Carbon Taxes and Joint Implementation

An applied CGE analysis for Germany and India

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Abstract

Germany has committed itself to reduce its carbon emissions by 25 % percent in 2005 as compared to 1990 emission levels. To achieve this goal the government recently has launched an environmental tax reform which entails a continuous increase in energy taxes joint with a revenue-neutral cut in non-wage labor costs. This policy is supposed to yield a double dividend in reducing at the same time the problem of global warming and high unemployment rates. In addition to domestic action international treaties on climate protection allow for the supplementary use of flexible instruments to exploit cheaper emission reduction possibilities elsewhere. One concrete option for Germany would be to enter joint implementation with developing countries such as India where Germany pays emission reduction abroad rather than meeting its reduction target solely by domestic action. The present paper provides a quantitative comparison of both abatement strategies, i. e. environmental tax reform *stand-alone* versus environmental tax reform *cum* joint implementation. Based on a large-scale computable general equilibrium model for Germany and India we address the question whether an environmental tax reform in Germany *combined with* joint implementation in the Indian electricity sector could improve the prospects for a double dividend: Not only that joint implementation would lower the level of emission taxes in Germany and thus reduce adverse effects on labor demand; but also direct investment demand for energy efficient power plants produced in Germany would trigger positive employment effects in the German manufacturing industries. From the Indian perspective, joint implementation would equip its electricity industry with additional capital goods leading to a more efficient power production with lower electricity prices for the economy.

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1. Introduction

In order to promote international climate policies Germany has committed itself to substantial unilateral emission reductions already in the early 1990s: The German government set a carbon emission reduction target of 25-30 % percent in 2005 as compared to 1990 emission levels which has been reconfirmed several times since then. Concerns on adverse employment effects of carbon emission constraints for the national economy have induced policy makers to adopt an environmental tax reform as a key instrument for meeting the reduction target. Such a reform entails an increase in environmental taxes together with a revenue-neutral reduction in labor costs. This policy is supposed to yield a double dividend in reducing at the same time harmful greenhouse gas emissions (first dividend) and alleviating unemployment problems (second dividend). However, while the environmental dividend is in general beyond controversy, the employment dividend is not. Environmental taxes may well exacerbate rather than alleviate pre-existing tax distortions. The reason is that environmental taxes induce market distortions similar to those of the replaced taxes. In addition, environmental taxes introduce new distortions in intermediate and final consumption. The negative impacts on labor demand induced by levying additional environmental taxes (tax interaction effect) may dominate the positive impacts of using additional revenues for cuts in labor costs (revenue recycling effect).[1] Theoretical and empirical work point out that the prospect for the second dividend depends crucially on the existing inefficiences of the tax system, labor market imperfections and the level of environmental taxes (i.e. the environmental target). As to the latter, adverse impacts on employment are potentially less likely the lower the level of additional environmental taxes.[2]

Under a higher emission/energy tax employment benefits from a positive, but small substitution effect of labor for energy. However, there is also a negative output effect due to higher prices and reduced domestic demand. This negative output effect could outweigh the positive substitution effect on labor demand. An environmental policy is therefore of interest

[1] See Goulder (1995).

[2] For a survey on the double-dividend literature see Bovenberg (1997).

which achieves an environmental goal with a weak negative output effect by reducing the tax burden and strengthening domestic demand.

The relationship between the level of environmental taxes and the induced economic effects is the starting point for our economic assessment of Germany's climate policy options. At the strictly domestic level, lower environmental taxes to ameliorate negative effects on production activities and labor demand, would directly trade off with higher emissions; Germany would then fall short off its stated reduction target. Yet, international treaties on climate protection allow for the supplementary use of flexible instruments to exploit cheaper emission reduction possibilities elsewhere. The concept of Joint Implementation (JI) has been incorporated into the Kyoto Protocol to the UN Framework Convention on Climate Change (UN FCCC).[3] Instead of meeting its reduction target solely by domestic action, Germany could enter joint implementation (JI) with developing countries such as India where Germany buys part of its emission reduction from abroad. JI then allows for the reduction of domestic emission taxes which might increase the prospect for an employment dividend without adverse effects on the environmental dividend.[4] In addition, JI is typically based on technology transfers where the JI host demands investment goods by the JI donor triggering direct positive employment effects for the latter. From the perspective of the JI host, joint implementation delivers scarce capital goods which increase production efficiency and decrease consumer prices.[5]

In our analysis below we investigate whether an environmental tax reform *cum* joint implementation provides employment and overall efficiency gains as compared to an environmental tax reform *stand-alone.* We address this question in the framework of a large-

[3] The exact term was not used in the Protocol, but the Joint Implementation mechanism clearly forms the basis of Articles 6 and 12. Under Articel 6 countries with emission reduction targets may fund JI projects in other countries with quantified emission limitations and reduction commitments (QELRCs) (Annex I countries) in return for „emission reduction units", which may be supplemental to domestic actions for the purpose of meeting the commitments. Articel 12 defines the Clean Development Mechanism (CDM). Under CDM donor countries receive certified emission reductions (CERs) in exchange for investment in abatement action in countries without targets (non-Annex I countries). See UNFCCC (1995).

[4] There are no ecological reservations against JI since only global emissions matter for climate change.

[5] For a detailed information on the concept of *JI* see Kuik et al. (1994), Jackson (1995) and Jepma (1995).

scale computable general equilibrium model for Germany and India where Germany may undertake joint implementation with the Indian electricity sector. Our general insights are:

(i) Unilateral action by Germany to reach the Kyoto targets is far more costly than a combined strategy with ETR and JI. The associated efficiency gains lead to a substantial increase in regional welfare.

(ii) An environmental tax reform is not likely to exert an employment double dividend given the initial tax distortions and labor market imperfections in Germany. JI reduces this negative impacts on employment through the reduction in carbon taxes and the additional demand for power plants in the German manufacturing sectors.

(iii) For India, joint implementation equips its electricity industry with additional capital goods leading to a more efficient power production with lower electricity prices for the economy.

The remainder of this paper is organized as follows. Section 2 lays out the generic model structure complemented with extensions for representing joint implementation and measuring productivity changes. Section 3 describes the policy scenarios and reports our simulation results. Section 4 entails our conclusions and lines of future research.

2. Analytical Framework

2.1 Basic Model

This section presents the main characteristics of a comparative-static multi-sector model for the German and Indian economies (see Appendix for the algebraic model formulation). The choice of production sectors captures key dimensions in the analysis of greenhouse gas abatement such 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). The non-energy sectors include important carbon-intensive and energy intensive industries such as transportation services (TRN) and an energy-intensive sector (EIS). The remainder of the economy is divided into other machinery (OME), construction (CNS) and other manufactures and services (Y). Primary factors include labor, capital and fossil-fuel resources. Labor is treated as intersectorally mobile within each region but cannot move between regions. Capital is sector specific and international immobile. Capital stocks are assumed to be not in the long-run equilibrium. The model captures only short run adjustment. A sector-specific resource is used in the production of primary fossil fuels (crude oil, coal and gas), resulting in upward sloping supply schedules for those goods. Table 1 summarizes the sectors, countries and primary factors incorporated in the model.

Table 1: Overview of sectors and countries

Sectors		Countries	
COL	Coal	GER	Germany
CRU	Crude oil	IND	India
GAS	Natural gas		
OIL	Refined oil products	**Primary factors**	
ELE	Electricity	CAP	Capital
EIS	Energy-intensive sectors	LAB	Labor
TRN	Transport equipment	RES	Sector-specific resource
OME	Other machinery		
CNS	Construction		
Y	Manufactures and services		
CGD	Savings good		

Production

Constant elasticity of substitution (CES) cost functions are employed to specify the substitution possibilities in domestic production between capital, labor, energy and material (non-energy) intermediate inputs. The cost functions employ several nests to allow for the representation of differences in fuel switching and energy savings across sectors.

In the production of commodities other than primary fossil fuels and electricity, intermediate non-energy goods and crude oil are employed in fixed proportions with an aggregate of energy, capital and labor at the top level. At the second level, a CES function describes the substitution possibilities between labor and the aggregate of capital and the energy composite. At the third level, capital and the energy composite trade off with a constant elasticity of substitution. The energy aggregate is in turn a nested CES composite of electricity and primary energy inputs. The primary energy composite is defined as a CES function of coal and a CES aggregate of refined oil and natural gas.

In the production of electricity non-energy goods, crued oil and refined oil products enter in fixed proportions with a composite out of labor, energy, and capital. The latter is given as a CES function between labor inputs and a restricted translog sub-function of capital and energy. At the lower energy nest, gas and coal inputs trade off with a constant elasticity of substitution.

In the fossil fuel production activity (crude oil, natural gas and coal) labor, capital and energy inputs are aggregated in fixed proportions at the lower nest. At the top level, this aggregate trades off with the sector-specific fossil-fuel resource at a constant elasticity of substitution. The latter is calibrated in consistency with exogenously given price elasticities of fossil fuel supplies.

Privat demand

Final private demand for goods and services in each region is associated with utility maximization of a representative household subject to a budget constraint. In the comparative-static framework, overall investment demand is fixed at the reference level i.e. the demand for the savings good (CGD) is given. Total income of the representative household consists of factor income and transfers. Final demand of the representative agent 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.

Government demand

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: (linear progressive) income taxes including social insurance contributions, capital taxes (corporate and trade taxes), value-added taxes and other indirect taxes (e.g. mineral oil tax). In all simulations, we impose revenue-neutrality in the sense that the level of public provision is fixed. Subject to this equal-yield constraint additional revenues from environmental taxes get recycled through cuts in labor costs (social insurance payments). As to India, we do not incorporate details of taxation, but assume that constant public good provision is financed lump-sum by the representative consumer.

International Trade

All commodities are traded internationally. We adopt the Armington assumption that goods produced in different regions are qualitatively distinct for all commodities (1968) Intermediate as well as final demands are (nested CES) Armington composites of domestic and imported varieties.

Germany and India are assumed to be price-takers 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 functions and ROW export-demand functions. There is an imposed balance of payment constraint to ensure trade balance between Germany and India on the one hand with ROW on the other hand. That is, the value of imports from ROW to Germany and India must equal the value of exports from these countries to ROW after including a constant, benchmark trade surplus (deficit).

Labor market

The analysis of the employment effects associated with an environmental tax reform requires an appropriate specification of unemployment for the German economy. In our formulation, unemployment is generated by the existence of a "wage curve", which postulates a negative relationship between the real wage rate and the rate of unemployment. The specific wage curve employed (see Appendix) can be be derived from trade union wage models as well as from efficiency wage models. As to India, we assume that labor is in fixed supply and labor markets are perfectly competitive.

2.2 Modeling Joint Implementation

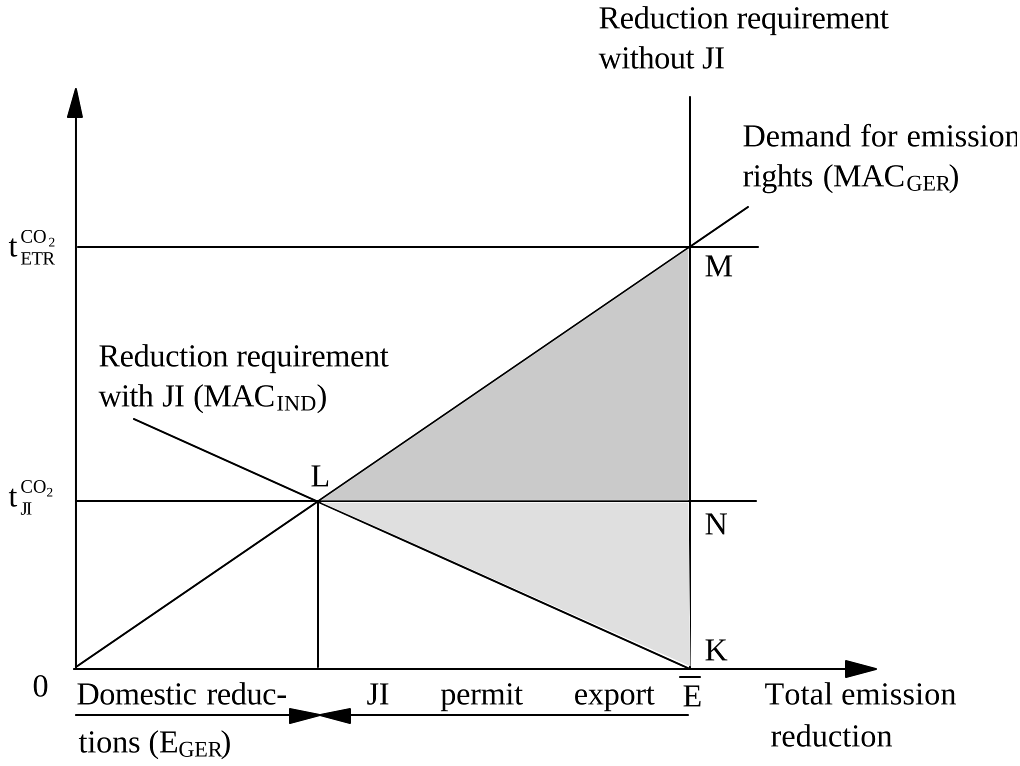
The rational behind Joint Implementation (JI) is the same as with emissions trading: cost-effectiveness requires that measures to limit greenhouse gas emissions should be taken where they are cheapest. However, as compared to emissions trading, JI is based on concrete projects. The JI donor country receives emission credits that may count towards its own emission targets for carrying out climate protection projects in return for funds and technology given to the JI host. The implementation of project based JI mechanisms in top-down models where sectoral production possibilities are given by aggregate functional forms raises some difficulties. Instead of using a discrete step-function for the abatement cost curve based on bottom-up estimates, emission abatement possibilities are implicit to the flexible functional form. The challenge is to specify and calibrate the functional form in such a way that it provides a reasonable approximation for the marginal abatement costs available from engineering data. To this purpose we employ flexible CES functions with a rather sophisticated nesting of energy inputs. Energy supply and demand calibration is based on physical energy flows and energy prices (see 2.4). In the model, JI is represented as a sectoral permit trade regime where sectors in non-abating countries qualifying for JI – in our case the Indian electricity sector – are endowed with (grandfathered) sector-specific emission budgets. The amount of permit rights is set equal to the baseline carbon emissions of the Indian electricity sector. Under JI the donor - here Germany - will demand emission rights (credits) from the JI host - here the Indian power industry - as long as the price of the emission credit (including transaction costs) is below its marginal abatement costs at home. On the other hand, the Indian power industry will deliver emission credits to Germany as long as the marginal costs of abating carbon in the power industry are lower than the price or revenue received for the emission credit. According to this arbitrage rule, the Indian electricity sector will allocate its baseline emission rights between credits for Germany and demand for its own domestic production. Without Joint Implementation, the quantity of available emission rights in German is fixed. Emission credits from Joint Implementation enlarge the total emission budget of Germany which allows for a reduction of the domestic carbon tax while complying with the overall carbon emission constraint.

The principal JI mechanism underlying our model simulations in section 3 is illustrated in Figure 1. Total carbon emissions in Germany amount to $\overline{CO_2}$ in the benchmark equilibrium. The flexibility mechanisms allow a redistribution of the emission reductions between the countries although the overall target reduction is unchanged. Given the total emission reduction requirement $\overline{E}$ in Germany only the volume E_{GER} will be achieved by domestic action whereas the remainder E_{IND} will be abated by the India power industry.[6] Total efficiency gains from JI are given by the shaded area KLM. Distribution of these gains are determined here via the market solution: The JI donor country receives a net gain NLM which is equal to his savings of abatement costs adjusted for the expenditure of purchasing emission

[6] We assume that JI abatement is fully credible towards domestic abatement requirements and that there is no minimum share for domestic abatement. For other specifications see Cansier and Krumm (1996), p. 165.

credits. The electricity industry in India receives a net gain KLN which equals the difference between the revenues from the sale of emission credits and its undergone abatement costs.[7]

Figure 1: Joint Implementation Mechanism



Reflecting the project character of JI, the electricity industry in India uses the revenues from the sale of emission reductions to buy directly capital goods from Germany. The German capital goods (coal or gas power plants) increase the capital stock in the Indian electricity sector. This direct investment exerts a positive effect on employment in the German manufacturing industries. Additional revenues from permits reduce the electricity price in India.

2.3 Joint implementation under productivity gaps in the electricity producing industry

[7] From a broader perspective the JI transfer includes the incremental costs of abatement, a share of the efficiency gains plus a cream scimming component. The cream scimming component takes into account that because the least cost abatement alternatives are implemented first developing countries will face higher costs than necessary today under JI when they commit themselves to emission abatement in the future. Torvanger et. al. (1994), pp. 39.

In JI it is presupposed that there is no environmental regulation in one of the two countries and/or that there are productivity differences. If the latter ones can be reduced by JI measures, this would improve energy efficiency and thus would reduced CO_2 emissions in the host country. Since energy efficiency of fossil fuel fired power plants is higher by 25 percent in industrialized countries compared to less developed countries, the German industry could invest in Indian power plants to reduce the productivity difference. India's energy producer use the German JI revenues for renewal of their power plant.[8] Because of inferior efficiency in India the transfer of resources from India to Germany result ceteris paribus in a decrease in variable costs or increase in output. This cost or productivity gap has to be taken into account when assessing Joint Implementation projects based on capital transfer to improve efficiency. To measure such a productivity gap between the German and the Indian electricity producing industries we employ the concept developed by Jorgenson and Nishimizu (1978). Within this approach of a JI, German industries invest in Indian electric utilities until the capital stock related productivity difference has disappeared. Such a measure is cost-effective if the resulting CO_2 reduction is attributed to the German reduction target.

To implement our approach, we choose instead of a CES specification for a sub-production function a translog specification. We consider an aggregate output EK produced by fossil fuel E and capital K. We use the dual concept of measuring a cost gap. The point of departure is the joint restricted sub-cost function for both counties:

$$(1) \qquad C = C(p^E, EK, K, D)$$

where p^E is the price of fossil fuel, EK the output, K the capital stock, and D a dummy variable. To incorporate the impact of quasi-fixed inputs' capacity restriction on total factor productivity (TFP) growth, a temporary (short-run) equilibrium should be assumed and consequently, a restricted cost function is used. As emphasized by Berndt and Fuss (1986), in

[8] India's electricity sector is largely in the responsibility of State Electricity Boards (SEBs). The electricity tariff is a state issue and fixed more on political rather than on economical considerations. The tariff structure is not reflecting the costs of energy delivered. Almost all SEBs are making losses and are nearly bankrupt. Therefore electricity sector in India has been suffering a severe shortfall in investment resources. See Bose and Shukla (1999).

order to derive accurate measures of TFP in a temporary equilibrium framework, quasi-fixed inputs should be evaluated at their shadow rather than their rental prices (or ex-post price rather than their ex-ante price). We assume the cost function to be linear homogenous in EK and K. Because output levels, capital stock and the factor price are expressed relative to India, the dummy variable takes on the value 0 for India (I) and 1 for Germany (G). The dummy variable catches country specific deviations from the joint cost function. It shifts the cost function inwards or outwards. The difference in cost between India and Germany at a given point in time is calculated as the total differential of the cost function (1). In form of logarithmic derivatives we get:

(2) $$\frac{d \ln C}{d\, D} = s_E \frac{d \ln\, p^E}{d\, D} + \frac{\partial \ln C}{\partial \ln EK}\frac{d \ln EK}{d\, D} + \frac{\partial \ln C}{\partial \ln K}\frac{d \ln K}{d\, D} + \frac{\partial \ln C}{\partial\, D}$$

where $s_E = \dfrac{\partial \ln C}{\partial \ln\, p^E} = \dfrac{p^E \cdot E}{C}$ is the cost share of energy in this aggregate (Shephard's Lemma). In equation (2) the partial derivatives of the variable cost function with respect to the capital stock K represents the savings in costs from a marginal increase in the stock. This savings in costs is the shadow price of the capital stock (p_s^K). In logarithmic partial derivative with respect to K, it is the cost share (multiplied by –1), i.e.:

$$p_s^K = -\frac{\partial\, C}{\partial\, K} \quad \text{and} \quad s_K = \frac{p^K \cdot K}{C} = -\frac{\partial \ln C}{\partial \ln K}.$$

Under the additional assumption of profit maximizing supply decisions, we have $p^{EK} = \partial\, C / \partial\, EK$. The logarithmic partial derivative with respect to output then corresponds to the revenue cost-share. By rearranging (2) we get:

(3) $$\frac{\partial \ln C}{\partial\, D} = \frac{d \ln C}{d\, D} - s_E \frac{d \ln\, p^E}{d\, D} - \frac{p^{EK} \cdot EK}{C}\frac{d \ln EK}{d\, D} + s_K \frac{d \ln K}{d\, D}.$$

Equation (3) shows the sectoral difference in costs between India and Germany if the costs were adjusted for the differences in the levels of production, capital stock, and factor prices at a given point in time. If there is a disadvantage in costs of an Indian sector, then $\partial \ln C / \partial D$ is negative. The left hand side means that with given Indian energy price, output EK and capital stock K in the German industrial environment, cost would be lower. In the production function approach $EK = F(E, K, D)$, the equivalent interpretation is that output would be higher by that percentage if Indian EK is produced with Indian E and K in Germany. Therefore, in Germany the resources are used more efficiently. The cost gap is calculated by adjusting the difference in costs by the weighted differences in p^E, EK and K. Since under CRTS of $C(\cdot)$ in EK and K and under marginal cost pricing $p^{EK} \cdot EK = C + p_s^K \cdot K$, or

$$\frac{p^{EK} \cdot EK}{C} - \frac{p_s^K \cdot K}{C} = 1$$

we can cast (3) into the expression

(3')
$$\frac{\partial \ln C}{\partial D} = \frac{d \ln C}{d\, D} - s_E \frac{d \ln p^E}{d\, D} - \frac{d \ln EK}{d\, D} - \frac{p_s^K \cdot K}{C} \frac{d \ln (EK/K)}{d\, D} .$$

An increase in capital productivity EK/K in India would lower the positive term $\frac{d \ln (EK/K)}{d\, D}$ and would therefore reduce the Indian productivity gap.

As a discrete approximation of the Divisia Index (3) we use the Törnquist index. Then the cost gap s_D can be calculated as:

(4)
$$\begin{aligned} s_D = {} & \ln C(G) - \ln C(J) - \bar{s}_E \left(\ln p^E(G) - \ln p^E(J)\right) \\ & - \bar{s}_{EK} \left(\ln EK(G) - \ln EK(J)\right) + \bar{s}_K \left(\ln K(G) - \ln K(J)\right) \end{aligned}$$

with $\bar{s}_j = \frac{1}{2}\left(s_j(G) + s_j(J)\right)$ for $j = E, EK, K$.

Regional differences in the cost structure of two industries result from differences in the quantities of inputs which in turn are determined by the level of production, by factor prices, and by the capital stock. A descriptive analysis indicates which components are accountable for the differences in costs but does not determine their contribution in explaining the differences in factor demand. Therefore, the causes for the changes in the cost gaps have to be determined by employing an econometric model. For our CGE analysis we use a translog specification of the cost function:

$$\begin{aligned}\ln C = a_0 + \ln\, p^E + \ln K + a_{EK} \ln \frac{EK}{K} + a_D \cdot D + \frac{1}{2} b_{EK,EK} \ln^2 \frac{EK}{K} \\ + b_{EK,D} \ln \frac{EK}{K} \cdot D\end{aligned} \qquad (5)$$

The cost shares s_E, s_{EK}, s_K and the gap $s_D = \dfrac{\partial \ln C}{\partial\, D}$ can be derived by differentiating the cost function logarithmically. Since we can not calibrate all parameters from one observation we set the parameter $b_{EK,EK}$ equal to zero. Then the cost function is

$$\ln C = a_0 + \ln\, p^E + \ln K + a_{EK} \ln \frac{EK}{K} + a_D \cdot D + b_{EK,D} \ln \frac{EK}{K} \cdot D \qquad (6)$$

and the cost shares are $s_E = 1$ and

$$s_{EK} = a_{EK} + b_{EK,D} \cdot D \qquad (7)$$

$$s_K = -\left(1 - a_{EK} - b_{EK,D} \cdot D\right) \qquad (8)$$

$$s_D = a_D + b_{EK,D} \ln \frac{EK}{K}. \qquad (9)$$

The parameter $b_{EK,D}$ measures the impact of EK/K on the difference in costs:

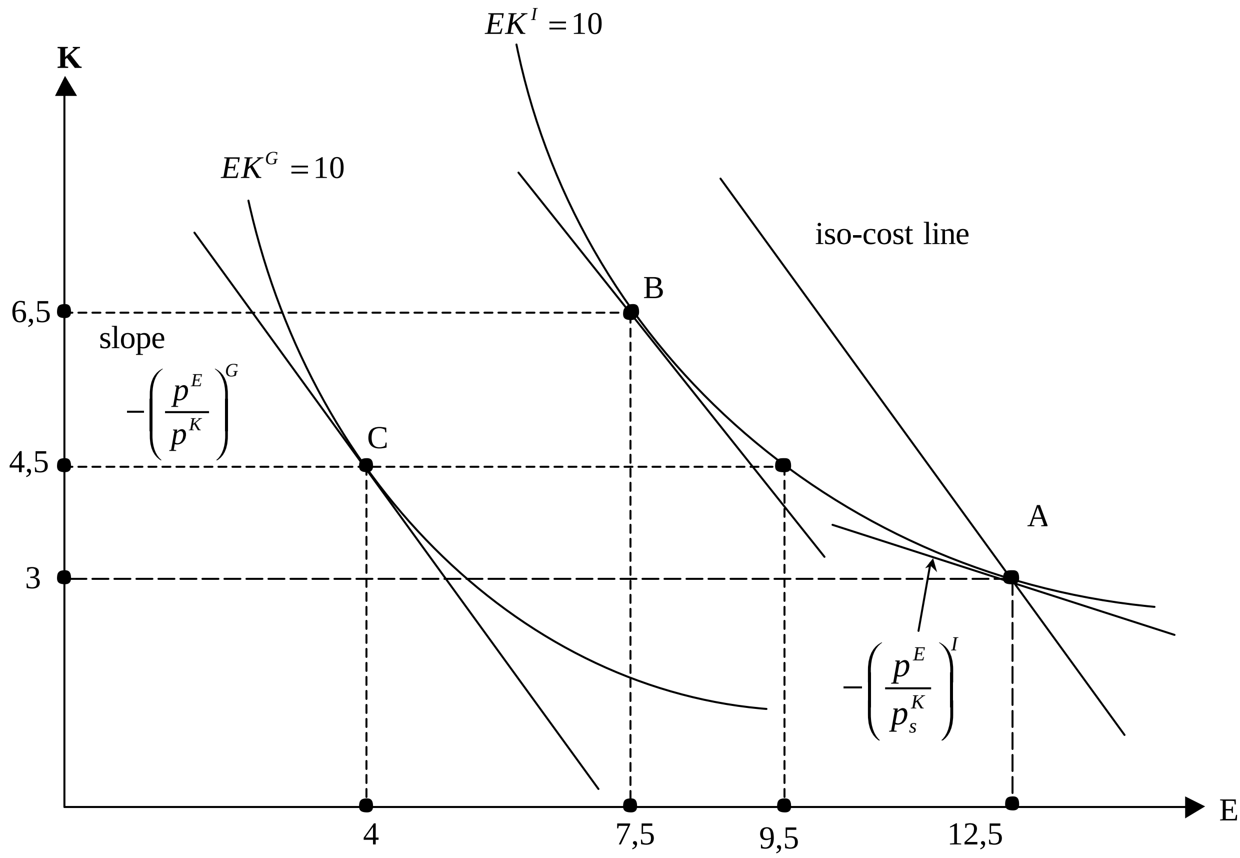
$$\frac{\partial\, s_D}{\partial \ln\left(\dfrac{EK}{K}\right)} = b_{EK,D}.$$

A positive parameter means that the difference in costs $\left(s_D < 0\right)$ will be reduced if capital productivity can be raised in India. In the cost share equation (8) for capital in turn a positive $b_{EK,D}$ implies that the cost share of capital increases when production switches from the Indian to the German industry. From (6) the short run production function can be derived as

$$EK = \exp\left[\frac{a_0 + a_D \cdot D}{-a_{EK} - b_{EK,D} \cdot D}\right] \cdot E^{\frac{1}{a_{EK} + b_{EK,D} \cdot D}} \cdot K^{\frac{1 - a_{EK} - b_{EK,D} \cdot D}{-a_{EK} - b_{EK,D} \cdot D}} \ .$$

The following figure presents the situation. We assume that output is the same in both countries and that the relative price of energy with respect to capital is normalized to be one in both countries in a long run equilibrium situation. Given capital shortage in India, the shadow price of capital, p_s^K, in India is higher than in Germany implying the less steep slope of the iso-cost line for India in its temporary equilibrium.

Figure 2: Productivity gaps in the electricity sector



Since capital $K^I = 3$ is quasi-fixed, India does not produce at its minimal cost combination B. It has to produce at A with $\bar{K} = 3,\ \tilde{E} = 12.5$. If India would produce $EK = 10$ with 4.5 units of capital instead of its 3 units, it would save 3 units of energy (9.5 instead of 12.5) in order to produce $EK = 10$. If it would use only 4 units of energy, it would require about 3 times as much capital than Germany. Since the Indian electricity industry is in a short-run equilibrium (*A*), investment in capital would help to reach the long-run equilibrium in *B*. Since energy and capital are internationally traded goods, we assume that the slope of the iso-cost line in *B* and *C* is the same for India's and Germany's electricity sector. Since costs are lower in *B* compared to *A*, the cost cap in (4) will be reduced by becoming less negative. From the production side, the saving in costs can be used to buy more inputs and the increase in the resulting output will reduce the productivity gap. Since $\ln C(I)$ in the cost gap calculation declines, the new $\tilde{s}_D$ will be less negative. Therefore the parameter a_D in the equation (9) for s_D has to be revised. Its new value enters into the variable cost function and thereby into the price determination of p^{EK}. Since for electricity the demand side determined the size of the aggregate EK (electricity can not be stored), only a CGE calculation can say whether capital productivity EK/K has changed. In a partial equilibrium framework EK/K will not change if K changes because EK then changes by the same magnitude, due to constant returns to scale. A positive impact on closing the gap s_D in (9) could come from raising capital productivity EK/K. By solving the supply function (7) for EK/K, capital productivity is positively related with p^{EK}. If therefore this price increases then this contributes to closing the gap s_D.[9]

2.4 Parameterization

Benchmark data are used to calibrate parameters of the functional forms from a given set of quantities, prices and elasticities. Data from two different sources are combined to yield a consistent benchmark data set for 1995:

- *GTAP database* (Version 4.0, McDougall 1997). GTAP includes detailed input-output tables for 30 regions and 37 sectors as well as a world trade matrix with bilateral trade flows for all sectors and regions.
- *IEA energy balances and energy prices/taxes* (IEA 1996). IEA provides statistics on physical energy flows and energy prices for industrial and household demands.

We accommodate a consistent representation of energy markets in physical units by replacing GTAP's aggregate input-output monetary values for energy supply and demand with physical energy flows and energy prices as given in IEA's energy statistics. This "bottom-up" calibration of energy demands and supplies yields sector-specific and energy-specific CO_2 coefficients. The advantage is that marginal abatement cost curves and hence the cost evaluation of emission constraints are based on actual energy flows rather than on aggregate monetary data, which strengthens the credibility of the quantitative results. The magnitude of

[9] If policy instruments are to be considered to close the gap, then instruments like research and development or infrastructure have to be introduced as arguments into the cost function.

efficiency gains from JI depend crucially on the emission structure in the Indian and German economy.

3. Scenarios and Results

In our simulations we distinguish two core scenarios. Our first scenario ETR refers to an environmental tax reform in Germany where carbon taxes are levied in order to meet a 25 % reduction of domestic emissions. Carbon taxes are recycled in a revenue-neutral way to lower non-wage labor costs. The second scenario JI allows for Joint Implementation with the Indian electricity sector. Germany's reduction target can be met simultaneously by domestic abatement and emission reduction undertaken in the Indian power sector. Table 1 summarizes the implications of the two different abatement scenarios for inframarginal welfare (measured in terms of Hicksian-equivalent variation), unemployment and marginal abatement costs.

Table 1: Welfare, unemployment and marginal abatement costs (% change)

	ETR	JI
Welfare in Germany	-0.57	-0.41
Welfare in India	0	0.50
Unemployment in Germany	1.53	0.78
Marginal Abatement Cost*	47.51	31.61

* in USD per ton of CO_2

Welfare

Within the reduction scenario ETR the welfare in Germany goes down by 0.57 %. Unilateral action by Germany to reach the Kyoto targets is far more costly than a combined strategy with ETR and JI. With strictly unilateral action a carbon tax of 47.51 USD is needed to reduce the German carbon dioxid emissions by 25 per cent. This tax rate lies within the likely range indicated by other studies. With JI the carbon taxes can be reduced to 31.61 USD while ensuring the same environmental effectiveness. There are substantial efficiency gains associated with JI that lead to an increase in regional welfare. In Germany the reallocation of resources towards less carbon-intensive production and the associated adjustment costs are reduced (see Table 2 for the sectoral effects on production). The increase in welfare of 0.50 % for India under JI results from the Indian participation in efficiency gains and the capital stock augmentation through Joint Implementation.

Unemployment

Looking at the employment effects of the environmental tax reform our simulations indicate, that an environmental tax reform is not likely to exert an employment double dividend given the initial tax distortions and labor market imperfections in Germany. Unemployment after ETR is by 1.53 % higher than before. This is in line with the widespread pessimism in the literature towards the “double dividend”. Carbon tax revenues under ETR amount to 34.68 bill. USD and result in a reduction in non-wage labor costs of 2.96 %. Yet Environmental taxes seem to exacerbate rather than alleviate the preexisting tax distortions in the German economy. This tax interaction effect outweight the positive revenue recycling effect and is responsible for the failure of the employment double dividend in our general equilibrium model.

JI reduces the negative impact of carbon abatement on employment in Germany. With JI, carbon taxes and carbon tax revenues in Germany are reduced. Thus JI lowers on the one hand the positive revenue recycling effect (carbon tax revenues total to 25.26 bill. USD and non wage-labor costs are reduced by only 1.99 %) but on the other hand the dominating negative tax interaction effect (negative output effect) is reduced as well. There are also direct positive effects on employment associated with direct investment under JI. India commits itself to buy capital goods from Germany with the JI revenues of 5.97 bill. USD. The additional demand for power plants in the German manufacturing sectors and in other sectors (Y, OME, CNS) has only small positive effects on employment (see Table 2 for sectoral effects on production and employment). Both effects cause unemployment to rise only by 0.78 % with JI .

Table 2: Sectoral effects on production and employment (% change)

	GER		IND
	ETR	JI	JI
	Production		
COL	-30.32	-19.55	0
GAS	-7.60	-5.71	0
OIL	-4.08	-2.70	0.08
ELE	-7.27	-4.83	5.18
EIS	-3.88	-2.56	3.22
TRN	-0.27	-0.19	1.31

OME	0.80	0.61	0.97
CNS	-0.17	-0.01	0.12
Y	-0.72	-0.44	0.03
	Employment		
COL	-45.03	-31.55	0
GAS	-12.35	-9.37	0
OIL	-5.74	-3.82	0.78
ELE	-3.03	-2.03	10.18
EIS	-2.80	-1.84	0.84
TRN	0.01	-0.01	-0.63
OME	1.01	0.76	-0.38
CNS	-0.08	0.06	-1.11
Y	-0.33	-0.17	-0.87

Emissions

With ETR German emissions are reduced from 972 mio. tons CO_2 to 729 Mio. tons CO_2, the domestic reduction target. Emissions in Germany rise to 799 mio. tons CO_2 under JI. An carbon abatement of 70 mio. tons CO_2 is done in India. Emissions in the Indian electricity sector decline from 353 mio. tons 283 Mio. tons CO_2. This means that 71 % of total emission reduction is done at home and 29 % is done in the Indian power sector.

Reduction in cost gap

Through Joint Implementation the capital stock in the Indian electricity sector increases by 14.31 %. The reduction in costs due to the movement of the temporary equilibrium towards the long-run equilibrium characterized by less energy and more capital input results in a decline of the price of electricity from 1 to 0.92 in India. Since the price of energy increases by the price of permit, the price of electricity increases in both countries. Energy intensity *E/K* dropped from 0.44 to 0.32 for India and from 0.33 to 0.23 for Germany. The price *PE* of fossil fuel increases by the price of a permit. As the fossil fuel mix of India has higher CO_2 emission coefficients, the price *PE* for India is higher than the price for Germany (see Table 3) Overall, *JI* improves the performance of the Indian economy and narrows the productivity gap in the Indian electricity sector with respect to the German sector. The initial gap s_d= -0.29 is reduced to s_d^{JI} = -0.12 with JI when calculated as a residual.

Table 3: Effects of JI on the electricity sector (in bill. USD) [10]

	Benchmark		JI	
	IND	GER	IND	DEU
K	1.314	2.386	1.502	2.386
PK	0.888	1	0.763	1.036
E	0.582	0.794	0.480	0.558
PE	1	1	2.121	1.511
EK	1.749	3.180	1.793	2.912
PEK	1	1	1.207	1.138

4. Conclusions

Carbon taxes have a considerable negative impacts on welfare and employment in Germany. JI can help to diminish this effects through the associated cost savings and additional investment demand from JI host countries. There are however some important points with our modeling of JI: There are considerable control and transaction costs involved in planning and implementing JI projects in a developing country like India. This costs reduce the positive effects of JI. In our analysis we have neglected this aspect since several developing countries have already started unilateral initiatives to lower the transaction costs of JI. Also we assume that we know the reference point for JI policies i.e. the benchmark emission levels. The implementation of JI in the real world gives an incentive to the parties to overstate baseline emission levels. We can account for this problem of asymmetric information by varying the emission levels of the developing countries.

The implications of our results for ongoing negotiations are important. Many developing countries are rather sceptical towards Joint Implementation, as they are towards the establishment of binding international objectives on emission reductions. Compensation projects are seen as a cheap buy-out from the obligation to reduce greenhouse gas emissions. However, JI may be the only possibility for developing countries like India to equip its electricity industry with additional capital goods. This leads to a more efficient power production with lower electricity prices for the economy. Our short-run analysis indicates that

[10] The shadow price of capital for India is 0.0753, for Germany it is 0.069. To calculate the normalized price PK for India, capital stock K^{st} (15.5 bill. USD) has to be multiplied by 0.0753 and then divided by the real capital flow 1.314 which yields 0.888.

the developing countries obtain large improvements in welfare through the participation in efficiency gains and the higher performance of the economy. An analyses of the process of capital accumulation in India towards the long-run equilibrium in an intertemporal model of ETR and JI will shed more light into the dynamic aspects of JI.

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Appendix

Algebraic Summary

This appendix provides an algebraic summary of the equilibrium conditions for generic comparative-static model without unemployment. Two classes of conditions characterize the competitive equilibrium: zero profit conditions and market clearance conditions. The former class determines activity levels and the latter determine price levels. In our algebraic exposition, the notation Π_i^z is used to denote the profit function of sector i where z is the name assigned to the associated production activity. Differentiating the profit function with respect to input and output prices provides compensated demand and supply coefficients (Shephard's lemma), which appear subsequently in the market clearance conditions. Tables A.1 explain the notations for variables and parameters.

Zero Profit Conditions

Competitive producers operating a constant return to scale technology earn zero profit in equilibrium. Profit maximization under constant returns to scale thus implies that the output price equals the unit cost functions. The value of output to the firms equals the value of sales in the domestic and the export markets. Costs of production include factor inputs and intermediate inputs.

1. Production of goods except fossil fuels and electricity:

$$?_i^Y = CET\left(PX_i, P_i\right) - LT\left(PA_j^Y, PA_{CRU}^Y, CES\left(PL, CES(PK_i, PE_i)\right)\right) = 0 \qquad i, j \notin EC$$

2. Production of fossil fuels:

$$?_i^Y = CET\left(PX_i, P_i\right) - CES\left(PR_i, LT\left(PE_i, PA_j^Y, PK_i, PL\right)\right) = 0 \qquad i \in FF, j \notin EC$$

3. Production of electricity:

$$\Pi_i^Y = CET(PX_i, P_i) - LT\left(PA_j^Y, PA_{cru}^Y, PA_{oil}^Y, CES(PL, TRANSLOG(PE_i, K_i, EK_i, D))\right) = 0 \quad i \in ELE, j \in NE$$

4. Sector-specific energy aggregate:

$$\Pi_i^E = PE_i - CES\left(PA_{ele}^Y, CES\left(PA_{col}^Y, CES\left(PA_{gas}^Y, PA_{oil}^Y\right)\right)\right) = 0 \quad i \notin EC$$

$$\Pi_i^E = PE_i - LT\left(PA_j^Y\right) = 0 \quad i \in FF, j \in EC$$

$$\Pi_i^E = PE_i - CES\left(PA_{gas}^Y, PA_{col}^Y\right) = 0 \quad i \in ELE$$

5. Armington aggregate:

$$\Pi_{di}^A = PA_i^d - CES(P_i, PM_i) - t^{CO2} a_{di}^{CO2} = 0$$

6. Aggregate imports across import regions:

$$\Pi_i^{M,IND} = PM_i^{IND} - CES\left(P_i^{GER}, PX_i\right) = 0$$

$$\Pi_i^{M,GER} = PM_i^{GER} - CES\left(P_i^{IND}, PX_i\right) = 0$$

7. Investment:

$$\Pi^I = PI - LT\left(PA_i^I\right) = 0$$

8. Public demand:

$$\Pi^G = PG - CD\left(PA_i^G, CES\left(PA_j^G\right)\right) = 0 \quad i \in NE, j \in EC$$

9. Household consumption demand:

$$\Pi^C = PC - CES\left(CD\left(PA_i^C\right), CD\left(PA_j^C\right)\right) = 0 \quad i \in NE, j \in EC$$

10. Utility production:

$$\Pi^{U} = PU - CES(PC, PL) = 0$$

Market Clearance Conditions

11. Labor:

$$\bar{L} = \sum_i Y_i \frac{\partial \Pi_i^Y}{\partial PL}$$

12. Capital:

$$\bar{K}_i = Y_i \frac{\partial \Pi_i^Y}{\partial PK_i}$$

13. Natural resources:

$$\bar{Q}_i = Y_i \frac{\partial \Pi_i^Y}{\partial PR_i} \qquad i \in FF$$

14. Domestic output:

$$Y_i \frac{\partial \Pi_i^Y}{\partial P_i} = \sum_j \sum_d A_i^d \frac{\delta \Pi_{dj}^A}{\delta P_j}$$

15. Sector specific energy aggregate:

$$E_i = Y_i \frac{\partial \Pi_i^Y}{\partial PE_i}$$

16. Import aggregate:

$$M_i = \sum_d A_i^d \frac{\partial \Pi_{di}^A}{\partial PM_i}$$

17. Armington aggregate:

$$A_i^d = \sum_j Y_j \frac{\partial \Pi_j^Y}{\partial PA_i^Y} + C \frac{\partial \Pi^C}{\partial PA_i^C} + I \frac{\partial \Pi^I}{\partial PA_i^I} + G \frac{\partial \Pi^G}{\partial PA_i^G}$$

18. Foreign closure:

$$\sum_i \left(PX_i \cdot \frac{\partial \Pi_i^{Y,IND}}{\partial PX_i} \cdot Y_i^{IND} + PX_i \cdot \frac{\partial \Pi_i^{Y,GER}}{\partial PX_i} \cdot Y_i^{GER} \right) = \sum_i \left(PX_i \cdot \frac{\partial \Pi_i^{M,IND}}{\partial PX_i} \cdot M_i^{IND} + PX_i \cdot \frac{\partial \Pi_i^{M,GER}}{\partial PX_i} \cdot M_i^{GER} \right)$$
$$+ \overline{B}^{IND} + \overline{B}^{GER}$$

19. Household consumption:

$$C \cdot PC = (PL \cdot \overline{L} + PK \cdot \overline{K} + \sum_{j \in FF} PQ_j \overline{Q}_j - PI \cdot \overline{I} - PC \cdot \overline{B}^{IND} \qquad \text{for IND}$$
$$C \cdot PC + (\overline{L} - L)PL = PL \cdot \overline{L} + \sum_i PK_i \overline{K}_i + \sum_{j \in FF} PQ_j \overline{Q}_j - PI \cdot \overline{I} - PC \cdot \overline{B}^{GER} \qquad \text{for GER}$$

20. Government consumption:

$$\begin{aligned}
G \cdot PG = {} & t^{CO2} \cdot \overline{CO2} + \sum_i t_i^y \left(P_i \, Y_i \frac{\partial \Pi_i^Y}{\partial P_i} + PX_i \, Y_i \frac{\partial \Pi_i^Y}{\partial PX_i} \right) \\
& + \sum_i \sum_j t_{ij}^{ID} PA_j^Y Y_j \frac{\partial \Pi_j^Y}{\partial PA_j^Y} + \sum_i t_i^L \, PL \cdot Y_i \frac{\partial \Pi_i^Y}{\partial PL} \\
& + \sum_i t_i^K PK_i Y_i \frac{\partial \Pi_i^Y}{\partial PK_i} + \sum_i t_i^G PA_i^G G_i \frac{\partial \Pi_i^G}{\partial PA_i^G} \\
& + \sum_i t_i^C PA_i^C C_i \frac{\partial \Pi_i^C}{\partial PA_i^C} + \sum_i t_i^{X,r} PX_i \left(\frac{\partial \Pi_i^Y}{\partial PX_i} \cdot Y_i \right) \\
& + \sum_i t_i^M PX_i \, M_i \frac{\partial \Pi_i^{M,s}}{\partial PX_i} \left(1 + t_i^{X,s}\right) \\
& + t^{INC} \cdot TAU \cdot PL \cdot L + \sum_i t_i^{INC} PK_i K_i + \sum_i t_i^{INC} PQ_i Q_i
\end{aligned}$$

21. Government output:

$$\overline{G} = G$$

22. Investment:

$$\overline{I} = I$$

23. German carbon emissions:

$$\overline{CO2} = \sum_d \sum_i A_i^d \frac{\partial \Pi_{di}^A}{\partial t^{CO2}}$$

Table A.1: Sets, activity and price variables, endowments and emissions coefficients

Sets	
i	Sectors and goods (aliased with j)
r	Regions (aliased with s)
EG	All energy goods: Coal, crude oil, refined oil, gas and electricity
FF	Primary fossil fuels: Coal, crude oil and gas
EC	Coal, crude oil, gas, electricity
d	Demand categories: Y = intermediate, C = household G = government and I = investment
Activity variables	
Y_i	Production in sector i
E_i	Aggregate energy input in sector i
M_i	Aggregate imports of good i
A_i^d	Armington aggregate for demand category d of good i
I	Aggregate investment
G	Aggregate public output
C	Aggregate household consumption
E	Aggregate household energy consumption
Price variables	
P_i	Output price of good i produced in region r for domestic market
PE_i	Price of aggregate energy in sector i and region r
PX_i	ROW prices of exports and imports in sector i
PM_i	Import price aggregate for good i
PA_i^d	Price of Armington aggregate for demand category d of good i
PI	Price of investment demand
PG	Price of government demand
PC	Price of aggregate household consumption
PU	Utility price index
PL	Wage rate
PK_i	Price of sector specific capital services in sector i
PQ_i	Rent to natural resources ($i \in$ FF)
t^{CO_2}	Price of CO_2 permit
Endowments and emissions coefficients	
$\overline{L}$	Aggregate labor endowment
$\overline{K}_i$	Aggregate capital endowment
$\overline{Q}_i$	Endowment of natural resource i ($i \in$ FF)
$\overline{G}$	Aggregate government demand
$\overline{I}$	Aggregate investment demand
$\overline{B}$	Balance of payment surplus (note: $\sum_r \overline{B}_r = 0$)
$\overline{CO2}$	Endowment of carbon emission rights

Table A.2: Selected elasticities

Elasticity of transformation between production for the domestic market and production for export	2
Elasticity of substitution between the capital and energy aggregate and labor in production (except fossil fuels and electricity)	0.3
Elasticity of substitution between capital and energy in production (except fossil fuels and electricity)	0.8
Elasticity of substitution between electricity and non-electricity energy goods in production (except fossil fuels and electricity)	0.1
Elasticity of substitution between coal and non-coal fossil fuels in production (except fossil fuels and electricity)	0.5
Elasticity of substitution between gas and oil in production (except fossil fuels and electricity)	0.9
Elasticity of supply in fossil fuel production	$\mu_{COA} = 0.5$ $\mu_{CRU} = 1.0$ $\mu_{GAS} = 1.0$
Elasticity of substitution between labor and the capital-energy aggregate in electricity production	0.5
Elasticity of substitution between gas and coal in electricity production	4
Elasticity of substitution between energy and non energy composite in final demand	0.5
Elasticity of substitution between energy goods and between non-energy goods in final demand	1
Elasticity of substitution between fossil fuels and non-fossil fuels in government demand	1
Elasticity of substitution between fossil fuels in government demand	0.3
Elasticity of substitution between imports from different regions (except electricity and gas)	4
Elasticity of substitution between imports from different regions for electricity and gas	0.7
Elasticity of substitution between imported and domestic inputs	4

Consideration of Joint Implementation

17'. Armington aggregate with additional investment demand through JI:

$$A_i^d = \sum_j Y_j \frac{\partial \Pi_j^Y}{\partial PA_i^Y} + C \frac{\partial \Pi^C}{\partial PA_i^C} + I \frac{\partial \Pi^I}{\partial PA_i^I} + G \frac{\partial \Pi^G}{\partial PA_i^G} + b_i \frac{EXP \cdot t^{CO_2}}{LT(PA_{OME}, PA_y, PA_{CNS})}$$

23'. German carbon emissions with JI:

$$\overline{CO2} + EXP = \sum_d \sum_i A_i^d \frac{\partial \Pi_{di}^A}{\partial t^{CO2}}$$

24. Carbon emissions in the Indian electricity sector:

$$\overline{CO2}_{ELE} - EXP = \sum_d \sum_i A_i^d \frac{\partial \Pi_{di}^A}{\partial t^{CO2}}$$

Table A.3: Activity and price variables, endowments and coefficients for JI

EXP	JI permit export from India to Germany
$\overline{CO2}_{ELE}$	Endowment of carbon emission rights in the Indian electricity sector
b_i	Share of JI investment demand directes to sector i

Labor market specification

Unemployment in Germany is generated by the existence of a "wage curve", which postulates a negative relationship between the real wage rate and the rate of unemployment:

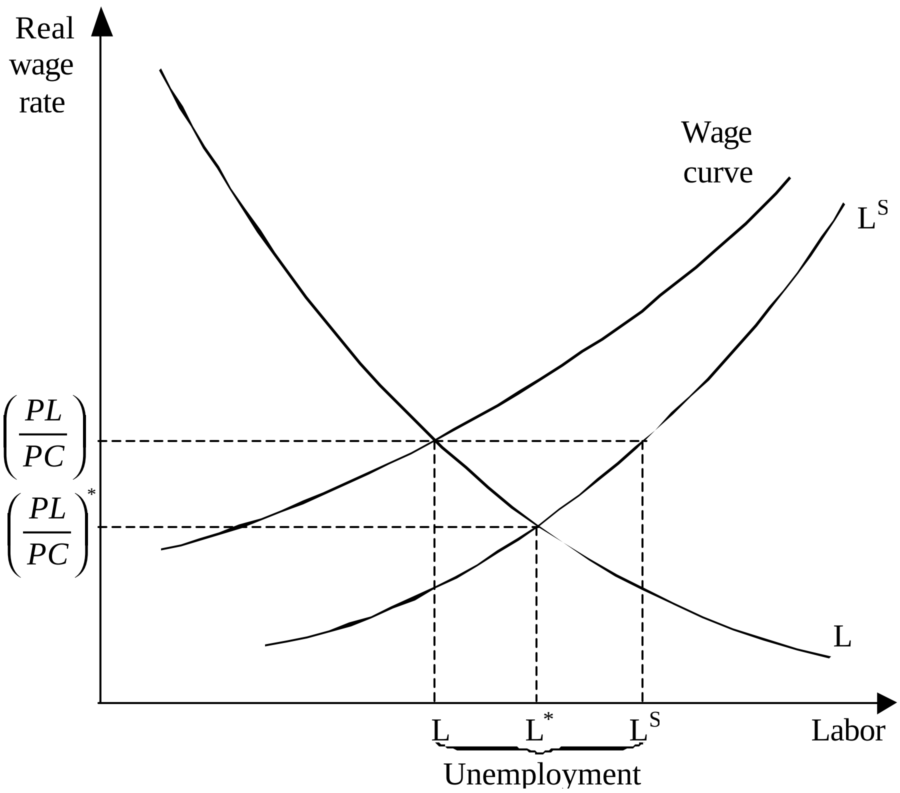
$$\frac{PL}{PC} = g(ur) \quad \text{with} \quad g' < 0.$$

with PC the consumer goods price index and $ur = (L^S - L^D)/L^S$, the unemployment rate. The wage curve replaces the labor supply curve. Consequently, the equilibrium wage rate *(PL/PC)* lies above the market clearing wage rate *(PL/PC)** leading to benchmark unemployment ($L^S - L^D$). We use a simple specification of the wage curve as a log-linear equation

$$\log\left(\frac{PL}{PC}\right) = \gamma_0 + \gamma_1 \log(ur) - \log\theta,$$

with γ_0 is a positive scale parameter, $\gamma_1 < 0$ indicates the elasticity of the real wage in relation to the unemployment rate and (1-?) the tax wedge between the employers' gross wage costs and the employees' net wages with $q \equiv \frac{1-t_w}{1+t_L}$.

Figure 3: Wage curve and equilibrium unemployment



If the household is rationed on the labor market, the budget restriction changes in so far as the actual net wage income is determined $PL(1-t_w)L^D$. The determination of the welfare effects is also based on enforced leisure consumption.