue that policies should correct the externalities directly and 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. (2011) 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 examined the impact of carbon prices on efficiency in the use of steel. They find that subsitutition possibilities between material and labour matters for the effect of the policy. We extend the analysis of Skelton and Allwood 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 is the optimal policy mix, but rather highlights what effects determines 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 unemployment and growth of wages.

2. Materials and Methods

In this section we describe the model that we use for simulations and characterize the simulation exercises that we conduct. Regarding the model description, we concentrate on specifying the production structure of the firms, since the specification for the remaining agents is standard for DSGE models. A detailed description of the model that we use can be found in Antosiewicz and Kowal (2016).

2.1. Model description

The model that we use for the simulation exercises 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 the household, a representative firm in each of the eight sectors and government.

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

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

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:

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

where θ_E^s is a paramter used to calibrate 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:

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

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

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

where parameter θ_M^s sets the shares 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 we proceed with the following approach. We assume that material good is composed of the material good of the Material Production sector $M_t^{s,RMP}$ and a bundle of goods from remaining sectors MO_t^s with a CES function which also accomodated endogenous material efficiency. Finally, the bundle of remaining material goods is produced using Leontief function. This can be summarized in the following equations:

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

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

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 normalized to unity.

Endogeneity of technology choices means that firms are allowed to change the characteristics of the technology parameters of their production function under market incentives. For instance, an increase in energy prices incentivizes 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. Since the technology in the model is embodied in the capital goods, the firm can only adjust the technology of a current vintage, i.e. the technology of goods purchased today. It cannot change the characteristics of the technology for capital goods purchased in the past periods. Only in the long run, when the share of old vintages in the total capital stock of the firm becomes negligible due to depreciation and new investments, the firm can fully adjust characteristics of the technology to the shocks in prices of inputs.

More specifically, we let EFF_t^s to be determined with

$$EFF_t^s K_t^s = EFF_{t-1}^s K_{t-1}^s + Z_t^s I_t^s$$

Where Z_t^s is the quality of capital goods purchased at time t, K_t^s is the stock of capital and I_t^s is the level of investment. Firms are free to choose the level of quality. However, higher level quality involves higher costs of a capital good. Specifically, the cost of capital goods is given by:

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

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

The frictions in the labour market are modeled according to the Mortensen-Pissarides setup. The unemployment rate is determined endogenously and depends on the number of vacancies generated by firms and the number of job seekers. The decisions of firms on opening of vacancies depends on the current and future states of the economy.

Table 1. Sector structure of model.

	Sector name	Sector abbrv.	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	Public Services	PBL	O, P, Q, R, S, T, U

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

The sector structure of the model is calibrated using the Nace Rev. 2 Input-Output matrices for the year 2010 available from Eurostat. The model is dissagregated 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 summarizes the sector structure of the model.

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 loss of output, employment or sector shifts in the conomy. 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, Construvtion and Transport sectors. In case of the output tax we define it as an excise (non-deductible) tax which is levied on the value added generated by the four sectors. In order to assess the taxes along a possible wide range of dimensions, we perform several varying simulation experiments. In the basic comparison of these two taxes we consider two simulation exercises which differ in the basis of comparison of the two taxes. In the first one we take a material reduction approach. To this end we conduct a simulation exercise in which the tax rates increase roughly linearly from the year 2021 up to 2050 such that the decrease of the output of the RMP sector is increasing linearly from 0% up to 20% by the end of the simulation horizon. In the second simulation exercise we follow a fiscal approach, in which we examine the ability of these two taxes to serve as stable source of government revenue. In these simulations we impose linearly increasing tax rates that both result in a revenue of approximately 1% of GDP at the end of the simulation horizon. For both these simulations we use the assumption of lump sum transfer closure for the household in order to analyze only the price incentives that the tax has for the behavior of firms.

In the third simulation experiment we check the possibility of the double dividend hypothesis. To this end we follow the first simulation experiment (in which the tax rate is set to match material reduction) and additionally assume that 20% of the revenue from the tax is spent on decreasing labour taxation. The main aim of this simulation is not to verify the double dividend hypothesis, but to compensate the fact that the two taxes differ significantly in their total tax revenue. The offsetting effect of labour tax reduction will therefore be much stronger in the case of the output tax.

Finally, in order to check the robustness of our results, which to a large extent rely on the endogenous material efficiency mechanism, we perform sensitivity analysis with respect to the elasticity parameter which governs this mechanism. In the sensitivity analysis we use the same assumption about the level of the tax rate as in the first simulation exercise. All simulations are performed using the Kalman filter. Results presented in the next section are shown as deviations from the steady state of the model, which we interpret as the baseline growth scenario for the EU.

3. Results

3.1. Equalling material reduction

This subsection shows results for the basic comparison simulation in which we set tax rates to achieve a material reduction of 20% at the end of the simulation horizon. We start with discussing the basic macroeconomic impact of the two taxes as measured by the respsonse of gross domestic product, employment, investment and exports, which is shown in Figure 1. Both taxes have a negative impact on all economic indicators, however it is clearly visible that the output tax causes a much stronger decline. The drop in GDP at the end of the simulation horizon is equal to 16.7%, against 1.7% for the input tax. This is eqiuvalent to a yearly growth rate which is respectively 0.6 and 0.06 percentage points slower than in the case without the taxes. The impact on employment and investment is slightly stronger for both taxes, with the final decrease in 2050 for the output tax equal to approximately 20.2% and 26.7% respectively, wheras for the input tax and 2.8% and 3.6%. The decrease for international trade as measured by value of exports (footnote: the drop for imports is roughly the same) is most pronounced, leading to a more closed European economy – the drop is equal to 31.1% and 10.6% percent for the output and input tax respectively, which is much stronger than the impact the taxes have 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 and does not take into account trade between EU member states. The relative impact on trade (measured in comparison to GDP decline) is much stronger in the case of the input tax, due to the fact that it directly taxes the import of material goods, as oposed to the output tax, which decreases the competitiveness of home produced vs foreign goods.

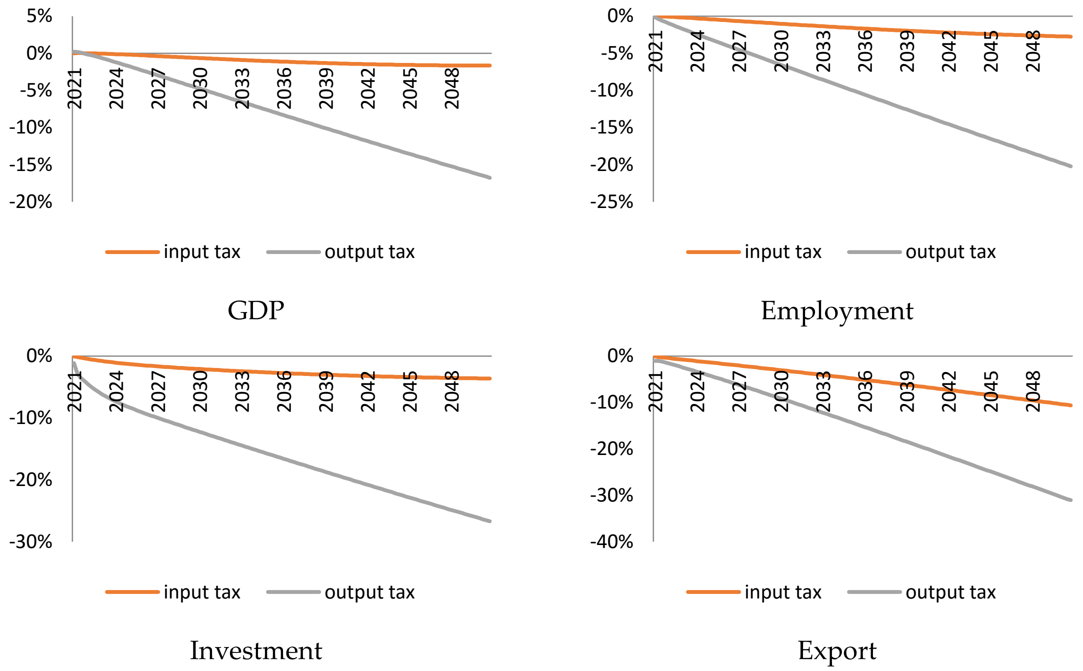

Figure 1. Basic macroeconomic impact of the input and output taxes on gross domestic product, employment, investment and exports. Results are shown as percent deviations from baseline scenario.

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 rates increase approximately linearly from 2021 and reach approximately 47% and 25% for the input and output tax respectively. However, an inspection of the generated tax revenue, which is shown on the right panel of Figure 2, shows a completely different story. The revenue generated from the output tax reaches 5% of baseline GDP (if we take into account the endogenous fall of GDP resulting from the tax, this figure would be even greater), which is almost the same order of magnitude as the revenue from value added tax in the European Union. We argue that this tax cannot be treated only as an measure whose aim is to reduce material use, but also as a considerable source of government income which would require changes in the tax system. The difference in total tax revenue is mainly due to the size of the base on which the taxes are levied – for the input and output cases it is approx. 3% and 25% of GDP. However it is important to note that the endogenous reduction of the tax base is considerably stronger in case of the input tax.

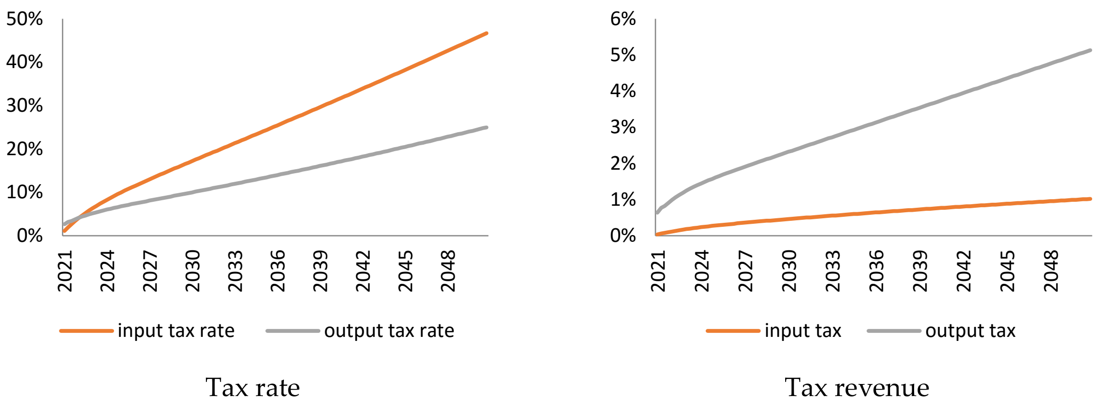

Figure 2. Tax rates (left panel) and tax revenue (right panel) which result in a 20% decrease in the output of the RMP sector. The tax revenue is presented as a percentage of the baseline GDP and does not take into account the endogenous drop in GDP.

The main difference between the two taxes is however in the endogenous reaction of firms concerning investment in material efficiency. Figure 3 shows the effect the two taxes have on investment in material efficiency in the sectors on which the tax is levied. The input tax, which increases the price of intermediate material input in the production function, induces offsetting, endogenous investment by firms in technology. At the end of the simulation horizon, firms operating in these sectors are able to produce aproximately 15% more goods from a unit of RMP intermediate material. In case of the 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 chose to 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 drop of GDP growth as reported in Figure 1.

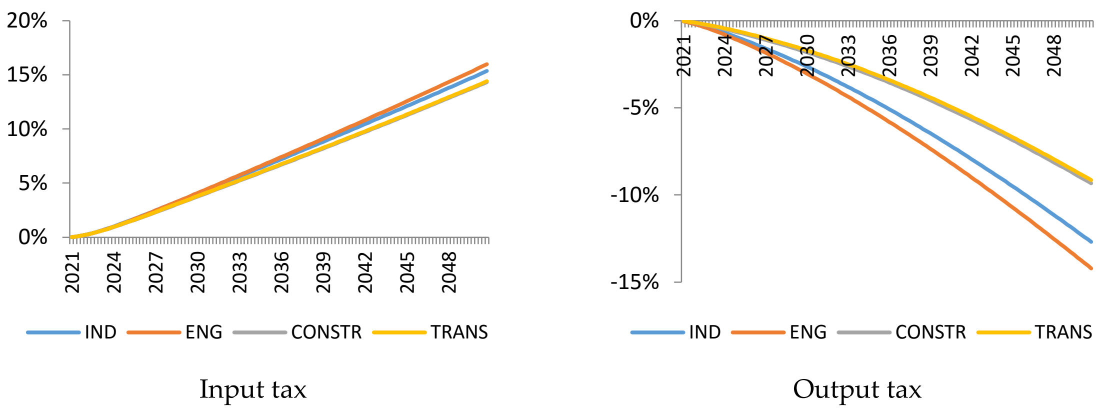

Figure 3. Effect on material efficiency in selected sectors of the input and output tax.

We now discuss the changes in the sector structure of GDP and employment and discuss the potential of shifting towards a more service based economy. Figures 4 and 5 show the effect of the two taxes on the sector structure with respect to the two indicators 2030 and 2050. The main result is that the two taxes do not bring about large sectoral shifts in the economy, with maximum changes equal to approx. 1.75 prct points measured by GDP for the private and public service sectors and 4% for employment in the public service sector. Overall, the output tax has a stronger effect on the sector structure of the economy, which is especially visible for shifts on the labour market. This is primarily due to firms' investment in material efficiency, thanks to which most of the adjustments go through this channel and not sector reallocation. For the output tax, the share of employment decreases in sectors on which the tax is levied and increases in remaining sectors, primarily in the public service sector. What is more, the share of GDP of this sector will also increase 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.

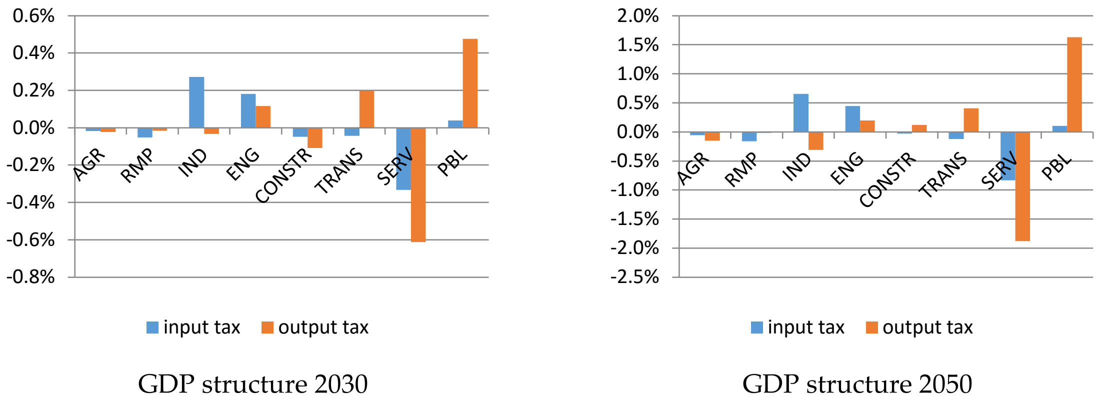

Figure 4. Effect on structure of GDP in 2030 and 2050 shown in percentage points with respect to baseline.

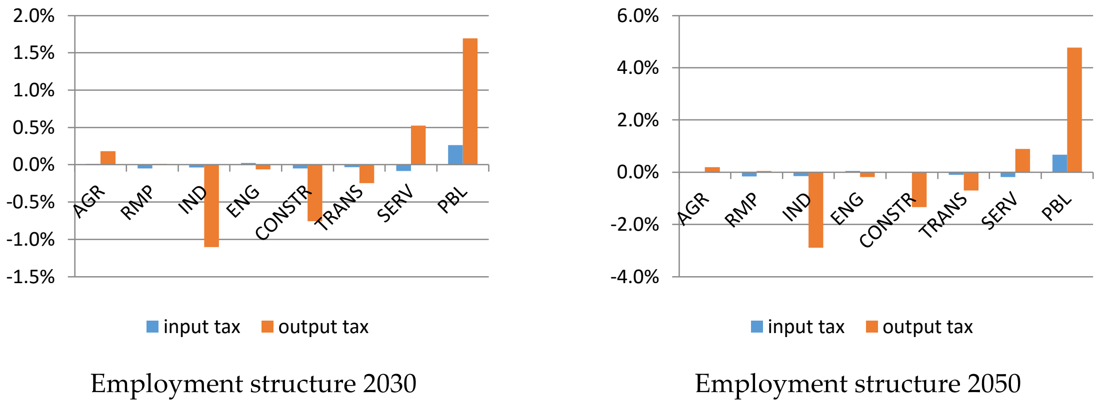

Figure 5. Effect on structure of employment in 2030 and 2050 shown in percentage points with respect to baseline.

3.2. Equalling revenue from the tax

This subsection shows the results for the simulation when 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 revnue for the end of the simulation horizon. This simulation is important when considering the double dividend hypothesis and spending the environmental tax revenue to decrease labour taxation. Conducting such a policy requires a stable source of government income to finance this 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 – showing that the base of this tax responds more strongly. The smaller volatility of the base of the output tax means that it is a more stable source of income and better suited for combining it with a policy of labour tax reduction.

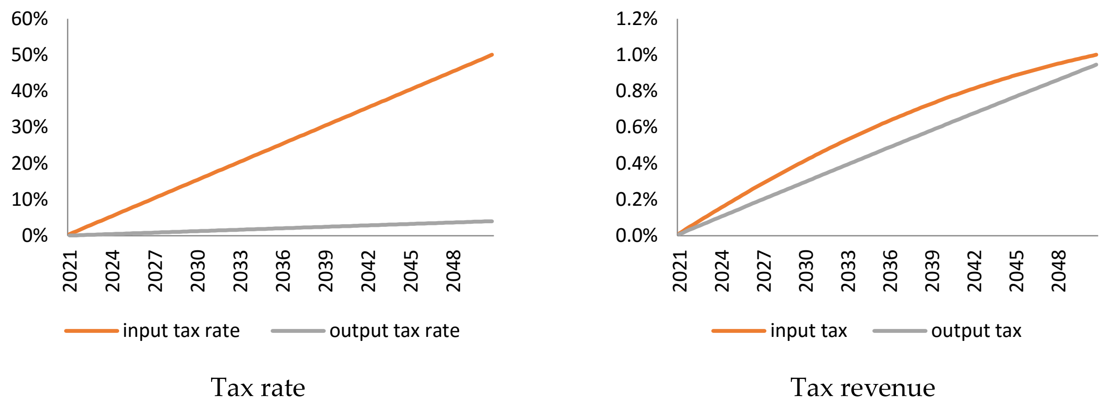

Figure 6. The tax rates (left) and the resulting revenue from the tax – set to approximately achieve 1% of GDP revenue in 2050.

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 approximately the same, however it is important to note that in the long run the negative effect of the input tax is weaker. This result is due to the fact that in case of this tax, firms are able to invest in material efficient technologies, therefore slowly reversing the economic decline.

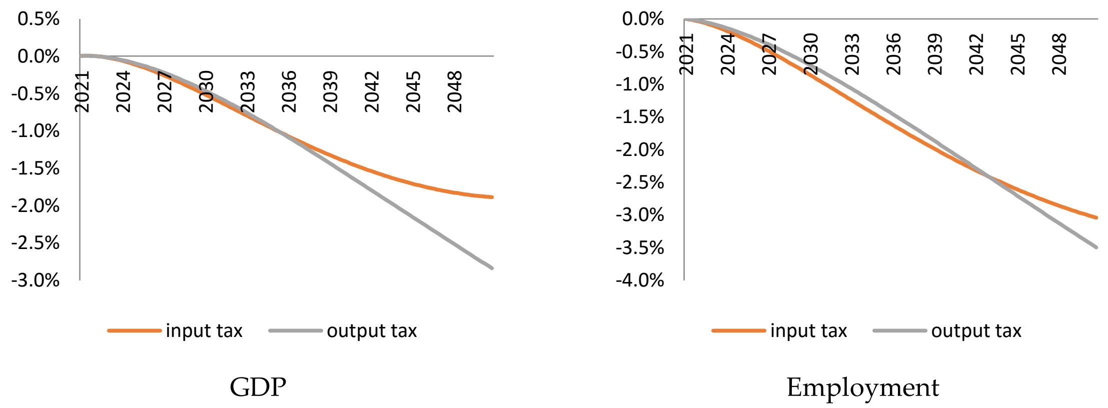

Figure 7. Impact on GDP and employment of environmental taxes when rates are set to equate tax revenue.

Finally, the left panel of Figure 8 shows the impact the two taxes have on the endogenous reaction of Industry sector (footnote: results for remaining sectors on which taxes are levied are of similar magnitude) firm regarding material efficiency. A relatively small output tax does not have a significant negative effect in this respect, 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 clearly offset by its ability to promote environmentally friendly development.

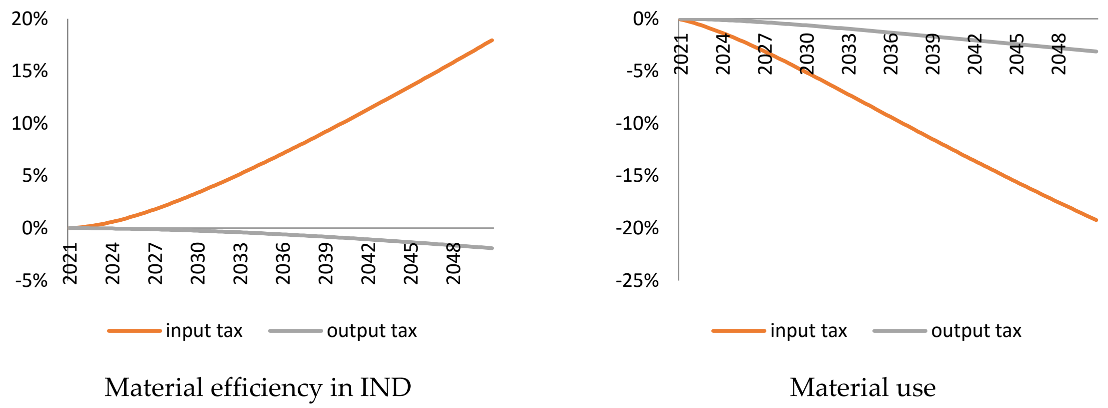

Figure 8. Effect of environmental taxes on material efficiency in Industry sector and on material use.

3.3. Tax recycling

This subsection discusses results for the case when 20% of the tax revenue from the environmental taxes is spent on reducing labour taxation. The additional rationale behind this simulation is the following: Policy makers believe a large part of the negative 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. Here, the case is especially important in case of the output tax.

Channeling environmental tax revenue for redution of labour tax has at least two important effects. First of all it is an incentive for inactive persons to take up work, therefore contribution to higher employment. On the other hand, the additional output brought about by increased labour has an offsetting effect on material use, especially if new jobs are created in resource-intensive sectors.

Figures 9 and 10 show the basic macroeconomic effects of such tax recycling on GDP and employment in comparison to baseline effect from the previous subsection, in which we assumed a standard lump sum closure. In case of the input tax, the negative effect is clearly countered by the reduction in labour taxation. The maximum deviation from baseline scenario is much lower for both variables, and in case of GDP it returns to the baseline at the end of the simulation horizon, implying only a temporary economic slowdown. However, the case of the output tax is completely different, with both indicators showing almost identical trajetories. The reason for this is that the resulting increase in emloyment has a strong side effect on material use, requiring a 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.

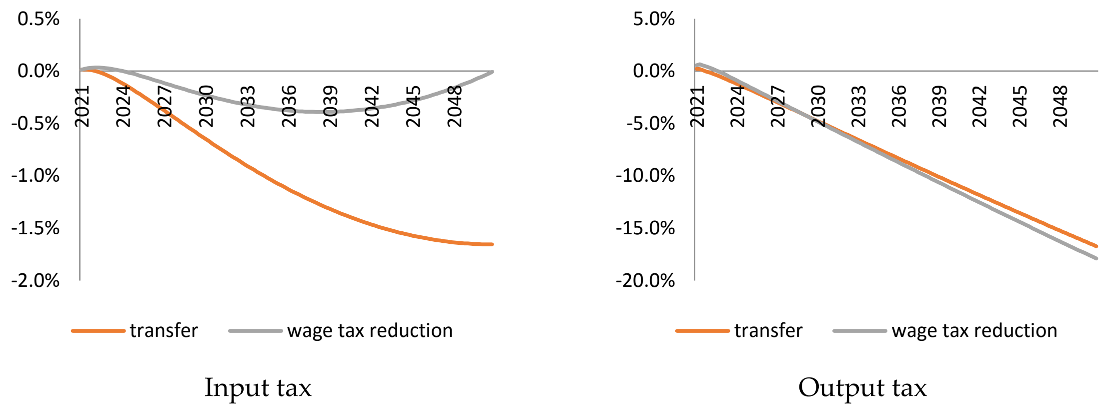

Figure 9. Effect of input (left panel) and output tax (right panel) on GDP under the assumption of 20% revenue recycling to reduce wage tax or transfer closure.

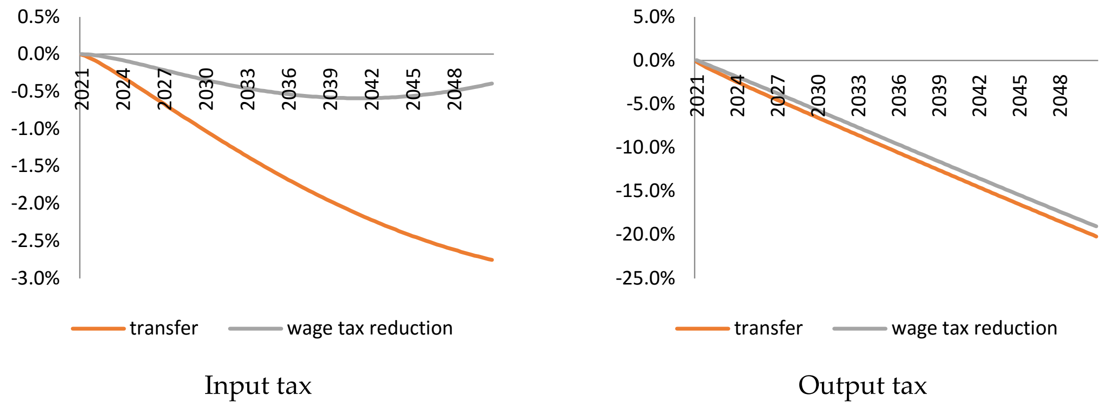

Figure 10. Effect of input (left panel) and output tax (right panel) on Employment under the assumption of 20% revenue recycling to reduce wage tax or transfer closure.

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 standard sensitivity analysis for parameter α, which sets cost of investment in resource efficienct. Figure 11 shows the expected path of GDP for the two taxes for a wide range of paremeter values. As can be seen from the left panel, the assumed cost of investment in material efficiency has a significant impact on the final economic decline. For the lower end of the parameter range, the drop in output is 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 cost parameter the lower the drop in GDP and the relative differences of the GDP decline are smaller, ranging from 18% to 12%. In order to explain the results the parameter α has to be interpreted as the extent of the rigidity of changes in material efficiency with respect to additional spending. 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. What is more, if we compare the decline in GDP for both taxes with a high value for this parameter, we see that it is still considerably smaller for the input tax (4.7%) than for the output tax (12.0%).

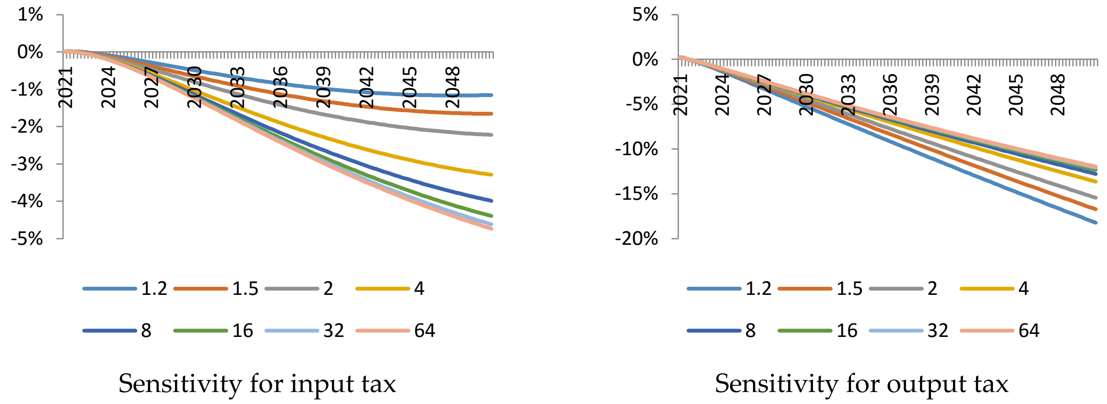

Figure 11. Sensitivity analysis for effect on GDP with respect ro parameter alpha for input tax and output tax.

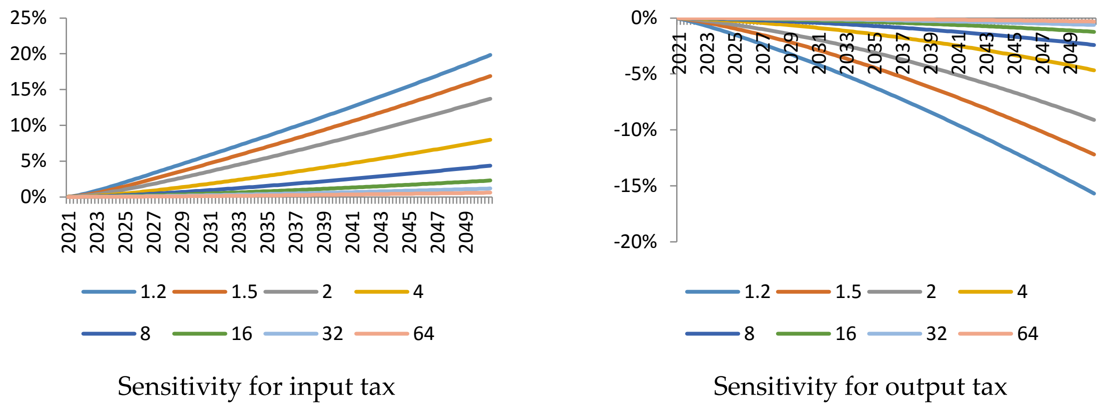

Figure 12. Sensitivity analysis for effect on material efficiency of Industry sector with respect ro parameter alpha for input tax and output tax.

4. Discussion / conclusions

The 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. Input tax leads to 16% percentage points smaller loss in GDP in 2050 and 17% percentage points smaller reduction in employment comparing to the output tax. Furthermore, the input tax achieves the same material reduction target with a smaller and less rapid changes in sectoral structure. This requires less need for a requalification of labour and therefore could potentially soften the social costs of an environmental policy. Interestingly, as indicated in section 3.4, with an appropriate recycling of the input tax, the economic costs of the policy could be only temporary – with zero macroeconomic effects in the long run.

We find that the significant part of the difference between macroeconomic effects of input and ouput taxes could be explained with the difference in technological adjustments resulting from these two taxes. The input tax incentivizes 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 does not brings incentive for firms in material intensive industries to substitute materials with technology. The direct effect of the tax is a reduction of the demand for firms' products. The firm responds to this 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 possibility to economize on quality of technology, the reduction in material efficiency is smaller.

In addition to the baseline scenario, we have considered two alternative scenarios. First, instead of targeting a given reduction in material use, we set the fiscal goal: we selected the ouput and input tax rates in the way that both taxes results in the same revenue for the budget. We found that also in this scenario input tax incvolves smaller economic costs (in terms of GDP and employment) than the output tax.

Finally, we considered a scenario in which the revenue from the taxes is partly 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 the case of input tax. When the tax revenue allows for a reduction in labour tax rate, the input tax has negligible effects on GDP and employment. In contrast, similar recycling of output tax produces almost exactly the same GDP loss as in the scenario in which the tax revenue is returned to consumer in the form of lump-sum. The reason for this is that lowering labour taxes incentivize more production and higher resource use. Thus, to meet the material reduction target, we need to substantially increase the output tax rate introducing more distortion into the economy.

Acknowledgments: The paper has received funding from the European Union's Seventh Framework Programme under grant agreement no 308674.

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