RECYCLING OF ECO-TAXES, LABOR MARKET EFFECTS AND THE TRUE COST OF LABOR– A CGE ANALYSIS

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Computable general equilibrium (CGE) modeling has provided a number of important insights about the interplay between environmental tax policy and the pre-existing tax system. In this paper, we emphasize that a labor market policy of recycling tax revenues from an environmental tax to lower employers' non-wage labor cost depends on how the costs of labor are modeled. We propose an approach, which combines neoclassical substitutability and fixed factor proportions. Our concept implies a user cost of labor which consists of the market price of labor plus the costs of inputs associated with the employment of a worker. We present simulation results based on a CO_2 tax and the recycling of its revenues to reduce the non-wage labor cost. One simulation is based on the market price of labor and the other on the user cost of labor. We found a double dividend under the first approach but not under the second one.

JEL classification codes: D58, J30, Q25
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I. Introduction

Computable general equilibrium (CGE) analyses have played over the last ten years a key role in the evaluation of green tax reforms, the reorientation of the tax system to concentrate taxes more on "bads" like pollution and less on "goods" like labor input or capital formation. The ongoing concern about the magnitude of distortionary taxation suggests the possibility of using environmental taxes to replace existing factor and commodity taxes. A conjecture called the "double

dividend hypothesis" points out that environmental taxes have two benefits: they discourage environmental degradation and they raise revenue that could offset other distortionary taxes.[1] The non-environmental dividend can be defined in various ways. Given the important unemployment problem in the EU, priority has been given to the analysis of distortions in the labor market that might explain persisting unemployment.[2] The revenue from the pollution taxes is recycled to cut labor taxes. On the one side, the narrow base of an energy tax constitutes an inherent efficiency handicap. On the other side, the impact of the tax reform on pre-existing inefficiencies in taxing labor could offset this handicap and a double dividend arises. Therefore, in principle a double dividend can arise only if (i) the pre-existing tax system is significantly inefficient on non-environmental grounds and (ii) the revenue-neutral reform significantly reduces this prior inefficiency. The double dividend actually arises only if the second condition operates with sufficient force. However, it could also arise if the burden of the environmental tax falls mainly on the undertaxed factor (e.g., immobile capital) and relieves the burden of the overtaxed factor (i.e., labor).[3] Since no existing tax systems are likely in a second-best optimum, i.e., minimizing the sum of deadweight losses given a fixed budget, the scope for a double dividend is always present.

Although CGE modeling has provided a number of important insights about the interplay between environmental tax policy and the pre-existing tax system, much remains to be done to improve our understanding of market-based environmental policy. One reason is that some CGE modelers affirm the double dividend hypothesis while others could not find a double dividend outcome. The specification of the labor market, for instance, could be crucial to the discussion on the effect of environmental policy on employment. A labor market policy of recycling tax revenues from an environmental tax to lower employers' non-wage labor cost depends on how the labor market is modeled. The objective of our analysis is not to show that non-competitive labor markets could provide a potential channel for a double dividend outcome. A variety of approaches are discussed in the literature to analyze the impacts of an ecological tax reform in the presence of wage setting institutions and involuntary unemployment. Typically, labor market

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[1] For a state of the art review on the double dividend issue, see Goulder (1997) and Bovenberg and Goulder (2001).

[2] For theoretical papers on the double dividend issue, see Goulder (1995) and Bovenberg and Goulder (1996). See Jorgenson and Wilcoxen (1992), Proost and van Regemorter (1995) and Welsch (1996) for empirical papers.

[3] See Bovenberg and Goulder (2001) on this point.

imperfections are introduced by an upward sloping wage setting curve, which replaces the labor supply curve used in the competitive model. The equilibrium wage and employment level are now determined by the intersection of the wage setting and the labor demand curve. The theory of equilibrium unemployment offers three microeconomic models, which all capture specific institutional factors of actually existing labor markets – namely trade union models, efficiency wage models, and mismatch models. Each model is appropriate to describe a specific part of the multi-facetted phenomenon of involuntary unemployment. So, unlike the recent double dividend literature, we will not emphasize the empirical relevance of a certain labor market model, but our aim is instead to attack the way the costs of labor are conceived in all neoclassical models.

The objective of this paper therefore is to advocate an approach where the cost of labor is not just wage per day, but the cost of the working place per day, including the wage. This new concept is that of the "user cost of labor", for which, the cost of an additional worker includes not just salary, but also the costs of inputs tied to the worker (e.g., office equipment, electricity, material, etc.).

Such a view will have a reduced impact on substitution possibilities between labor and other inputs and hence will affect the outcome of a double dividend policy in a different way than under the traditional approach of pure market prices. We will use an approach proposed by Conrad (1983) who combines the approaches to neoclassical substitutability and fixed factor proportions. This cost-price approach uses Leontief partially fixed factor proportions to identify both a disposable or variable part and a bound or fixed portion of each input. The true cost, or cost price, of any input consists of its own price plus the costs associated with the portion of that input bound to other inputs. Within the cost-price framework, the demand for an input can be separated into a committed component linked to the use of other inputs, and a disposable component that is free for substitution. At one extreme, when the disposable quantities of all inputs equal zero, no factor substitution is possible and the cost-price approach reduces to the Leontief fixed-proportion case. At the other extreme, when the committed quantities of all inputs are zero, the neoclassical model is relevant and the cost-price of any input equates the market price.

We include this user-cost approach in CGE modeling and then run a model to check its relevance and to understand the effects of imperfect substitution in the labor market.[4] We econometrically estimate cost share equations in cost-prices

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[4] In Section V we relate our result to the findings in the theoretical and empirical literature on the double dividend issues.

and then use cost prices as well as market prices to investigate the double dividend hypothesis.

The paper is organized as follows. In Section II, we present the cost-price approach and in Section III the parameter estimates for a restricted version of the manufacturing industry. In Section IV, we briefly outline our CGE model. In Section V, we present our simulation results based on a CO_2 tax and the recycling of its revenues to reduce the non-wage labor cost. One simulation will be based on market prices and the other one on cost prices. Our objective is to compare the results in the light of the conjecture of a double dividend. The conclusion from our result is summarized in Section VI.

II. Conditioned input demand and cost share equations in cost-prices

In contrast to Leontief production functions, we assume that only fractions of the input quantities are related to each other in fixed factor proportions and that therefore, in contrast to the neoclassical theory, only fractions of the input quantities are disposable for substitutions. With capital, labor and energy as inputs, we regard a truck, a truck driver and the minimal possible fuel consumption as bound inputs. In general, however, not the total quantity of an input is bound by other inputs with fixed proportions, but a fraction is unbound and disposable for substitution. It is this fraction which is relevant for a reallocation of inputs if relative factor prices change. If the energy price increases, the maintenance of the machinery will be improved (an additional worker), and truck drivers will drive slower (working overtime or less mileage per day). However, this substitution effect can primarily be observed with respect to the unbound component of an input. Bound factors like machinery, the stock of trucks, or truck drivers are not objects of a substitution decision; they will be replaced either simultaneously or not at all as one more unit is linked to high costs due to bound inputs (an additional truck requires an additional truck driver). In case of a higher energy price, therefore, the disposable energy input will be the one that will be reduced. The fact that other inputs are bound to energy should be indicated by a cost-price or user cost in which the price of energy enters with an appropriate weight. In order to take into account this aspect, we separate the quantity of an input (v_i) into a bound part and into an unbound one:[5]

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[5] For more details, see Conrad (1983).

$$v_i = \bar{v}_i + \hat{v}_i, \ i = 1, \ldots n \tag{1}$$

where $\bar{v}_i$ is the number of units of factor i bound by the usage of the remaining n - 1 inputs, and $\hat{v}_i$ is the disposable quantity of factor i. The bound quantity of an input, $\bar{v}_i$, depends with fixed factor proportions upon the disposable quantities of the other inputs. Here, $\bar{v}_i$ is a simple sum, defined as

$$\bar{v}_i = \sum_{j \neq i} \alpha_{ij} \hat{v}_j, \alpha_{ij} \geq 0, \ i = 1, \ldots n, \tag{2}$$

where α_{ij} is the quantity of v_i bound to one disposable unit of v_j. Substituting (2) into (1) yields

$$v_i = \sum_{j=1}^{n} \alpha_{ij} \hat{v}_j, \text{where } \alpha_{ii} = 1 \tag{3}$$

by definition. If the disposable part of input j is increased by one unit, this increases the total quantity of input j by just this unit and all other inputs i ($i = 1, \ldots, n, i \neq j$) by the quantities α_{ij}. These α_{ij} coefficients constitute a matrix $A = (\alpha_{ij})$ that describes the degree of affiliation for any data set. If $\alpha_{ij} = 0$ ($i \neq j$) for all i and j, the neoclassical model is relevant and the cost-price of any input is its own price. If $\hat{v}_i = 0$ (or $v_i = \bar{v}_i$) for all i, no factor substitution is possible and the cost price approach reduces to the Leontief fixed proportion production function.

We next replace the quantities v_i in the cost minimizing approach by the partitioning given in (3). Instead of

$$\min\left\{ \sum_i P_i v_i \ | \ x = H(v_1, \ldots, v_n) \right\}, \tag{4}$$

where x is the given output quantity and P_i is the price for i, we write

$$\min\left\{ \sum_j \hat{P}_j \hat{v}_j \ | \ x = F(\hat{v}_1, \ldots, \hat{v}_n) \right\} \tag{5}$$

where

$$\hat{P}_j = \sum_j \alpha_{ij} P_j \ \text{ and } \alpha_{jj} = 1, \qquad j = 1, \ldots n \tag{6}$$

is the cost-price of input j. It consists of its own price (P_j) plus the additional costs

associated with factors bound to v_j. By substituting the cost-minimizing factor demand functions $\hat{v}_j = f_j(x; \hat{P}_1, ..., \hat{P}_n)$ into (3) we obtain the cost-minimizing input quantities in terms of cost prices $\hat{P}_1, ... \hat{P}_n$. The dual cost function with respect to the cost prices is then:

$$C(x; \hat{P}_1, ..., \hat{P}_n) = \sum_j \hat{P}_j . f_j(x; \hat{P}_1, ..., \hat{P}_n). \tag{7}$$

The analogue to Shephard's lemma holds:

$$\frac{\partial C(x; \hat{P})}{\partial \hat{P}_i} = \hat{v}_i \tag{8}$$

$$\frac{\partial C(x; \hat{P})}{\partial P_i} = \sum_j \left[\frac{\partial C}{\partial \hat{P}_j} \right] \left[\frac{\partial \hat{P}_j}{\partial P_i} \right] = \sum_j \alpha_{ij} . \hat{v}_i = v_i \tag{9}$$

Equations (8) and (9) provide the disposable amounts of each input as well as the cost minimizing quantities of total inputs. From Equation (9), we can determine the cost shares (w_i) of each factor as follows:

$$w_i = \frac{P_i . v_i}{C} = P_i \left(\frac{\partial \ln C(x; \hat{P})}{\partial P_i} \right). \tag{10}$$

These share equations can then be used to empirically estimate the parameters of the cost prices.[6] In the next Section, we will estimate econometrically the cost-price model.[7]

III. Empirical results for a Cobb-Douglas cost function

As a specification of the cost function we will choose the simplest case, namely a cost function of the Cobb-Douglas type (henceforth, CD). However, an

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[6] Technical change can be introduced into the cost prices (see Olson and Shieh 1989). We have omitted this aspect in our CGE analysis.

[7] The cost-price concept has been employed econometrically within a model of consumer behaviour by Conrad and Schröder (1991). They use a specification of an expenditure function in durables and non-durables and identify the part of goods complementary to consumer

approach with cost prices and committed inputs does not result in simple measures of the degree of substitutability as in the conventional CD case where the elasticity of substitution is unity and all inputs are price substitutes. As shown in Conrad (1983), even under the CD-assumption, variable elasticities of substitution and complementary relations are possible. Under our assumption of constant returns to scale and disembodied factor augmenting technical change, $b_j t$, the CD-cost function is $\ln C(x; \hat{P}) = \ln x + \alpha_0 + \sum_j (\gamma_j + b_j t) \ln \hat{P}_j$, where $\sum_j \gamma_j = 1$ and $\sum_j b_j = 0$. Because of (10),

$$w_i = P_i \left\{ \sum_j \left[\frac{\gamma_j + b_j t}{\hat{P}_j} \right] \alpha_{ij} \right\} \tag{11}$$

where $\hat{P}_j = P_j + \sum_{k \neq j} \alpha_{kj} P_k$.

We have nested the inputs of a sector, based on an input-output table with 49 sectors, such that in the first stage the inputs for the CD-production function are capital K, labor L, electricity E, material M, and fossil fuel F. As data for disaggregated energy inputs are available only for a short period of time (1978-90), we are constrained to a pooled time-series cross-section approach.[8] A total of 49 sectors for which data are available in the German national account statistics are pooled into four sector aggregates: the energy supply sectors aggregate; the energy-intensive manufacturing sectors aggregate; the non-energy-intensive manufacturing sectors aggregate; the service sectors aggregate.

The five-equation system, consisting of the five cost-share equations for K, L, E, M, F, is estimated for each of the four sector aggregates, employing the panel data set in yearly prices and cost shares. It is assumed that the cost prices are identical in each sector aggregate (i.e., sectoral dummy variables are added only to the coefficients γ_i in (11)).

Due to the high degree of non-linearity inherent in the share equations, we

durables like gasoline, electricity or repair services. In the GEM-E3 model for the EU (Capros et al. 1996) the demand for durables takes into account the demand for complementary goods bound to consumer durables.

[8] We are indebted to Henrike Koschel and Martin Falk for providing us with the data set. For more details see Koschel (2001) and Koebel et al. (2003).

have simplified our approach by concentrating on the cost-price of labor. Hence, the composition (3) is reduced to

$$K_i = \alpha_{KL}.\hat{L}_i + \hat{K}_i, L_i = \hat{L}_i, E_i = \alpha_{EL}.\hat{L}_i + \hat{E}_i, M_i = \alpha_{ML}.\hat{L}_i + \hat{M}_i, \tag{12}$$

$$F_i = \alpha_{FL}.\hat{L}_i + \hat{F}_i$$

where $i = 1, 2, 3, 4$ for the four sector aggregates. The cost-prices for K, E, F, M are therefore market prices, i.e. $\hat{P}_{K,i} = P_{K,i}$, $\hat{P}_{E,i} = P_{E,i}$, $\hat{P}_{M,i} = P_{M,i}$ and $\hat{P}_{F,i} = P_{F,i}$. The cost-price of labor is:

$$\hat{P}_{L,i} = P_{L,i} + \alpha_{KL}.P_{K,i} + \alpha_{EL}.P_{E,i} + \alpha_{FL}.P_{F,i} + \alpha_{ML}.P_{M,i} \tag{13}$$

As mentioned before, $\alpha_{iL}, i = K, E, M, F$ are the same for each sector aggregate and so are the technical progress parameters $b_i, i = K, L, E, M, F$. The system of cost share equations we have to estimate is:

$$w_{L,i} = \frac{P_{L,i}.L_i}{C_i} = \frac{(\gamma_{Li} + b_L.t).P_{L,i}}{\hat{P}_{L,i}}, \tag{14}$$

$$w_{K,i} = \frac{P_{K,i}.K_i}{C_i} = \gamma_{Ki} + b_K.t + \frac{\alpha_{KL}.(\gamma_{Li} + b_L.t).P_{K,i}}{\hat{P}_{L,i}}, \tag{15}$$

$$w_{E,i} = \frac{P_{E,i}.E_i}{C_i} = \gamma_{Ei} + b_E.t + \frac{\alpha_{EL}.(\gamma_{Li} + b_L.t).P_{E,i}}{\hat{P}_{L,i}}, \tag{16}$$

$$w_{M,i} = \frac{P_{M,i}.M_i}{C_i} = \gamma_{Mi} + b_M.t + \frac{\alpha_{ML}.(\gamma_{Li} + b_L.t).P_{M,i}}{\hat{P}_{L,i}}, \tag{17}$$

$$w_{F,i} = \frac{P_{F,i}.F_i}{C_i} = \gamma_{Fi} + b_F.t + \frac{\alpha_{FL}.(\gamma_{Li} + b_L.t).P_{F,i}}{\hat{P}_{L,i}}. \tag{18}$$

with $\hat{P}_L$ as given in (13). In addition to using nonlinear techniques, the cost price model must be estimated with non-negativity constraints imposed on the parameters $\alpha_{iL}, i = K, E, M, F$. Table 1 presents the estimated parameters.

The bias of technical change is capital, electricity and material using ($b_k > 0$, $b_E > 0$, $b_M > 0$), and labor and fossil fuel saving ($b_L < 0$, $b_F < 0$). The cost price of labor (13) for the industry with the dummy variable of zero is

Table 1. Maximum likelihood estimates for parameters of cost-prices and technical change

Dummy for factors			Parameters of technical progress			Parameters of costs prices		
γ_K	0.092	(17.173)	b_K	$8.5\ 10^{-4}$	(0,935)	α_{KL}	0.002	(0,431)
γ_L	0.458	(11.340)	b_L	-0.005	(-1,824)	α_{EL}	0.055	(2,611)
γ_E	$4 \cdot 10^{-8}$	$(6 \cdot 10^{-6})$	b_E	$4.2\ 10^{-4}$	(1,889)	α_{FL}	0.072	(2,993)
γ_F	0.048	(3.508)	b_F	-0.002	(-1,143)	α_{ML}	0.422	(3,128)
$\gamma_M{}^*$	0.402	–	$b_M{}^*$	0.006	–			

Log Likelihood = 3540.189, Observations: 637

Notes: Asymptotic t-ratios in parentheses. *As the error terms add to zero, they are stochastically dependent and we have omitted equation (17) for estimation.

$$\hat{P}_L = P_L + 0.002.P_K + 0.055.P_E + 0.422 P_M + 0.072.P_F. \tag{19}$$

Using the α_{iL} parameter estimates in Table 1, we conclude from (12) that an additional unit of labor needs 0.002 units of capital, 0.055 units of electricity, 0.422 units of material and 0.072 units of fossil fuel. In other words, reducing labor input by one unit will release 0.002 units of capital, 0.055 units of electricity, 0.422 units of material and 0.072 units of fossil fuel for possibilities of substitution as the disposable components $\hat{K}, \hat{E}, \hat{M}, \hat{F}$ increase with the reduction of $L\ (= \hat{L})$. In the next Section we will use committed inputs, disposable inputs, and the corresponding cost-price of labor within the framework of a CGE model to investigate their impact on the outcome of the double dividend conjecture.

IV. The features of the CGE model

This Section presents the main characteristics of a comparative-static multi-sector model for the German economy designed for the medium-run economic analysis of carbon abatement constraints. Here, the concrete specification of the model covers seven sectors and two primary factors.[9] The choice of production sectors captures key dimensions in the analysis of greenhouse gas abatement, such

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[9] The overall sectors are still the sectors F, E, M and the primary factors K and L. However, F and M will be disaggregated to F_i and M_i, $i = 1,2,3$ (see Table 2).

as differences in carbon intensities and the scope for substitutability across energy goods and carbon-intensive non-energy goods. The energy goods identified in the model are coal (COL), natural gas (GAS), crude oil (CRU), refined oil products (OIL) and electricity (ELE). Non-energy production consists of an aggregate energy-intensive sector (EIS) and the rest of production (OTH). Primary factors include labor and capital, which are both assumed to be intersectorally mobile. Table 2 summarizes the sectors and primary factors incorporated in the model.

Table 2. Overview of sectors and factors

		Sectors		Primary factors	
1	COL	Coal	⎫	CAP	Capital - K
2	OIL	Refined oil products	⎬ -F	LAB	Labor - L
3	GAS	Natural gas	⎭		
4	ELE	Electricity - E			
5	CRU	Crude oil	⎫		
6	EIS	Energy-intensive sectors	⎬ -M		
7	OTH	Rest of industry	⎭		

The model is a well-known Arrow-Debreu model that concerns the interaction of consumers and producers in markets. Market demands are the sum of final and intermediate demands. Final demand for goods and services is derived from the utility maximization of a representative household subject to a budget constraint. In our comparative-static framework, overall investment demand is fixed at the reference level. The consumer is endowed with the supply of the primary factors of production (labor and capital) and tax revenues (including CO_2 taxes). Household preferences are characterized by an aggregate, hierarchical (nested) constant elasticity of substitution (CES) utility function. It is given as a CES composite of an energy aggregate and a non-energy consumption composite. Substitution patterns within the energy aggregate and the non-energy consumption bundle are reflected via Cobb-Douglas functions. Producers choose input and output quantities in order to maximize profits. The structure in production is nested. At the top level, we have the KLEMF-structure with the CD specification in cost-prices. At the second level, a CES function describes the substitution possibilities between the material components. The primary energy composite is defined as a CES function of coal, oil and natural gas. Key substitution elasticities are given in the Appendix.

The government distributes transfers and provides a public good (including public investment) which is produced with commodities purchased at market prices. In order to capture the implications of an environmental tax reform on the efficiency of public fund raising, the model incorporates the main features of the German tax system: income taxes including social insurance contributions, capital taxes (corporate and trade taxes), value-added taxes, and other indirect taxes (e.g. mineral oil tax).

All commodities are traded internationally. We adopt the Armington (1969) assumption that goods produced in different regions are qualitatively distinct for all commodities. There is imperfect transformability (between exports and domestic sales of domestic output) and imperfect substitutability (between imports and domestically sold domestic output). On the output side, two types of differentiated goods are produced as joint products for sale in the domestic markets and the export markets respectively. The allocation of output between domestic sales and international sales is characterized by a constant elasticity of transformation (CET) function. Intermediate and final demands are (nested CES) Armington composites of domestic and imported varieties. Germany is assumed to be a price-taker with respect to the rest of the world (ROW), which is not explicitly represented as a region in the model. Trade with ROW is incorporated via perfectly elastic ROW import-supply and export-demand functions. There is an imposed balance-of-payment constraint to ensure trade balance between Germany and the ROW. That is, the value of imports from ROW to Germany must equal the value of exports to ROW after including a constant benchmark trade surplus (deficit).

The analysis of the employment effects associated with an environmental tax reform requires the specification of unemployment. In our formulation, we assume that unemployment is caused by a rigid and too high consumer wage (see, for example, Bovenberg and van der Ploeg 1996).

For each input structure of the industries, we choose the KLEMF-model at the top level. We employ in the cost share equations and in the cost price of labor the parameters, estimated from another source of input-output tables. Since the cost shares within the six industries differ from the cost shares calculated in the econometric part, we have to calibrate one parameter per cost share in order to adjust the estimated cost shares to the observed ones in the 7-industry base year table. Therefore, γ_{Li} (i = 1, ..., 7) follows from (14), given the cost shares of the 7-industry table. If γ_{Li} is determined, γ_{Ki}, γ_{Ei}, γ_{Fi} and γ_{Mi} can be calculated from (15) - (18).

Allen elasticities (σ_{ij}) for the Cobb-Douglas function in cost prices for each sector can be calculated.[10] They are related to the price elasticities of demand for

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[10]   See the Appendix.

factors of production (ε_{ij}) according to $\varepsilon_{ij} = \sigma_{ij} . w_j$, $i, j = K, L, E, F, M$. Table A2 in the Appendix presents Allen elasticities and price elasticities of demand in the CGE model with the parameter estimates of the cost-price model. Capital is a substitute for all inputs with an elasticity of substitution close to one. Electricity and fossil fuel have a complementary relationship to labor; material is a substitute for labor, for electricity and for fossil fuel; electricity and fossil fuel are complements in the non-energy intensive industries (OTH).

The disposable quantities of each factor of production can be derived from equation (12). The disposable quantity of material, for instance, is $\hat{M} = M_i - \alpha_{ML} . L_i$, $i = 1, 2, ..., 7$.

From Table 3 we observe that in the non-energy-intensive industries (OTH) 82 percent of electricity is bound to labor, whereas in the energy intensive industries (EIS) only 16 percent are bound to labor (i.e., up to 84 percent are disposable for substitution). This part could be partly linked to capital (if $\alpha_{EK} > 0$) and/or to material (if $\alpha_{EM} > 0$), which we have not looked into because we concentrated only on the part of each input bound to labor. For materials, 13% of this input in the sector OTH is bound to labor and 87 percent is free for substitution. In the industry EIS only 6 percent is linked to labor and 94 percent is substitutable. Similarly as for electricity, a high percentage of fossil fuel (96 percent) is linked to labor in the industry OTH and only 22 percent in the energy intensive industry EIS. In this industry, about 80 percent of fossil fuel is a candidate for substitution, whereas in other industries (OTH) only 4 percent is such a candidate. The 80 percent of fossil fuel which are not bound to labor could be bound to capital, to electricity, to material or are substitutable in the conventional sense.

Table 3. Disposable and bounded fraction of each factor of production in CGE model

	Disposable		Bound (to labor)	
	OTH	EIS	OTH	EIS
K	0.999	0.999	0.001	0.001
L	1	1	0	0
E	0.185	0.841	0.815	0.159
M	0.868	0.937	0.132	0.063
F	0.040	0.784	0.960	0.216

Under constant returns to scale and price-taking behavior, the price of an industry j, P_j, is equal to its unit cost: $P_j = c_j(P_K, \hat{P}_{L,j}, P_E, P_{M,j}, P_{F,j})$.

Written in logarithmic terms, using our CD specification in cost-prices, we obtain

$$\ln P_j = (\gamma_{Kj} + \beta_K.t)\ln P_K + (\gamma_{Lj} + \beta_L.t)\ln \hat{P}_{L,j} + (\gamma_{Ej} + \beta_E.t)\ln P_E$$

$$+ (\gamma_{Mj} + \beta_M.t)\ln P_{M,j}(P_5, P_6, P_7) + (\gamma_{Fj} + \beta_F.t)\ln P_{F,j}(P_1, P_2, P_3).$$

In addition, we have unit cost functions of the CES type for material, $P_{M,j} = f_j(P_5, P_6, P_7)$, $j = 1, 2, ...7$, and for fossil fuel, $P_{F,j} = f_j(P_1, P_2, P_3)$, $j = 1,2,...7$. In order to solve the price system $P_1, \ldots, P_7$, we have to add the labor-cost price equations (13), where $P_{L,j} = P_L$ for all j. If the price system has been solved, next price dependent input-output coefficients as derived input demand functions can be determined and the sectoral output levels can finally be calculated. A detailed description of the model is available from the authors upon request. The main data source underlying the model is the GTAP version 4 database, which represents global production and trade data for 45 countries and regions, 50 commodities and 5 primary factors (McDougall et al. 1998). In addition, we use OECD/IEA energy statistics (IEA 1996) for 1995. Reconciliation of these data sources yields the benchmark data of our model.

V. Empirical results

In our simulation, we distinguish two types of scenarios. In each simulation, carbon taxes are levied in order to meet a 21 percent reduction of domestic carbon dioxide emissions as compared to 1990 emission levels. This is the reduction target the German government has committed itself to in the EU Burden Sharing Agreement adopted at the environmental Council meeting by Member States on June 1998. One type of simulation is based on the market price of labor and the second type on the cost price of labor. We impose revenue-neutrality in the sense that the level of public provision is fixed. Subject to this equal-yield constraint, we consider two ways to recycle the CO_2 tax revenue for each type of simulation. One way is to recycle it by a lump-sum transfer (LS) to the representative household. The other way is to adopt an environmental tax reform (ETR) in view of the adverse employment effects of carbon emission constraints. In such a case, the tax revenue is used to lower the non-wage labor costs (social insurance payment). Table 4

summarizes the implications of the two types of simulation studies under two ways of recycling the tax revenues. If firms decide on production and substitution on the base of the market price of labor and the tax revenue is recycled by a lump-sum transfer, then employment rate will be lower by 0.15 percent (see column 1 in Table 4). Welfare, expressed here as a change in GDP, will be lower by 0.55 percent. The CO_2 tax rate at the 21 percent CO_2 reduction level (marginal abatement cost) is 13.9 US\$ per ton. Production in all industries declines, succeeding by a lower demand for labor. If the tax revenue is used to lower non-wage labor costs, we obtain an employment dividend because employment increases by 0.43 percent. Since GDP does not increase(–0.38 percent), we do not obtain a "strong double dividend" where the level of emissions is reduced and employment as well as GDP are increased from the tax reform by itself. The positive substitution effect on labor from the ETR outweighs the negative output effect on labor. For the producer, the price of labor is lower by 0.72 percent compared to the policy of a lump-sum transfer (last rows in Table 4). The prices P_F of fossil fuel have increased by the CO_2 tax, and this increase differs by industry according to the size and composition of this input.

The results under the user cost (cost-price) concept of labor can be explained best by comparing the change of the market price of labor with the change of the user cost of labor after the ETR. From the producer's point of view, the price of labor declined by 0.72 percent after the ETR but only by about 0.59 percent under the user cost concept. As the second half of Table 4 shows, the cost-price of labor differs by industry because the price aggregates P_M and P_F in (19) differ by industry.[11] Since direct wage costs are only about two-thirds of the user cost of labor, the reduction in the cost of labor from the cut in social insurance payments is smaller under the cost-price concept. Hence, the substitution effect on labor is weaker and is outweighed by the negative output effect from higher energy prices (lower GDP). Therefore, we do not obtain a double dividend under the cost-price concept. The higher price $\hat{P}_L$ from (19) (about 1.55) is not the reason for this result, because this figure is taken into account when calibrating the parameters. The crucial impact comes from the aspect that a higher price of energy also raises the cost-price of labor because workers need energy in order to be productive. Therefore, employment declines more under the cost-price approach than under the market price approach (–0.55 versus –0.15 percent). When the tax revenue is

[11] The cost-price approach has not been adopted for the industries coal, crude oil, and gas.

Table 4. Empirical results of tax reforms

	Market price of labor		User cost of labor	
	LS	ETR	LS	ETR
Employment	–0.15	0.43	–0.55	–0.06
Consumption	–0.47	–0.14	–0.38	–0.02
Carbon tax*	13.92	14.24	14.54	14.92
GDP	–0.55	–0.38	–0.43	–0.22
P_L (producer cost)	1	0.9928	1	0.9927
P_L (consumer wage)	1	1	1	1
P_K	0.9992	0.9977	1.0005	0.9993
P_E	1.0355	1.0310	1.0246	1.0199
P_F – prices in the corresponding industries				
OTH	1.0632	1.0606	1.0650	1.0625
EIS	1.0949	1.0929	1.0982	1.0964
ELE	1.3708	1.3743	1.3869	1.3919
P_M – prices in the corresponding industries				
OTH	1.0031	0.9997	1.0022	0.9986
EIS	1.0057	1.0023	1.0045	1.0009
OIL	1.0032	0.9999	1.0023	0.9988
Cost prices – $\hat{P}_L$ in the corresponding industries				
OTH			1.5582	1.5490
EIS			1.5616	1.5524
COL			1	0.9927
OIL	1	0.9928	1.4251	1.4164
CRU			1	0.9927
GAS			1	0.9927
ELE			1.1016	1.0947
% change of $\hat{P}_L$ in the corresponding industries				
OTH			–0.5936	
EIS			–0.5898	
COL			–0.7275	
OIL	–0.7240		–0.6147	
CRU			–0.7275	
GAS			–0.7275	
ELE			–0.6291	

Notes: * In US$ (all other figures are percentage values or price indices). LS stands for Lump-Sum Transfer, ETR for Environmental Tax Reform. A breakdown by sector of results on labor demand and production is available from the authors upon request.

recycled, the firm perceives a reduction of the cost-price by 0.59 percent on the average, which is too small to induce a substitution process high enough to yield a double dividend. Although the decline in GDP is less under the cost-price approach than under the market price approach (–0.22 versus –0.38 percent), the incentive for substitution is weaker under the cost price approach and therefore employment declines (–0.06 versus 0.43 percent).

VI. Conclusions

In our analytical and empirical analysis of a double dividend policy we emphasized that a labor market policy of recycling tax revenues from an environmental tax to lower employers' non-wage labor cost depends on how the costs of labor are modeled. We proposed an approach that consists of the market price of labor plus the costs of inputs associated with the employment of a worker. We presented one simulation based on the market price of labor and another one based on our user cost of labor concept. We found a double dividend under the first approach but not under the second one.

Our final results are in principle the same obtained by Bovenberg and de Mooij (1994) and Bovenberg and Van de Ploeg (1994) theoretically or by Bovenberg and Goulder (1996) empirically using a CGE model for the US. Our initial results, however, are not the same because they do not reject the employment dividend. The result in Bovenberg and de Mooij (1994), that pollution taxes reduce the incentive to supply labor, is not in contradiction to our initial result (a labor dividend) because their proof is based on the assumption of a single input (labor). In Bovenberg and Van de Ploeg (1994), three inputs are used (L, F and K), prices of capital and fossil fuel, however, are determined on global competitive markets, i.e., they are exogenous. In their factor price frontier a given tax on fossil fuel uniquely determines the producer wage. Hence, the energy tax is fully born by the immobile factor labor and thus amounts to an implicit labor tax. In the factor price frontier of our model, derived from the unit cost function, prices of capital, material and of energy are endogenous. The carbon tax is therefore not an implicit labor tax, i.e., the effect of a lower tax on wages is not fully offset by the carbon tax. Another reason for rejecting the labor dividend is how the range of pre-existing taxes and transfers is included in the model. In contrast to the assumption of, e.g., Bovenberg and de Mooij (1994), the pre-existing tax system in our model is not optimal. Hence, one could argue that a tax reform could enable efficiency gains, which are not linked solely to a new environmental tax but to a general change in (effective) factor tax

rates.[12] But, this is still in line with the findings of Bovenberg and Goulder (1996), who show that both, the analytical and the empirical analysis, coincide even if one considers pre-existing taxes. While they find analytically that the prospects of a double dividend are enhanced if "… a revenue neutral tax reform shifts the burden of taxation to the less efficient (undertaxed) factor …", there is no empirical evidence obtaining such a situation in their numerical analysis. We obtain such a situation, however, in our initial model, but our findings are at the end compatible with those of others. The reason is that labor bears some cost of the energy tax because labor and energy are partly bound in producing output. And, in addition, hiring labor because of substitution, or, because of lower marginal cost of production adds more to the cost of production than only the monthly wage bill for an additional worker.

Policy makers are used to an economist's advice that the outcome of a policy is ambiguous and depends on assumptions made. However, we think that our point that user costs of labor matter more than the normal wage costs is intuitively attractive when arguing about the double dividend hypothesis.

Appendix

Table A1. Key substitution elasticities

Description	Value
Substitution elasticities in production	
σ_M Material vs. material (within material inputs)	0.5
σ_F Fossil fuel vs. fossil fuel (within fossil fuel inputs)	0.3
Substitution elasticities in private demand	
σ_C Energy goods vs. non-energy goods	0.8
Substitution elasticities in government demand	
σ_G Fossil fuel vs. fossil fuel (within fossil fuel inputs)	0.8
Elasticities in international trade (Armington)	
σ_A Substitution elasticity between imports vs. domestic inputs	4.0
ε Transformation elasticity domestic vs. export	4.0

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[12] Goulder (1995).

Allen elasticities of substitution for the Cobb-Douglas function in cost prices in the CGE model for each sector are given by

$$\sigma_{ij} = 1 - \frac{P_i.P_j}{w_i.w_j}.\left[\sum_k \frac{(\gamma_k + b_k.t).\alpha_{ik}.\alpha_{jk}}{\hat{P}_k^{\,2}}\right], \; i, j, k = K,L,E,F,M.$$

The price elasticities of demand for factors of production (ε_{ij}) are $\varepsilon_{ij} = \sigma_{ij}\,w_j$. Table A2 presents these elasticities.

Table A2. Allen elasticities of substitution and price elasticities of demand

Sector	OTH	EIS	Sector	OTH	EIS
σ_{KL}	0.996	0.993	ε_{KF}	0.011	0.032
σ_{KE}	0.997	0.999	ε_{LK}	0.333	0.185
σ_{KM}	0.999	0.999	ε_{LE}	-0.024	0.0003
σ_{KF}	0.996	0.998	ε_{LM}	0.217	0.375
σ_{LE}	-2.181	0.009	ε_{LF}	-0.035	-0.014
σ_{LM}	0.444	0.580	ε_{EK}	0.334	0.187
σ_{LF}	-3.035	-0.432	ε_{EL}	-0.334	0.001
σ_{EM}	0.579	0.937	ε_{EM}	0.283	0.607
σ_{EF}	-2.053	0.786	ε_{EF}	-0.024	0.025
σ_{MF}	0.466	0.909	ε_{MK}	0.335	0.187
ε_{KK}	-0.664	-0.812	ε_{ML}	0.068	0.056
ε_{LL}	-0.491	-0.547	ε_{ME}	0.006	0.034
ε_{EE}	-0.259	-0.820	ε_{MF}	0.005	0.029
ε_{MM}	-0.414	-0.306	ε_{FK}	0.333	0.186
ε_{FF}	-0.073	-0.761	ε_{FL}	-0.465	-0.042
ε_{KL}	0.153	0.097	ε_{FE}	-0.023	0.028
ε_{KE}	0.011	0.036	ε_{FM}	0.228	0.589
ε_{KM}	0.489	0.647			

Note: The calibrated parameters are $\gamma_{L,EIS} = 0.151$ and $\gamma_{L,OTH} = 0.238$. The benchmark value shares for Germany are $w_{K,EIS} = 0.187$, $w_{L,EIS} = 0.097$, $w_{E,EIS} = 0.036$, $w_{M,EIS} = 0.648$, $w_{F,EIS} = 0.032$, $w_{K,OTH} = 0.335$, $w_{L,OTH} = 0.153$, $w_{E,OTH} = 0.011$, $w_{M,OTH} = 0.489$ and $w_{F,OTH} = 0.011$.

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