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Theory and Applications

The double dividend issue: modeling strategies and empirical findings

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ABSTRACT This paper reviews recent developments in the study of the so-called 'double dividend', i.e. the possibility of improving the environment and, at the same time, reducing the distortions of the tax system through revenue-neutral green taxes. The main goal of the analysis is to identify the relationship between the modeling strategy and the double dividend results. Recent modeling advances are considered at both the theoretical and the empirical levels. In particular, we note that the most significant theoretical advances have been made in the direction of allowing for imperfectly competitive markets, especially the market for labor. At the same time, we argue that empirical work, particularly on the 'employment double dividend', is still relatively scant and that much more needs to be done both in the direction of more realistic empirical models and of an extended sensitivity analysis of the main findings.

1. Introduction

To the non-specialist, the notion of 'double dividend' could be simply explained as the possibility of killing two birds with one stone. Here, the two birds represent a better quality of the environment and a less distortionary tax system, while the stone represents an environmental fiscal reform. A bit more specifically, a double dividend means improvements in the environmental variable which is the target of the environmental tax

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and overall improvements of the allocation of goods in the economy in other respects.

The 'double dividend' is a topic currently much debated among environmental economists, green activists, and policy makers. This debate is very recent, as it dates back to the beginning of the current decade. According to Pezzey and Park (1998), at the beginning of the 1990s, a few extreme weather episodes caused increasing concern among scientists and observers about the possibility of climate changes. From this viewpoint the threat of global warming caused by increased CO_2 emissions was particularly prominent. Pollution taxes were a natural candidate to curb discharges into the atmosphere. However, calculations showed that the tax rates needed to achieve significant results were too high to be politically acceptable. To overcome this difficulty it was therefore suggested to use the proceeds from a green fiscal reform in order to significantly reduce existing taxes and therefore the cost of carbon taxation (Pearce, 1991; Repetto, Dower, Jenkins, and Geoghegan, 1992; Oates, 1993).[1]

Subsequently, following the seminal work of Sandmo (1975), which linked optimal taxation to environmental issues, the double dividend idea caught the interest of public finance economists and set off a technical debate concerning the conditions ensuring the emergence of a double dividend and its economic consequences. Roughly speaking, the double dividend literature can be divided in two strands.

A first group of contributions focuses upon the distortions of the tax system, before and after an environmental fiscal reform. Because lump-sum taxation is not a feasible form of taxation in practice, and existing taxes are therefore necessarily distortionary, a relevant issue for study is whether the revenues generated by a pollution tax reduce existing taxes and associated distortions or not: if so, the environmental policy may improve welfare even without taking the environmental dividend into account (see for instance Goulder, 1995). The emphasis here is typically on individual welfare or utility, derived from consumption, leisure, and environmental quality, with less attention being paid to the specific modes in which the environmental tax revenues are recycled and their consequences for the economy. These studies usually ignore distributive equity and, above all, presuppose a world where exchanges take place without frictions or imperfections. They rather focus on the welfare impact of the increased or reduced tax distortions introduced by an environmental fiscal reform. It is shown that, aside from some special cases, environmental tax swaps in competitive models typically exacerbate the welfare costs of the tax system. This line of study, especially pursued in the US, where markets are relatively more competitive than elsewhere, could be referred to as 'welfare double dividend'.

A second crop of papers on the double dividend issue looks at the impact that recycled fiscal revenues can have on relevant macroeconomic variables, especially employment, output, or growth. The papers in this

[1] Even before the double dividend terminology, Tullock (1967) was perhaps the first one to recognize the potential significance of the revenue from environmental levies. Peerce (1991) first used the term 'double dividend' in this context.

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area are motivated by the persistently high levels of unemployment which have now afflicted Europe for a decade. Because, according to many observers, high labor costs and heavy taxes are among the causes of this situation, the possibility of using the receipts of pollution taxes to reduce labor costs has made the double dividend idea especially appealing to both economists and policy makers. This specific form of double dividend, where both emissions and unemployment are reduced by the fiscal reform, has been especially studied by European economists given the frequent reference to non-competitive labor markets: this hypothesis could thus be termed 'employment double dividend' (see, for instance, Carraro, Galeotti and Gallo, 1996).

Unemployment rates in the three-year period 1997–1999 have been equal to 4.5 per cent in the US and 9.9 per cent in the European Union with, for instance, the UK at 6.3 per cent, the Netherlands at 4.5 per cent, France at 11.8 per cent, Italy at 11.7 per cent and Spain at 18.5 per cent (OECD, 2000). These figures reveal that in the US there does not seem to be much involuntary unemployment. Similarly, labor markets are rather inflexible in continental Europe but not in all the EU countries. It follows that for the US and these European countries the discussion concerning what we call 'welfare' double dividend appears most applicable, not so for the other countries afflicted by high unemployment levels.

The idea of an employment double dividend (EDD hereafter) was originally contained in a proposal for a European plan designed to reduce unemployment (Drèze and Malinvaud, 1994). The plan, also known as Delors' plan, included the suggestion that moving the tax burden away from employment towards undesirable pollution would provide a welcome boost to employment and thus to the tax base of the public sector. In particular, shifting the tax system away from labor toward polluting sources would encourage employers to substitute labor for capital and other inputs, thereby making production more labor intensive at the aggregate level. If, at the same time, the impact on labor supply is negligible, this policy would reduce unemployment.[2] A notable feature of the literature on the EDD is the assumption that markets, especially labor markets, are imperfectly competitive: correctly modeling their function is thus crucial to understand whether or not the employment dividend may be reaped.

This paper aims at providing an updated review of the advances in the study of the double dividend issue. To be sure, the present survey is not the only one to be recently circulated on the double dividend issue: besides the often-quoted article by Goulder (1995), see Oates (1995), Bohm (1997), Ekins (1997), Park and Pezzey (1998), Pezzey and Park (1998), and Bovenberg and Goulder (1999).[3] The present paper, however, distin-

[2] It is interesting to note that in the original proposal, environmental taxation was only one of several measures that were suggested in order to cure the European unemployment problem. It should also be noted that the plan explicitly referred to the European Carbon Tax proposed by the European Commission *(Official Journal of the EC*, 1992).

[3] A survey paper which looks at the macroeconomic effects of environmental taxes, and thus touches upon the double dividend issue, is Ligthart (1998).

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guishes itself in at least three aspects: the emphasis on modeling strategies, an account as complete as possible of very recent empirical work, and the role attributed to market imperfections which we believe is a crucial ingredient of the analysis. Following this, we organize the presentation of the material by distinguishing between studies that analyze the double dividend in terms of welfare (section 2) and studies that focus on the double dividend in terms of employment (section 3). In addition, in each section, we first review a number of very recent theoretical studies and discuss their implications for empirical analyses. We then present the findings of existing empirical investigations and provide an assessment of their reliability and policy implications.

The main goal of the analysis is to identify the relationship between the modeling strategy and the double dividend results. For example, if the objective is an assessment of the employment double dividend, the modeling of the labor market becomes crucial. As we shall see, when the model assumes that wages are determined through a bargaining process involving unions and firms, the resulting effects on the plausibility of an EDD are different from those obtained when it is assumed that wages are determined by search costs or by an efficiency wage mechanism.

The main novel feature of this survey paper is its focus on empirical results and on their relationships with theoretical findings. We explore when empirical models are adequately designed to test theoretical findings and, if this is the case, when empirical results support those findings. One main conclusion of the analysis is that empirical models are still unable to capture all relevant aspects which characterize the double dividend issue and which are necessary to provide a reliable assessment of a proposed fiscal reform. In addition to market imperfections (both in the labor and goods markets), the role of technical progress, equity considerations, alternative ways of recycling the environmental fiscal revenues to the benefit of employment, the existence of segmented labor markets, and the institutional decision process in a federal state are just a few of the topics which empirical models have recently started to analyze and which merit further consideration. A brief discussion of these issues is provided in section 4. Finally, section 5 summarizes the main findings of our analysis and outlines further research directions.

2. Weak and strong 'welfare' double dividends

During the initial phase of the double dividend debate, it was more or less taken for granted that recycling the revenues from environmental taxes was beneficial for society: indeed, along with an improved environment, rates on other distorting existing taxes (particularly taxes on labor and capital) could be reduced. In so doing, the economic costs of the tax system would *necessarily* be lower, economic efficiency higher and possibly the record on some crucial macroeconomic variable improved. At the same time, initial theoretical and empirical work on carbon taxes tended to ignore other distortionary taxes, assuming that the revenues from these taxes would be returned to the economy in a lump-sum fashion.

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Table 1. *Strong and weak double dividend – selected empirical results*

Model	*Country*	*Tax policy*	*Welfare change*	*Pct. change in real GDP (first period)*	*Pct.change in real GNP (twenty-first period)*
DRI	US	Phased in carbon tax (a) compensated through personal tax cut	−0.39 (b)	0.00	−0.76
Goulder	US	25 US$ carbon tax compensated through personal tax cut	−0.536 (c)	−0.60	−0.74
	US	25 US$ carbon tax compensated through lump-sum transfers	−0.712	−0.70	−0.90
Jorgenson–Wilcoxen	US	Phased in carbon tax (a) compensated through capital tax cut	+0.19 (d)	+0.20	+0.95
LINK	US	Phased in carbon tax (a) compensated through personal tax cut	−0.51 (b)	0.00	−0.35
Shah–Larsen	US	10 US$ carbon tax compensated through personal tax cut	−1049 (e)	−0.020 (f)	
	India		−129	−0.060	
	Indonesia		−4	−0.005	
	Japan		−269	−0.008	
	Pakistan		−23	−0.070	
Brinner *et al.*	US	Tax to stabilise CO2 emissions from light-vehicle fleet in 2010, compensated through payroll tax cut		+30 (i)	
Proost–Regemorter	Belgium	10 US$ carbon tax compensated through SSC cut	−1.35 (g)		
		10 US$ carbon tax compensated through lump-sum transfers	−0.60		
Denis–Koopman	EU12	3 US$ carbon tax compensated through labor tax cut	+0.06 (h)		

Notes. (a) Beginning at 15 US$ ton in 1990 (period 1), growing at 5 per cent annually to 39 US$ per ton in 2010 (period 21) and remaining at that level thereafter. (b) Percentage change in the present value of consumption: the model does not allow for utility-base welfare measures. (c) Welfare cost per dollar of tax revenue, as measured by the equivalent variation. (d) Equivalent variation as a percentage of benchmark private wealth. (e) Compensating variation in levels (millions of US$). (f) Percentage change in GDP (not GNP). This is a one-period model. (g) Equivalent variation as a percentage of benchmark total welfare in the case of flexible wages and inequality aversion. This is a two-period model. (h) Welfare measured in terms of percentage of GDP. This is a one-period model. (i) Cumulative discounted real GNP gain per cumulative discounted ton of CO2 reduction in 1982 US$.

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Theoretical aspects

Following Goulder (1995) we can define a 'weak' form of the double dividend according to which it is always preferable to return environmental tax revenues by reducing a distorting tax rather than by returning them in a lump-sum fashion. This weak form is not controversial. What has instead been disputed, following the seminal paper by Bovenberg and de Mooij (1994), is the 'strong' form of the double dividend. The strong double dividend exists if the revenue-neutral substitution of a green tax for typical or representative distortionary taxes produces zero or negative welfare 'gross' costs, that is, costs that do not account for the increase in environmental quality. Unfortunately, once we acknowledge the pre-existing distortions associated with the tax system, we must take full account of the basic linkages between the proposed environmental fiscal reform and existing taxes. The insight provided by the contributions of Bovenberg and co-authors using general equilibrium and optimal taxation theory is that the interaction between environmental levies and existing taxes is the source of additional excess burdens, largely from taxes on labor.

Suppose that capital cannot be taxed (or that it is perfectly mobile) and therefore all taxes are ultimately born by labor. This market is significantly distorted as there is typically a large wedge between the gross wage paid by firms and the net wage received by workers. The size of the deadweight loss in the market depends upon demand and supply elasticities. From here the idea to decrease the deadweight losses, substituting environmental tax revenues for labor taxes revenues inducing the so-called 'revenue recycling effect'. However, there is also a 'tax-interaction effect' due to the impact of different taxes on the after-tax wage. This becomes evident when one considers that a new green tax creates a wedge between the before-and-after tax wage exactly as an income tax, and that workers are likely to respond to real rather than nominal tax wages.[4] If environmental taxes are 'particularly' effective in lowering pollution, they exert a negative effect on their own tax base (tax erosion effect) as agents are strongly induced to lowering demand of polluting inputs. If the government needs to maintain the overall tax revenues, it could thus be unable to sufficiently compensate workers with cuts in the labor tax for the increased environmental tax. This may reduce the real net (after-tax) wage, discourage labor supply, and a strong double dividend may not emerge. In other words, when the tax-interaction effect more than offsets the revenue-recycling effect, labor bears the burden of the pollution tax, with a negative impact on employment. In addition, overall welfare decreases.

The outcome just described is the basic result of Bovenberg and de Mooij (1994), derived within a representative agent general equilibrium model

[4] The primary welfare gain is given by the difference between benefits and partial equilibrium costs of environmental improvement. The revenue effect refers to the welfare gain derived from using environmental taxes to lower distortionary taxes compared with recycling in a lump-sum manner. The tax-interaction effect measures the efficiency losses due to the exacerbation of prior tax distortions caused by a rise in environmental taxes. This decomposition of the welfare effect of a green tax swap is due to Parry (1995).

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with a constant returns technology using one primary input, labor, and two intermediate inputs, one 'clean' and one 'dirty'. Output is used for consumption of a public and a private good, as well as for the demand for clean and dirty inputs. Environmental quality is negatively related to the amount of dirty input used, and household's utility depends upon leisure, environmental quality, and the consumption of private and public goods. Leisure and private consumption are weakly separable from the public good and the environmental quality. The authors consider an initial situation where the only tax is a labor income tax and then introduce a revenue-neutral tax on the consumption of the dirty good whose revenues are used to reduce the labor tax rate. The strong double dividend obtains if the utility derived from the private consumption and leisure aggregate (irrespective, therefore, of environmental quality) is increased by the policy. The basic result is that welfare increases only if the labor supply is backward bending, that is, if the uncompensated wage elasticity of labor supply is negative. Because most empirical studies tend to yield positive values for that elasticity, the double dividend is unlikely to materialize. In addition, by lowering labor income, the environmental fiscal reform has an adverse effect on employment and even a EDD does not obtain.

The bottom line of the basic model is therefore that shifting taxes off labor and on to a polluting input exacerbates the (gross) costs of the tax system. This is basically because there are greater substitution possibilities for avoiding the (narrow-based) input tax than the (broad-based) labor tax. Hence, it is more distortionary. However, when some simplifying assumptions of the Bovenberg and de Mooij (1994) model are relaxed, a double dividend can occur. Among such instances are: (i) when output from the externality-generating sector is a relatively weak substitute for leisure (e.g. cigarettes, national parks, pollutants used in the agricultural sector); (ii) when reducing externalities causes a positive feedback on labor supply (e.g. reducing traffic congestion associated with people commuting to work reduces the time costs of going to work); (iii) when the tax system contains significant tax deductions (e.g. for owner-occupied housing and medical care in the US)(see Parry and Bento, 2000).[5]

How general are the results just mentioned? In a series of subsequent papers, the basic model has been generalized and extended. In particular, the results of the double dividend analysis, with special attention to employment, are summarized in two survey articles by Bovenberg (1997, 1998). The author notes that, in general, two conditions must be met for a green tax reform to benefit employment by reducing the tax burden on labor.[6] First, the 'overall' burden of taxation on private incomes must be contained. Second, the tax burden must be shifted from workers to other

[5] We thank a referee for pointing out these aspects.

[6] A lower tax burden on labor generally raises the income from work to the employee and reduces labor costs for the employer. The incidence of the tax cut, i.e. whether the lower tax burden is reflected primarily in lower wage costs per unit of output or higher after-tax wages, depends on supply and demand elasticities and on various labor market institutions. The next section addresses this aspect.

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groups, such as the owners of capital, the owners of resources, and the recipients of income transfers (if the government engages in income redistribution). As for the 'tax burden effect', notwithstanding the recycling of revenue, the overall burden of taxation on private incomes is increased by pollution taxes. The reason is that green taxes reduce the 'subsidies' provided to the private sector in the form of underpriced pollution. As for the 'tax shifting effect', once we acknowledge that labor is not the only production factor, which inputs bear, the tax incidence depends on both the production structure and the supply elasticities of the various inputs. If all non-labor inputs (such as capital and energy) are fully mobile internationally, they will avoid new taxes by moving abroad, leaving labor to bear the entire tax burden. More generally, this will be the case for all those inputs which, in a small open economy, cannot be moved abroad cost free (Bovenberg and van der Ploeg, 1994). Over the short term, an example is given by fixed capital. Hence the owners of both human and physical capital will bear the brunt of tax incidence.[7] Here the structure of the technology becomes relevant: with a tax on energy, capital will bear part of the tax burden if it is a poor substitute for energy in comparison to labor (Bovenberg and van der Ploeg, 1998). Indeed, several econometric studies have revealed a pattern of complementarity between those two inputs. Moreover, empirical evidence suggests that unskilled labor tends to be a good substitute for energy and capital. Thus, the tax burden will tend to be relatively heavier for this category of worker, whose unemployment rate in Europe is already fairly high.

The results considered above show that for the emergence of a double dividend, and in particular for a green tax reform to benefit employment, a crucial role is played by two types of elasticities: price elasticities of labor supply (and demand) and substitution elasticities in production between labor, energy, and capital inputs. It should therefore be clear how important the contribution of empirical models is to the double dividend debate, as only applied work can attribute a quantitative dimension to those crucial indicators. Still, a public economist would remind us that looking at whether environmental tax swaps increase employment or not tells us nothing about social welfare. To be sure, employment effects are

[7] However, in the face of international capital mobility, taxing capital on a sustainable basis is likely to require international coordination on a global level (Bovenberg, 1995; Bovenberg and de Mooij, 1996). Moreover, capital taxes distort the intertemporal margin, i.e. the margin between consuming today and consuming in the future (by saving), and the larger the intertemporal substitution elasticity in consumption, the greater this distorsion will be (Goulder, 1995). On the other hand, the option of shifting the tax burden onto the recipients of income tranfers raises important distributional issues. In general, a negative dividend in terms of a less equitable tax system emerges. A final option could be to shift the tax burden on to foreigners by reducing world-market prices of energy fuels. In fact, in open economies welfare can also be affected by another economic dimension, changes in the terms of trade. However, even this case can be considered unlikely, unless the environmental tax reform is adopted in a large number of countries with substantial market power in world markets.

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important, but an increase in employment is not sufficient to guarantee an overall improvement in social welfare.

Empirical evidence

To our knowledge the only empirical study which provides results in favor of the strong form of the double dividend from the implementation of carbon/energy taxes is that of Denis and Koopman (1995).[8] The authors use a partial equilibrium model which analyses the demand for five energy products used by households and industry sectors. Different sectors are considered and employment is determined as a function of real after-tax wages. The authors show that the introduction of a \$3 CO_2 energy tax, the revenues from which are redistributed back into the economy by the means of reduced marginal labor taxes of all workers, would reduce emissions by 1.26 per cent and increase employment by 0.2 per cent in the long term. Moreover, welfare increases (by 0.06 per cent of GDP), even without taking the environmental benefit into account. The positive result obtained by Denis and Koopman (1995) is probably due to adoption of a partial equilibrium approach, which leaves out a number of potentially important macroeconomic feedbacks. Furthermore, only long-term equilibrium effects are analyzed, while changes in employment are evaluated through changes in labor supply only, and no conclusion can be drawn in terms of unemployment trends.

Most empirical investigations, however, provide evidence against the double dividend in its strong form. Probably the most complete empirical analysis is that of Goulder (1995). The same scenario (an environmental tax starting form \$15/ton CO_2 and reaching \$38/ton CO_2 introduced over the period 1990–2010 and neutrally compensated for by a reduction in income taxes) is considered for four different models: the DRI and LINK macroeconometric models for the US, the Jorgenson–Wilcoxen econometric general equilibrium model for the US, and the Shah-Larsen partial equilibrium model applied to five countries including the U.S.. Welfare improvements, disregarding the environmental quality gain, are measured by means of the Hicksian equivalent variation in the Jorgenson–Wilcoxen model, the compensated variation in the Shah–Larsen model, and in terms of the variation in utility from consumption in the remaining two models.

In all cases, with the exception of the Jorgenson–Wilcoxen model, the green tax reform is welfare diminishing, entailing positive gross costs. As far as the fiscal reform implemented in the Jorgenson–Wilcoxen model is concerned, consisting of an energy tax compensated for with a lower capital tax, a possible explanation of the different outcome can be traced to the higher estimated elasticities of capital supply and demand, resulting in a higher marginal excess burden of capital taxation. As this is lowered, welfare is strongly improved.

Evidence against the strong double dividend hypothesis has also been provided using a general equilibrium model for the US economy built by Goulder (1992) (see also Bovenberg and Goulder, 1996; Parry, Williams,

[8] See, however, also the evidence from the Jorgenson–Wilcoxen model reported in Goulder (1995) and mentioned below.

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and Goulder, 1998). This model is particularly interesting as it provides a detailed description of the energy sector, taking into account resource exhaustibility and back-stop technologies. Moreover, the impact of fiscal changes on firms' investment decisions, bonds value, and profits and on household demand and labor supply as well as on consumption patterns are carefully designed. The model's simulations show that a $25/ton carbon tax applied unilaterally in the US between 1990 and 2050, even if compensated for with cuts in different distortionary taxes (corporate taxes, personal taxes, payroll taxes), always generates positive gross costs: welfare is reduced by 0.48 per cent in the case of a corporate tax cut and by 0.53 per cent in the case of a cut in personal taxes.[9]

A few other quantitative studies should be mentioned. Parry (1995) demonstrates the unfeasibility of the 'strong' double dividend by deriving an analytical expression which accounts for all the positive and negative distortionary effects of a pollution tax. He emphasizes that, when plausible values are attributed to the parameters involved, the gains from using pollution tax revenues to substitute for labor tax revenues tends to be more than offset by the cost of exacerbating the pre-existing distortion in the labor market. Schöb (1996) uses commodity taxation as a revenue-returning instrument and shows that the environmental dividend depends on the complementarity/substitutability relationship between the polluting good and the revenue-returning instrument chosen. The author uses estimates (produced by others) of an almost ideal demand system for a representative household in the UK and finds that the strong form of the double dividend fails. Scholz (1997) analyzes the empirical case for the double dividend using the indirect tax reform model of Ahmad and Stern (1984) extended to consider environmental externalities. The key parameters involved are the marginal cost of public funds and the environmental benefits, both estimated on the basis of an almost ideal demand system. The analysis, conducted for Germany, highlights the high distortionary impact of energy taxation and demonstrates the impossibility of compensating for the increased marginal cost of public funds with cuts in other taxes, especially taxes on labor income. Furthermore, the analysis shows that the welfare loss due to this effect is higher than the increased welfare due to the improved environment. A double dividend could only be obtained by increasing various taxes (on cosmetics and health, educational and cultural goods) and compensating for them by cutting taxation on personal goods, (clothing, transportation and communication).

As a final note, very few studies consider the weak double dividend from an empirical perspective. Goulder (1992) also studies the double dividend in its weak form and provides empirical evidence in its favor. Environmental taxes, even if compensated for, are costly because they are more distortionary than the taxes they are intended to replace; but com-

[9] A recent study for the US case on the welfare effects of various tax substitution schemes is carried out by Boyd, Krutilla, and Lightart (1998), in which a newly developed dynamic computable general equilibrium model is used for the purpose.

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pensating for a green tax with cuts in distortionary taxation (Goulder considers cuts in personal income taxes, in corporate income taxes, and in payroll taxes) is in any case less costly than compensating for it via lump-sum transfers. When lump-sum transfers are involved, Goulder (1992) finds an increased welfare loss, which is about 35 per cent higher than in the case of cut in other taxes. Using the same model, Bovenberg and Goulder (1996) find that marginal welfare costs would be two to three times larger for a zero revenue (lump-sum replacement) carbon tax than for a tax-reducing (personal income tax replacement) carbon tax (see also Goulder, Parry, and Burtraw, 1997).

The above findings are generally confirmed by the empirical literature, although they may not hold in all cases. Proost and van Regemorter (1995), for instance, show that if wages are flexible and the utility function of households is weighted with a factor representing the preference for an equitable income distribution, an increase in lump-sum transfers to compensate agents for higher carbon taxes is less costly than a reduction in social security contributions. The reason is that higher energy taxes are paid more or less proportionally to income, whereas welfare payments are concentrated in the lowest income groups; in addition, flexible wages help to reduce the distortions in the labor market. By contrast, the weak double dividend holds if wage rates are instead fixed, in which case the distortions in the labor market arising from excessive wage rates ensure that a cut in social security contributions and in labor costs is welfare improving. The study also confirms previous findings regarding the strong double dividend: an environmental tax reform can only produce net benefits if the environmental improvement is taken into account. The authors use a dynamic perfect foresight computable general equilibrium model for an open economy which considers two periods and is solved as a Negishi welfare optimum for four types of agents: households, firms, government and Rest of the World. To account for equity preferences, households are divided in four homogeneous groups of consumers. The equity issue is a very important one, and we shall return to it in the last section.

In general, it must be noted that, even if there is not a strong double dividend, if the net impact of an environmental tax swap is to reduce the efficiency costs of the tax system, this would still offset a large portion of the 'partial equilibrium' costs of the policy and greatly enhance the overall welfare gain.

The papers reviewed so far are based on models which assume an economy where, in the absence of any taxes, environmental externalities, or the need for public funds, an efficient allocation would be reached. Disregarding environmental effects, all inefficiencies are those created by the tax system itself. In fact, there are other types of inefficiencies that have to be dealt with by the tax system. These are prominent in the EDD literature to which we now turn.

3. The 'employment' double dividend

As we have noted in the previous section, if we adopt a social welfare perspective, looking at whether environmental tax swaps increase employment or not tells us nothing about changes in social welfare. The

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Table 2. *Employment double dividend — selected empirical results*

Model	*Labor market features*	*Tax policy*	*Tax value*	*Employment (short-term)*	*Employment (long-term)*	*CO2 emissions (long-term)*
Denis–Koopman	Analysed as demand for labor input.	Cut in marginal labor taxes of all workers financed through a CO2/energy tax	10 US$ boe		+0.71%	−4.19%
QUEST	Imperfectly competitive: wages adjusting according to the augmented Philips curve mechanism.	1% of GDP cut in SSC neutrally financed by a CO2/energy tax	10 US$ boe	+0.3% (first year)	+1% (seventh year)	
	Segmented labor force, but with substitution elasticities between high and low skilled workers exogenously given.	1% of GDP cut in low skilled SSC neutrally financed by a CO2/energy tax	10 US$ boe	+0.8% (first year)	+3% (seventh year)	
HERMES	Imperfectly competitive: wages adjusting according to the augmented Philips curve mechanism.	Cut in SSC neutrally financed by a CO2/energy tax growing from 0.3% of GDP in 1993 to 1% in 2001	From 3 to 10 US$ boe	+0.04 (first year)	+0.64% (ninth year)	−4.4% (ninth year)
GEM-E3	Perfectly competitive.	Energy tax to accomplish a 10% cut in CO2 emissions in 10 years, neutrally recycled through cut in SSC	22.01 ECU/ton. CO2		+0.54% (tenth year)	−10% (tenth year)
	Rigid wage rates.				+0.97% (tenth year)	−10% (tenth year)
	Wages adjusting according to lagged labor productivity.				+1% (tenth year)	−10% (tenth year)

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Kemfert–Welsh	Adjusting according to the augmented Philips curve mechanism. Substitution elasticities among inputs estimated.	Carbon tax to stabilize CO2 emissions at 1990 level by 2020 recycled through lump-sum transfers	From 2.56 to33.53 ECU/ton. CO2	−0.12% (fifth year)	−0.10% (twentieth year)	−24.25% (twentieth year)
		Carbon tax to stabilize CO2 emissions at 1990 level by 2020 recycled through wages subsidies	From 2.80 to 38.38 ECU/ton. CO2	+2.36% (fifth year)	+3.94% (twentieth year)	−24.25% (twentieth year)
E3ME	Imperfectly competitive: unionized (wage outcome of a bargaining process).	Multilateral EU coordinated excise duty recycled through cuts in SSC	16 US$ boe		+1.23% (eleventh year)	−10% (eleventh year)
WARM	Imperfectly competitive: unionized (wages outcome of bargaining process) and segmented in high and low skilled workers.	Uniform CO2/energy tax neutrally recycled trough cut in SSC and redistribution of revenues among EU countries	10 ECU toe	+2% (fifth year)	+1.3% (thirty fifth year)	+2.4% (thirty fifth year) −0.1% (fifth year)
		Uniform CO2/energy tax neutrally recycled trough cut in low skilled SSC and redistribution of revenues among EU countries	10 ECU toe	+1.1% (fifth year)	+0.3% (thirty fifth year)	+0.1% (thirty fifth year) −0.8% (fifth year)

point is that an increase in employment is not sufficient to guarantee an overall improvement in social welfare. However, as stated in the introduction, because unemployment is perceived and indeed is an acute social and economic problem, especially in continental Europe, focusing on the employment impact of environmental fiscal reforms has been the subject of several contributions in the literature.

An assumption implicitly or explicitly maintained by all models considered so far is that all markets clear, and that the labor market in particular is perfectly competitive. However, when there is significant involuntary unemployment, as in Europe today, labor supply elasticities have little relevance for employment. Those models are therefore not especially suited for predicting the employment effects of an ecological tax reform. There, all unemployment is voluntary and, therefore, given the real wage, labor supply determines employment. As soon as we allow for involuntary unemployment, employment is determined by labor demand, which is, given the real wage, lower than labor supply. In this case, the negative output effect of a green tax and the substitution effect away from energy and capital toward labor work in opposite directions: if the substitution effect prevails, employment increases.[10] These remarks therefore show that, in order to study the impact of an environmental fiscal reform on employment, it is essential to modify and extend the theoretical models in the more realistic direction of imperfectly competitive goods, with particular regard to the labor market.

However, although there is only one way of modeling perfectly competitive markets, there are many ways of modeling imperfect markets. As far as labor markets are concerned, imperfections can be modeled through the addition of unions, which bargain with firms about wages. Alternatively, search costs or efficiency wages can be used to model wage rigidity and labor market disequilibrium. As shown below, these different modeling strategies lead to different results and crucially affect conclusions about the possible emergence of an employment double dividend.

Theoretical aspects

Bovenberg and van der Ploeg (1993, 1998) allow for unemployment in the labor market wage by introducing rigidities in the basic model. Wages are fixed, but their rigidity is not endogenized or explained in the model. The results are no more encouraging than those discussed in section 2.1. Indeed, the introduction of a fixed real consumer wage above the market-clearing level does not modify the basic result: a revenue-neutral environmental tax reduces labor productivity and shifts the labor demand schedule leftward. In the model (where production is realized using resources, labor, and a fixed factor), the introduction of a green tax reform whose revenues are used to cut the labor tax will only raise employment and the non-environmental component of welfare if substitution between labor and resources is easy and if the production share of the fixed factor

[10] As illustrated in section 3.2.3, the contribution by Welsch (1996) is an exception in this respect.

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is large. A further result derived by Carraro and Soubeyran (1996a) and Bovenberg (1997, 1998) is that, if the initial tax system is sub-optimal from a non-environmental point of view, then a fiscal reform can reduce both pollution and unemployment (unless the tax-interaction effect, which exacerbates tax distortions, prevails). Nonetheless, it must be recognized that in this case the need for a fiscal reform is independent of environmental concerns. Note that the model used by Carraro and Soubeyran (1996a) assumes that all prices, not only the wage rate, are fixed. Hence, markets clear through quantity adjustments rather than through price changes.

While allowing for imperfect labor markets, one limitation of the above analysis is that the wage rate is given exogenously. This assumption misses an important feature of modern industrial economies. Only recently have the first attempts been made to consider green tax reforms within models which allow for unemployment in equilibrium and for endogenous wage setting.

In some recent papers, the wage rate is the outcome of a bargaining process between a trade union and an employer organization. In 'right-to-manage' models, unions and employers play a cooperative game over wages, and firms then choose the profit-maximizing level of employment. This is an appropriate framework for studying the EDD issue in Europe because in most European countries, over three-quarters of the workforce earn wages that are covered by collective bargaining.

Brunello (1996) and Carraro, Galeotti, and Gallo (1996) appear to have been the first authors to introduce the role of unions and wage bargaining into a general equilibrium model used to study the EDD. The equilibrium wage rate is obtained as the solution of the maximization of a Nash objective subject to the labor demand function (as in, for example, Creedy and McDonald, 1991). The union's utility function is the product of overall employment multiplied by the individual earnings of employees in the unionized sector. These earnings are expressed relative to an alternative wage, which is derived from a weighted average of earnings when unemployed (i.e. unemployment benefits) and earnings from being employed elsewhere in the economy (Layard, Nickell, and Jackman, 1991). The solution of the maximization problem yields an equation in which the ratio between gross wage and profits per capita increases as the union's bargaining power increases, and decreases as the unemployment rate, the wage elasticity of labor demand and the weighting of employment relative to earnings in the utility function of the union increase. Using this model, Brunello (1996) analyses the EDD issue from a theoretical viewpoint. The main result is that in the long term, unions succeed in transferring the reduction in gross wages introduced through the fiscal reform into an increase in net wages (which are the outcome of the bargaining process). Hence, labor demand does not increase and the double dividend is lost. Even the environmental dividend may disappear if the revenue effect of the net wage increase is sufficiently large. In the short term, the double dividend may appear, depending on the so-called wage-resistance and on revenue effects. However, this becomes an empirical issue that will be analyzed below.

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A very similar framework is adopted by Koskela and Schöb (1999).[11] This is used by the authors to derive a number of analytical results within a detailed examination of the various institutional arrangements existing in the EU fifteen member states regarding the taxation of unemployment benefits, types of tax exemption, and the price indexing of unemployment benefits and tax exemptions. The analysis uses a right-to-manage model in which the solution of an asymmetric Nash bargaining problem is given by the nominal wage as a function of income tax, the personal tax allowance, the rate of green tax on the consumption of a dirty good, and the size of unemployment benefits. Koskela and Schöb (1999) then use the government budget constraint to investigate the impact of a revenue-neutral green tax reform on equilibrium employment, carried out through either a cut in labor income taxes or an increase in personal tax allowances. They show that the qualitative results are sensitive to the institutional arrangements regarding the taxation and indexing of unemployment benefits and the personal tax allowance. In particular, a revenue-neutral green tax reform will boost employment if unemployment benefits are nominally fixed and taxed at a lower rate then labor income; if, on the other hand, they are price indexed, employment will fall as a higher consumer price level increases nominal wages.[12]

While interesting because they highlight the importance of labor market institutions for the EDD issue, the results of Koskela and Schöb (1999) are not so general as it would be desirable. For instance, labor is the only production factor. This last limitation is overcome in Koskela, Schöb, and Sinn (1998): while the former paper considers a model with consumption externalities, a single production factor, and exogenous goods prices, in the latter contribution green tax reforms are studied with production externalities, two factors of production, and monopolistic firms. The main focus is again on the impact the revenue-recycling effect has on the wage negotiations and employment.

A similar model of wage bargaining in the labor market is also a key feature of a recent contribution by Marsiliani and Renström (1997), who incorporate the endogenous wage determination process in a general equilibrium model.[13] This is then used to assess the impact of a revenue-neutral

[11] One difference with respect to Brunello (1996) and Carraro, Galeotti, and Gallo (1996) is the specification of the union's utility function which depends linearly upon the earnings of its members, when they are both employed and unemployed. It would be interesting to verify the robustness of results to different specifications of the union's utility, both theoretically and empirically.

[12] In addition, if the revenues from pollution taxes are recycled through an increase in personal tax allowances, employment is increased more than through a reduction in income taxes.

[13] In the model, the endogenously determined net wage is taken as given by firms which then choose the profit-maximizing level of employment, along with capital stock (which is predetermined) and energy. Energy is the polluting input and firms are subject to an energy tax (there are no payroll taxes in the model). Households derive utility from consumption of individual commodities and from energy, which is taxed. Utility is additively separable from the externality. If employed, households are also subject to a tax on labor income, while they are

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environmental fiscal reform (see also Marsiliani, 1999). The main finding of the study is that, provided the labor tax is Laffer efficient (that is, an increase in the tax rate leads to an increase in tax revenues), the green tax reform yields an increase in employment, thereby generating an EDD. The less competitive the goods market and the stronger the unions, the greater the magnitude of the changes in employment after the reform.[14] In addition, the same green reforms lead to a reduction in energy use and an increase in welfare, even without counting the gain from reducing the externality.

Two recent papers by Strand (1998, 1999) also belong to the above crop of contributions. They deal respectively with monopolistic union wage setting and individual worker–firm wage bargaining, under the assumption that firms must commit to an environmental technology before wages are set. In the individual bargaining case (with free entry of firms) it is shown that higher environmental taxes (starting from the Pigouvian level) used for subsidizing firm establishment or investment can create a double dividend. In the monopolistic union case (with no entry) a double dividend may arise when firms' investments are relatively insensitive to increases in pollution taxes.

The studies described above seem to show that, once we allow for imperfectly competitive labor markets, the likelihood of an EDD increases.[15] It is nevertheless important to bear in mind that unions represent quantitatively a smaller distortion relative to taxes in the labor market. Thus, the impact of union is likely to dampen, not completely eliminate, the revenue recycling and tax interaction effects that arise in competitive labor market models. Ultimately, this is again an empirical question that depends, besides the model assumption, upon the magnitude of the relative tax changes.

Models of wage bargaining are not the only explanation of involuntary unemployment current in the literature. The EDD issue has been investigated in other theoretical models of labor market imperfections, such as search costs or efficiency-wage models.[16]

In Bovenberg and van der Ploeg (1995) (see also Bovenberg, 1997), for

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entitled to benefits if unemployed. A third group of households have a stake in the firms and their income consists of profits. Finally, the government finances public spending and unemployment benefits through labor and energy tax revenues.

[14] Note that this is true also in Koskela, Schöb, and Sinn (1998) with respect to union power if the technology is Cobb–Douglas. Otherwise the result depends upon the value of the substitution elasticity between labor and energy. The model concerns the short run (capital is predetermined), the technology is CES, and the goods market is perfectly competitive.

[15] Another alternative is pursued in Nielsen, Pedersen, and Sørensen (1995) in the context of an endogenous growth model. In their paper the inefficiency of the labor market is due to monopoly union power, all workers work the same hours (worksharing) and production externalities are present. In their model, however, marginal tax revenues from green taxes are always zero. Employment effects only result from changes in the provision of public goods and not because additional tax revenues are used to cut labor taxes.

[16] Needless to say, whether or not these theoretical models, and which one, are supported by the empirical evidence is another matter. Clearly, the policy implications in terms of EDD hinge upon that fact.

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instance, unemployment is the result of hiring and search costs. Workers can be employed in the formal and informal sectors. The overall effect of a green tax reform on employment depends upon the relative strength of the tax burden and tax-shifting effects.[17] Even if the former is large (although it will typically be lower than in the case of fixed consumer wages), employment may rise if workers accept a large drop in their disposable income. An environmental tax reform succeeds in moderating wages if it makes work in the formal sector more attractive compared to being unemployed.[18]

Further investigation of the EDD issue has been conducted in yet another theoretical framework for explaining involuntary unemployment. The model by Schneider (1997) is an efficiency-wage model with endogenous effort. Here firms, not workers, set wages that are too high for the labor market to clear.[19] Whenever the outside opportunities of workers worsen, cost-minimizing efficiency wages can be reduced. Thus, an increasing rate of unemployment lowers wages, resulting in an inverse relationship between unemployment and wages. The author shows that environmental policy can in fact generate a second employment dividend: workers who are already employed benefit from higher after-tax income and labor costs are reduced. However, employment might actually fall if workers respond to lower unemployment by strongly reducing effort. This will be the case when unemployment rates are low. Moreover, if the tax on labor is high initially, a reduction in the tax rate is more likely to lower the unemployment rate. The model here is quite stylized, in that it lacks a goods market, a role for consumption by households, and an analysis of the substitution responses of inputs to the environmental reform.[20] In par-

[17] The model is a variant of the basic general equilibrium model used by the authors in previous work. In particular, the only non-labor income, capital, is perfectly mobile internationally. It can thus escape the tax burden by moving abroad. The tax burden, however, can be shifted to transfer recipients who, in the model, are those not employed in the formal sector and collecting unemployment benefits.

[18] Even when a distinction between formal and informal sectors is not made, the presence of non-labor income (such as unemployment benefits, capital and profit rents, lump-sum transfers) makes the base of the environmental tax (which must be paid also by earners of non-labor income) larger relative to the base of the labor tax and consequently works in favor of an EDD. In this case, as already noted (Bovenberg, 1997, 1998; Koskela and Schöb, 1999), the reform shifts the burden of taxation towards the recipients of non-labor income.

[19] The production technology in the model is linearly homogenous in effort-augmented labor and emissions, which are the only inputs. Perfect competition across firms ensures zero profits, while the government provides a public good financed by wage taxes and revenues from emission permits. Emissions and public good are exogenous.

[20] Strand (1996) also uses an efficiency-wage model with shirking and the special assumption that workers use effort both to increase output and to reduce firms' pollution. An effort enforcement problem leads to wages above the market-clearing level. The author considers two cases: one in which total work effort is constant, and one in which only productive effort is constant. He shows that an EDD may occur in all cases investigated but is more likely with constant total effort, and less likely with constant productive effort.

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ticular, this last aspect seems important in the light of the so-called 'tax shifting effect' discussed in the previous section. The efficiency-wage model has received mixed support in empirical work: the evidence from econometric studies (Campbell, 1993; Ackum Agell, 1994) and from interviews (Agell and Lundborg, 1995) appears to be inconclusive.

In contrast to the reassuring results described above, the alarm is sounded by Bayindir-Upmann and Raith (1997), who argue that, while the EDD debate is centered upon the effects on employment, a revenue-neutral green tax reform may lead to the loss of the first dividend, that of a better-quality environment. The authors use a right-to-manage bargaining model of the labor market embedded within a simple general equilibrium model to show that an environmental fiscal reform may backfire: employment increases but aggregate pollution is intensified.[21] An increase in the pollution tax does indeed cause households to substitute dirty with clean consumption and this, *ceteris paribus*, will lead to improved environmental quality. However, the basic reason for the adverse result is that reduced labor taxes increase employment and overall incomes. This is likely to lead to higher aggregate dirty consumption and the disappearance of the environmental dividend. This will happen under the plausible conditions of a large expenditure share of dirty consumption and a high distortionary tax rate on income. The implications of the authors' results are relevant: a rise in employment has undesirable consequences for the environment. While successful per se, a green tax reform implemented under revenue neutrality results in a trade-off between environmental quality and employment. This conclusion corresponds to the informal intuition according to which stronger growth leads to an increase in emissions: this effect may or may not be completely offset by the reduction induced by the (revenue-neutral) green tax.[22] While, in our opinion, this is another case that calls for empirical investigation, it would be interesting to see how robust this result is to changes in the theoretical general equilibrium model and the labor market structure.

We conclude this theoretical section by observing that, while it is true that high rates of unemployment plague many European countries, imperfect competition in goods markets is a typical feature of all industrialized countries. According to a recent study by the OECD (Oliveira Martins,

[21] The representative household's utility function is additively separable into two aggregates: a combination of public good and environmental quality, and a combination of leisure and consumption good. This consumption good in turn is a linearly homogeneous function of both clean and dirty goods. Households' income is allocated between these two goods, whose prices differ because there is a tax on the dirty good. Production is carried out by competitive firms who use a single input, labor, to produce with constant returns a single type of output, taking the form of clean, dirty, and public goods. The public good consumption is financed by the revenues of the environmental levy and the tax on labor. Unemployed households receive no income.

[22] Further theoretical work on the possible incompatibility between environmental and employment dividends in high-tax countries is conducted by Bayindir-Upmann and Raith (1998). In their empirical investigation Carraro, Galeotti, and Gallo (1996) find evidence of this trade-off, at least in the long term.

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Scarpetta, and Pilat, 1996), for instance, the average price mark-up over marginal cost in total manufacturing (for the period 1970–1992) is equal to 15.2 per cent in the US, 15.3 per cent in the UK, 17.3 per cent in France, 17.4 per cent in Italy, and 20.8 per cent in Germany. It must be said that nearly all the models of the contributions reviewed so far assume perfectly competitive goods markets.[23] There are only a few exceptions. Besides the extreme assumption of fixed prices and wages maintained by Carraro and Soubeyran (1996a), Carraro and Galeotti (1996) are perhaps the first to assume that all firms in their model are price makers which apply a price mark-up over marginal costs. For simplicity, given the empirical nature of the model, mark-ups are assumed to be constant but goods-specific (firms discriminate prices in markets).[24] The other paper which assumes imperfectly competitive goods markets is the contribution of Marsiliani and Renström (1997) referred to above. In their models, firms are monopolistic and face constant elasticity demand functions for the goods they produce. Within the context of EDD analysis, the authors show that the less competitive the goods market and the stronger the unions, the greater the likelihood of the employment dividend and the stronger the increase in welfare. These theoretical results do not appear to square well with intuition, nor with the empirical analysis of Carraro, Galeotti, and Gallo (1996), who find that, *ceteris paribus*, the stronger the unions, the lower the tax benefit for firms' labor costs: this may not lead to an increase in labor demand and the employment double dividend may disappear or not materialize at all (the authors' results are however also driven by R&D investments). Clearly, further analysis, especially of an empirical sort, is also needed for these aspects. It is therefore to surveying empirical investigations of the EDD issue that we now turn.

Empirical evidence

The existing empirical evidence is based on the use of top–down models, which are clearly the most appropriate quantitative tools for EDD analysis compared to the available alternatives, such as bottom–up modeling. However, even within the top–down family, there are several different approaches to the modeling of energy–economy interactions. Partial equilibrium models are often characterized by accurate representation of production technologies and of the energy sector of the economy, but are extremely restrictive as far as interactions between the energy sector and the rest of the economy are concerned. Macroeconometric models belong to the neo-keynesian tradition of demand-driven growth, underutilization of production capacity, and of market-based modeling philosophy. Applied general equilibrium models, on the contrary, share the theoretical

[23] Clearly, no market is perfectly competitive. The important issue is how large the distortions induced by imperfect competition are: see, for instance, Oates and Strassmann (1984) who find little effect of imperfectly competitive product markets on optimal environmental policies.

[24] The model builds upon the partial equilibrium analysis by Carraro and Soubeyran (1996b) of the effects of environmental taxes on output and profits in an oligopolistic industry composed of n asymmetric firms.

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assumption of a Walrasian representation of the economic system, allowing for a high degree of sectoral disaggregation, and usually featuring perfectly competitive markets. Finally, there is a more recent group of econometric general equilibrium models, which also provide an agent-based representation of the economy, but devote particular attention to the modeling of market imperfections and technological change. Hereafter we review the EDD evidence, using this model taxonomy.

Partial equilibrium analysis

Some tests of the EDD hypothesis have been carried out using a partial equilibrium model focused on the production side of the economy and aimed at a specific identification of the factor substitution possibilities. The study by Kuper (1996) is representative of this kind of analysis. It examines the feasibility of an EDD in the Netherlands using a dynamic investment model based on a putty-clay vintage production structure with three inputs: labor, capital, and energy. The experiment is interesting as the putty-clay hypothesis is one way of endogenizing technical progress through capital embodiment: as prices change in response to either energy taxes or the reduced cost of labor, production is free to adopt a new capital vintage which is more labor intensive and less energy and pollution intensive. The study shows that as labor costs are reduced, labor demand, employment, energy use, and thus pollution increase. To cut the resulting increase in pollution, energy taxes have to be raised to such a level that economic activity and employment become negative despite factor substitution.

The model neglects any general equilibrium analysis and so denies, among other aspects, the possible shift of demand toward less-polluting goods and sectors. Moreover, it does not include government outlays and receipts, which should also be considered in order to test the EDD hypothesis. Nevertheless, this study is interesting because it shows that substitution between capital and energy is somewhat higher than the substitution between the capital-energy bundle and labor, thus emphasizing the importance of a precise assessment of the elasticities of substitution and of technical change for a reliable DD analysis.

Another partial equilibrium approach characterizes the previously mentioned model of Denis and Koopman (1995). As said, it is focused on demand and looks only at the direct effect of taxes on the energy and labor markets. This simplification allows a detailed representation of the energy market. Within the limitations of this model discussed already, the empirical results obtained with this model provide support for the EDD.

Macroeconometric models

QUEST (EC, 1991, 1994; Majocchi, 1996) is one of the first models specifically designed to assess the feasibility of an EDD. It shows that a cut in payroll taxes of about 1 per cent of GDP, financed by a revenue-neutral increase in carbon-energy taxes, can produce positive effects on consumption and employment. Consumption prices increase slightly in the short term, as firms benefit totally from the cut in labor taxes whereas they pay

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just part of the environmental tax. This increases investment (+0.5 per cent), employment (+0.4 per cent) and decreases unemployment (−0.3 per cent). Emissions are reduced on average by 4 per cent.

An interesting result of QUEST is that the EDD grows stronger with the passing of time. Redistribution of the tax revenue through lower social security contributions directly reduces costs and enhances price competitiveness. Inflation is reduced and aggregate demand is restored (by −0.7 per cent and +1.3 per cent respectively in the last year of the simulation). This is due to the specific neo-Keynesian nature of QUEST, in which delays in the adjustments of economic variables to price shocks are explicitly modeled. Crucial to the positive effect on employment is the fact that the substitution process in favor of labor goes on for a considerable amount of time because the replacement of old vintages of capital with new more labor intensive ones depends on the sluggish turnover of capital. It is worth noting that labor supply in QUEST is exogenous. This model cannot therefore take into account two relevant mechanisms operating in the labor market: on the one hand, wages cannot increase in response to a reduction in the labor supply; on the other, it is impossible to assess the extent to which higher wages might worsen involuntary unemployment by boosting the labor supply.

Finally, QUEST has also been used to test the effectiveness of alternative policies of tax shifting: the options considered are cuts in social security contributions alternatively financed by increased personal income taxes or by increased VAT rates. Here the results show that, as far as employment is concerned, a cut in social security contributions financed by an increase in energy taxes is the preferable policy.

A major criticism of the QUEST model is that energy does not appear as an input in its production function. Moreover technical progress is completely exogenous. This implies that QUEST cannot provide reliable estimates of the substitution possibilities between labor, capital, and energy, which are essential to evaluate not only the impact on employment, but also on the first dividend, i.e. environmental quality.

Conclusions reached using the HERMES model (Capros and Karadeloglou, 1992; Majocchi, 1996) are in line with the above results. In HERMES, technical progress is still exogenous, but in contrast to QUEST, energy enters the production function along with labor, capital, and an intermediate input. In a study prepared for the European Commission (Bureau du Plan-Erasme, 1993), which covers six European Countries (France, UK, Belgium, Italy, Netherlands, and Germany), a cut in social security contributions neutrally financed by the revenues of increased energy taxes proves effective in fostering employment in all countries. This increase is spread over the simulation period, reflecting the gradual implementation of the energy tax, the revenue from which grows from 0.3 per cent of GDP for the six countries in 1993 to 1 per cent of GDP in 2001. Employment consequently increases from 0.04 per cent in 1993 to 0.64 per cent in 2001, ranging from 0.3 per cent in the Netherlands to 0.9 per cent in Belgium.

The HERMES model can also provide a sectoral analysis of the impact of green taxes on employment, in that it comprises seven sectors (energy;

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three types of industry, respectively producing intermediate, consumption, and investment goods; building; transport; services). The projected cut in social security contributions is proportional for all sectors and amounts on average to 12 per cent for the six countries. It is more favorable for the most labor-intensive sectors and for those where social security contributions are highest. The energy tax is particularly penalizing for the energy sector. The results are explained by two basic mechanisms: a positive effect on employment due to the wage/price tax which encourages substitution of labor for the energy/capital input, and a negative effect exerted by higher energy prices on income, on capital accumulation, and thus on aggregate demand. The gradual implementation of the environmental policy guarantees that the first effect overcomes the second. The positive expansion of employment thus crucially relies on the assumption that first, lower social security contributions will effectively translate into lower labor costs and that, second, because of high unemployment rates, the growth of employment does not fuel a wage–price spiral.

Finally, the DRI macroeconometric model has also been applied to the EDD issue. Brinner, Shelby, Yanchar, and Cristofaro (1991) examine the macroeconomic effects of the gasoline tax that would be necessary to stabilize CO_2 emissions from the US light vehicle fleet over a 20-year period. The authors show that if the revenue from the tax (which is raised to 0.45 US$ per gallon above the baseline by 2000 and 1.30 US$ per gallon by 2010) is neutrally rebated through a cut in the payroll taxes paid by businesses, GNP is likely to increase above the baseline value, while prices, interest rates, and income distribution between households and firms are unaffected. Moreover, a demand shift from gasoline-intensive goods toward labor-intensive goods and services has a positive effect on employment. The choice of a gasoline tax is interesting since it has two distinct advantages over a carbon tax: on the one hand, it encourages consumers to increase the fuel efficiency of their vehicles (replacing old and inefficient vehicles sooner, driving less, and maintaining their vehicles to maximize fuel efficiency), thereby reducing oil dependence on unstable parts of the world; and on the other, the incidence of the tax falls on personal mobility that cannot move abroad, and so makes a crucial contribution to the emergence of the strong double dividend. The latter guarantees high and reliable revenues, at least in the medium term.[25]

In our opinion this study illustrates well the need to extend double dividend investigations to a broader set of environmental tax options.

General equilibrium models

One of the most extensive general equilibrium studies of the EDD hypothesis has been carried out using the GEM-E3 model for Europe (Capros *et. al.*, 1996). In a recent application (Conrad and Schmidt, 1997), it is shown that a fiscal policy using the revenue of a carbon tax (designed to lower

[25] One should, however, be reminded of the possibility of a rebound effect according to which, in the present example, if the fuel efficiency of vehicles increases one may want to drive more (if kilometers is a normal good).

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CO_2 emissions by 10 per cent in ten years) to cut social security contributions, even if implemented unilaterally, could produce an eventual increase of employment in Germany, for example, of 0.26 per cent. If all European countries cooperate to accomplish an overall reduction of 10 per cent, employment could be increased on average by 0.54 per cent with respect to the baseline, ranging from 1.17 per cent in Portugal to 0.26 per cent in Italy. Only Greece experiences a slight decrease of employment in the last simulation year by 0.06 per cent.

As the perfect flexibility on the labor market plays an important role in the employment dividend, two imperfect labor market regimes are then examined. In the first case, the variation of the real wage rate is kept constant, while in the second case, real wage rates adjust in proportion to lagged changes in labor productivity. In the two cases, average European employment goes up by 0.1 per cent and 0.97 per cent respectively if Germany acts unilaterally, and by 0.11 per cent and 1 per cent respectively if the EU countries cooperate. Obviously, in the second case, the labor market dividend is higher as wages decline with productivity.

Note that in the case of a fixed wage rate, the cut in social security contributions produces higher labor demand and employment, implying rigidity in wage adjustment relative to the case of perfect wage flexibility. The reason is that, in a perfectly competitive world, a positive effect on employment leads to an increase in the after-tax real wage rate, whereas if the real wage rate is fixed, firms can hire the formerly unemployed labor force at an unchanged unit cost. In reality, as discussed in section 3.1, labor market rigidities are likely to affect wage dynamics in the opposite way. A reduction in labor costs may be blocked by union bargaining for higher nominal wages and by insider effects when social security contributions are reduced. In the long term, these two mechanisms work so as to leave real wage rates unaltered, thereby leaving employment also unchanged.

Another general equilibrium analysis is performed by Welsch (1996), who uses a recursively dynamic two-region (West Germany and EC9-Europe) model to quantitatively assess the shift of the cost of a carbon/energy tax from labor to energy. This paper emphasizes the modeling of labor supply, in contrast to most general equilibrium models, which assume that labor supply is either perfectly elastic or inelastic. The key finding is that, for a reasonable range of estimates of the parameter representing the employment elasticity of the wage rate (conceived to be an inverse labor supply relationship), a double dividend exists, in terms of reduced emissions and increased employment. The same model is used for Germany by Kemfert and Welsh (1998). Here, instead of taking values from the literature for the substitution elasticities among primary inputs (labor, capital, and energy), the authors employ econometric techniques to estimate them for industry as a whole and for seven subsectors. The impact on the economic system of stabilizing of CO_2 emissions at 1990 levels for the period 2005 to 2020, accomplished through the imposition of carbon taxes (which are implicitly defined by the emission target), is then analyzed under two recycling strategies: a lump-sum redistribution of the tax to households or a redistribution in terms of wage subsidies. In the former

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case, in addition to reduced emissions, employment is also decreased by 0.1 per cent by 2020, in conjunction with lower GDP; in the latter case however, employment increases by 3.94 per cent due to reduced labor costs. Higher employment also leads to higher GDP.

While, as shown, general equilibrium models have been used to verify the impact of alternative environmental fiscal reforms on GDP and employment, they appear to be ill suited to direct investigation of the EDD, mainly because they rely on the restrictive hypothesis of perfect competition in all markets, including the labor market.

Imperfect markets models

That a green fiscal reform has a positive impact on employment, at least in the short term, is also the general finding of a group of recent macroeconometric models. These are models which attempt to combine the top–down perspective, based on agents' behavior, with the bottom–up and I/O features of a disaggregated sectoral analysis and a detailed description of the energy sector. Perfect competition in goods and factor markets, especially in energy and labor markets, is abandoned and the possibility of endogenizing technical progress is entertained.

The WARM model (Carraro and Galeotti, 1996) and the E3ME model (Barker and Gardiner, 1996) are prominent examples of this class of models, and they share many features: both allow for wage bargaining in the labor market and assume imperfect competition in goods markets; in both, technical change is endogenized; both include every EU country and study the effects of both coordinated and uncoordinated policies. At the same time, significant differences characterize the two models as regards the estimation strategy (pooling versus error correction/cointegration approaches), sectoral disaggregation (across sectors versus across goods and inputs), and the use of functional forms (flexible functional forms versus log-linearized relationships).

Imperfect competition in goods and labor markets are a distinctive feature of the WARM model, one of the main applications of which is the double dividend analysis under a variety of tax recycling schemes. In Carraro, Galeotti, and Gallo (1996) several types of environmental fiscal reforms are analyzed. In the basic case, a carbon-energy tax of 10 ECU per toe is introduced and then recycled into a revenue-neutral cut in social security contributions. This fiscal reform produces an increase in employment in the European countries, but only in the first three years of the simulation period on average. In addition, the employment gain is very small (on average, slightly higher than 1 per cent with respect to the base case, and rapidly declining to the base value).

The explanation of these results can be found in the way in which the labor market is modeled in WARM (Brunello, 1996). It is assumed that firms maximize profits, whereas unions maximize the total rent, given by the level of overall employment multiplied by the individual earnings of employees in the unionized sector. The problem yields an equation in which the cost of labor (given in the model by the ratio between gross wage and profits per capita) increases as the bargaining power increases, and decreases as the unemployment rate, the employment elasticity to

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wages, and weight attributed by the union to employment in its utility function increase.[26]

A subsequent version of WARM divides the labor market into skilled and unskilled segments (Bosello and Carraro, 1999). It will be recalled that the distinction between skilled and unskilled labor was shown to be highly relevant in the theoretical work of Bovenberg (1995) regarding the so-called tax-shifting effect of revenue-neutral green fiscal reforms. In WARM, the net wage is the outcome of a bargaining process between firms and two domestic unions with different bargaining powers. The results of the estimation show that skilled workers' unions have a higher bargaining power than unskilled workers' ones. This difference in bargaining power captures not only the effective institutional influence of unions (usually related to the number of their members), but also the insider effect due to the different degree of specialization of the workers (a skilled worker who is difficult to substitute for is likely to have a greater influence on a firm's decisions than an unskilled, easily substitutable, worker).

The dynamic bargaining process embodied in the WARM model is such that unions succeed in transferring the initial reduction in social security contributions (financed through the emission tax) to employed workers through higher wage rates. Hence, an EDD can emerge in the short term, but tends to disappear in the long term. Moreover, the results provided in Carraro, Galeotti, and Gallo (1996) show that the EDD is more likely when unions' bargaining power is low (the labor market is more competitive) and/or when a revenue policy is adopted which leads unions to limit wage increases. A further significant aspect of the results is that, in the long term, the revenue effects induced by higher net wages can offset the substitution effects induced by the fiscal reform, thus leading to higher emissions. Hence, the first environmental dividend may be lost without achieving the second (employment) one. This is in line with the warning given by the theoretical model of Bayindir-Upmann and Raith (1997), as mentioned above.

When the labor market is segmented, it is possible to carry out simulation experiments with the WARM model in which the tax revenue is used to reduce the gross wage of unskilled workers only, rather than that of the whole labor force as in previous analyses. What emerges is that overall employment in the first five simulation years increases by 1 per cent without fiscal cooperation between EU countries, and by 1.1 per cent with cooperation. By contrast, it has already been noted that when the tax revenue is recycled across the whole labor force, employment increases by 1.5 per cent and 2 per cent respectively. The reason for this finding lies in the low substitution between skilled and unskilled workers estimated in the WARM model. As a consequence, recycling targeted at unskilled workers exerts a negative effect on skilled employment. This mechanism is strengthened by the role of skilled workers' unions which, given their higher bargaining power, can compensate for the decrease in skilled

[26] It has to be pointed out that the wage equation is estimated in a partial equilibrium framework. It is then nested within the WARM general equilibrium model.

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employment with an increase in their wage rate, thus introducing an additional negative effect on total labor demand.[27]

The E3ME model (Barker and Gardiner, 1996) also captures the upward pressure on wages exerted by worker representatives. Unions are able to respond to the increase in profits induced by the reduction in payroll taxes by obtaining higher nominal wages. However, to produce an increase in real wages and lower employment, the increase in nominal wages must be larger than the reduction in payroll taxes. This is not the case in the short term, but, according to the estimated coefficients used in the model, takes place in the longer term. In fact, in the long term, wages react positively to a cut in payroll taxes (the average long-term elasticity of wages to payroll taxes is equal to -1.2), and, in addition, the average long-term responsiveness of employment to real wage rates is equal to -0.56. At the same time, although environmental taxes increase energy prices, the negative effect of this on employment is much smaller (11 times lower) than the positive effect caused by the reduction in wage rates, which is an encouraging result with regard to the prospects of an EDD. The other aspect is obviously the feasibility of a reduction in real wages through a reduction in social security contributions, but this appears to be possible in the short term only.

In a recent simulation (Barker, 1998), E3ME shows that even ten years after the beginning of the fiscal reform, a double dividend could be experienced by all the European Countries: when a multilateral EU-coordinated excise duty is levied on the energy sectors of the economy in order to cut emissions by 10 per cent and the subsequent revenues are recycled through a reduction in social security contributions, employment goes up by 1.23 per cent. This result is relevant because the model accounts for two key issues directly connected to the EDD: the role of technical progress and imperfect competition in the energy and goods markets. Technical progress enters the labor demand function and the firm's cost function and is represented by an index which depends on cumulated gross investments and on the change in R&D expenditures. These two variables are directly affected by changes in energy prices, implying that any price changes affect technical progress and, via the cost function, the decisions of all firms. Moreover, price formation in different industries takes into account an estimation of the 'index of the market structure', ranging from one for monopoly to zero for perfect competition, which affects sluggishness in price adjustments. These are also distinctive features of the WARM model, although modeled in different ways.[28]

[27] A segmented labor market is also incorporated in an updated version of the QUEST model (EC, 1994). Simulations show that a cut of 1 per cent of GDP in unskilled workers' gross wages leads to an employment increase of 3 per cent in the last year of simulation. The labor market dividend is three times higher than in the case of a cut in the overall labor costs. This result seems rather optimistic as it is based on the assumption that the additional employment generated from the substitution of unskilled for skilled workers does not trigger additional wage pressure.

[28] A last notable feature of E3ME is its great degree of detail: based on input–output tables, it breaks up each European economy into 32 sectors.

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A very recent addition to this group of empirical models stressing imperfections in goods and labor markets is the study conducted by Marsiliani (1998). Basically the author carries out an econometric estimation of the general equilibrium theoretical model by Marsiliani and Renström (1997) described in section 3.1. An empirical model with market imperfections computes the impact of a revenue-neutral environmental tax compensated for with a cut in labor-income tax. The study is performed (only) for the Italian economy and provides estimates of the 'imperfection' parameters, namely the price mark-up applied by firms on top of costs and the unions' bargaining power, which exert a crucial influence on the double dividend outcome. The price of goods is found to be 1.13 times greater than marginal production costs, thus providing evidence for a certain degree of imperfect competition in the Italian goods market, whereas the union power coefficient of 0.12 is surprisingly low, attributing minimal relevance to the role of the unions in wage setting. In the empirical exercise, an energy tax equal to 0.1 per cent, 0.8 per cent, 2.55 per cent, 5 per cent and 10 per cent, of the total energy expenditures of Italian households and businesses is imposed, while government revenue is held constant. In all cases a double dividend is experienced: energy use decreases and employment increases. These results confirm that the modeling strategy adopted for the labor market is the crucial factor that determines whether or not an EDD can actually be achieved. As soon as the labor market becomes sufficiently competitive, the employment double dividend can appear (a result stressed in Carraro, Galeotti and Gallo (1996) who also show that a cooperative union can lead to the same conclusion). Of course, the functioning of the labor market is not the only factor explaining whether or not the EDD can be reaped; other aspects of the modeling endeavor are important. Among them the way tastes and technologies are represented is likely to play a role. Thus, for instance, in their theoretical work Koskela, Schöb, and Sinn (1998) postulate a constant returns CES production function with (only) two inputs, while Marsiliani and Renström (1997) have consumers with homothetic preferences and firms using a Cobb–Douglas technology. By contrast, Carraro, Galeotti, and Gallo (1996) estimate a more general model, where both consumers and firms use flexible functional representations of multi-good preferences and multi-input technologies respectively.

4. Further issues in double dividend analysis

Generally speaking, the double dividend literature has by and large neglected several important issues. A few papers have touched on single aspects of these, but they are still the exception rather than the rule.

Equity considerations

A first important remark is that the papers in this strand of literature 'measure' the second dividend either in terms of individual welfare assuming homogenous households, or in terms of economy-wide employment. Little attention is usually paid to equity considerations. In fact a fundamental ingredient of the EDD recipe is the possibility of shifting the

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tax burden from labor to other production factors, such as physical capital (if immobile) or human capital. Another possibility is to shift the tax burden toward the recipients of transfers (the unemployed) or pensioners (the elderly). In this case, double dividend studies, especially empirical ones, should account for different types of revenue and also quantify the distributional effects of the tax shift. We have already seen that the very possibility of a strong double dividend, relative to a weak one, is uncertain if we account for equity considerations, as in Proost and van Regemorter (1995) (see also Bovenberg, 1998). Another issue is whether revenue-neutral green tax reforms are regressive. This question is theoretically non-trivial if it is labor tax that is being reduced (Park and Pezzey, 1998). In general, accounting for distributional considerations may entail other negative effects. For example, if the tax burden is shifted toward human capital, growth may be reduced because an increase in human capital, in conjunction with technical change, is widely recognized as the main engine of growth. If the tax burden is shifted toward transfers and pensions, low-income households are likely to be negatively affected, thus inducing negative consumption effects and social costs (marginalization, conflict, and so on).

Equity considerations are especially relevant if they are of the intergenerational type. In particular, the result according to which revenue recycling is preferable in welfare terms to revenue retention holds when papers refer to current generations (as they do implicitly). But what about future ones? Present pollution activities are also of intergenerational relevance because emissions damage the environment and therefore the welfare of all future generations. The implementation of environmental taxation in order to internalize this kind of externalities implies non-environmental welfare losses for the generations bearing them. Thus transfers across generations might be devised to compensate for these losses. As an example, when the revenue of the tax is recycled through a reduction in the rate of social contributions, the fulfillment of this equity criterion represents a 'third dividend' contributing to the improvement of non-environmental welfare (Assouline and Fodha, 1998). In another vein, an original empirical contribution to the employment double dividend debate is provided by Wendner (1998), who analyses its feasibility in the perspective of an aging population and of wealth redistribution between younger and older generations. The author constructs an applied dynamic general equilibrium model for the Austrian economy with a nested structure of overlapping generations and explicit modeling of the functioning of the pension system. A carbon tax aimed at reducing CO_2 emissions to the Kyoto level is introduced with three different recycling options: an increase in transfer payments to households; an increase in wage subsidies; and, in the third scheme, 40 per cent of the tax revenue is used for wage subsidies and 60 per cent is used for partially financing the old-age pension system. Even though in this third case the direct financing of labor costs is lower relative to the case of full wage subsidies, here the social security tax rate decreases due to partial financing of the pension system, while in all other scenarios it increases. Due to the aging structure of population, in the pension policy case far more resources are disposable for the

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savings, investments, and consumption of younger generations; as a consequence, GDP and labor demand are moderately higher than under other options. This last study also illustrates the value of analyzing alternative recycling schemes to those traditionally considered in the double dividend literature.

Technical change

A crucial aspect which all theoretical contributions appear to neglect and which most empirical analyses treat too simplistically is the way in which technical progress is modeled. It has already been argued that the significant substitution of energy by labor is a basic ingredient of the EDD. This substitution depends on technical change, i.e. on the availability and adoption of energy-saving technologies. If technical change is exogenous, as is the case in most models used to assess the EDD, it cannot be affected by the fiscal reform, thus playing no role in the reform-induced substitution process between energy and labor. Hence, a better evaluation of the existence and size of the EDD can be obtained by endogenizing technical change. This is for instance done in the WARM model, where an indicator of technical progress, interpreted as an indicator of the environmental quality of the capital stock, is modeled as a function of variables, such as energy prices and taxes, public and private R&D expenditure, patents, output, etc. It is in fact assumed that the capital stock can be broken down into two parts, the energy-saving/environment-friendly capital stock and the energy-consuming one. Each year a new vintage of the capital stock becomes operational, i.e. new capital is added to the two components. Given the non-observability of the two types of capital, a latent variable approach is adopted and the equations defining the rate of growth of the two kinds of capital are estimated using the Kalman filter. In the equations, R&D, output and interest rates play a dominant role, and R&D is in turn endogenized as a function of output, public R&D, energy prices, and taxes. As a consequence, an increase in emission taxes boosts environment-friendly R&D and leads firms to use environment-friendly vintages of the capital stock. This reduces the amount of energy per unit of production, thus increasing energy efficiency and the substitution rate between energy and labor.[29]

Modeling environmental variables

A further relevant issue regards the modeling of environmental variables. In most models, emissions are a pollution flow that disappears in each period, thus neglecting the importance of pollution stocks and of their feedbacks on production and consumption. As a consequence, the effects of a fiscal reform that reduces emissions and concentrations, thereby inducing greater production and consumption, cannot be adequately

[29] It is possible that if the new, best available, environment-friendly technologies are also labor saving (see Boetti and Botteon, 1994), increased technical progress may even have negative effects on employment. The E3ME model also endogenizes technical change as a function of cumulated gross investment and R&D spending.

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assessed. While data problems render this issue difficult to handle in empirical models, in theoretical contributions the quality of the environment is typically treated as a public consumption good entering the agents' utility function in a weakly separable way. However, when separability is abandoned, a cleaner environment can influence the labor market both through labor supply (environmental quality is likely to be complementary to leisure) and through labor demand, because of positive effects on productivity (Bovenberg, 1997). For instance, Bovenberg and de Mooij (1997) use an endogenous growth model and find that a second dividend may exist if the quality of the environment has an effect on production (rather than solely on consumption, as usually postulated) or if there is a shift of the tax burden from capital accumulation to profits. De Mooij (1998) extends the 'Bovenberg' general equilibrium model to include environmental externalities in production, on the one hand, and non-separable environmental externalities in consumption, on the other. The author shows that, in the presence of production externalities, or if consumption externalities are relatively good substitutes for leisure, an environmental tax reform may stimulate labor supply and the (strong) double dividend may be feasible. However, if consumption externalities are complementary to leisure, a cleaner environment may reduce labor supply even more than in the case of separable externalities. Hence, interactions between environmental quality and private behavior may provide both opportunities and risks for a double dividend. Clearly, such results merit validation in empirical investigations.

Institutional design of fiscal reforms

We noted in the previous section how the institutional design of the fiscal reform significantly affects the magnitude of the EDD. An internationally coordinated policy appears to be more effective than a unilateral reform, whereas tax harmonization without cooperative revenue recycling may not achieve the EDD (Carraro and Galeotti, 1997a).[30] Further analysis with WARM (Bosello and Carraro, 1999) shows that cooperation among EU countries can increase the probability of success of an environmental fiscal reform. It is assumed that a uniform tax rate across EU countries, set at ten ECU per toe, is imposed so as to equalize marginal abatement costs. The revenue is then redistributed among European countries in order to achieve the same employment increase in all countries. This kind of harmonized fiscal reform yields an employment increase of 2 per cent in the first five years of simulation and of 1.3 per cent in 2030 (the last simulation year). To achieve this result in the presence of a uniform tax rate, a 'cooperative' redistribution of the fiscal revenue among European countries is therefore necessary.

Developing countries perspective

As a final remark we point out that a couple of very recent papers have drawn attention to the fact that almost all the analyses on the double divi-

[30] It will be recalled that simulations with the GEM-E3 and E3ME models are also carried out for the alternate hypotheses of a cooperative and a non-cooperative regime across EU countries.

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dend issue have been performed in the context of developed economies. In such cases, results may depend upon the nature of the pollutant considered and on the existing tax system. Thus, Bento and Rajkumar (1998) study the case of Indonesia where, unlike most developed countries, the oil and natural gas industry play a dominant role, and where energy and emission taxes are therefore broad-based taxes. According to Coxhead (2000), the case against the double dividend may be overstated where developing countries are concerned. In contrast with industrialized economies, the tax base in many developing countries relies heavily on trade taxes (especially tariffs), which are highly distortionary. Moreover, in many cases industries protected by tariffs are leading sources of emissions. Similarly, accumulated evidence suggests that in many cases the structure of agricultural protection distorts producer incentives towards crops and technologies that contribute disproportionately to soil erosion, land quality degradation and water pollution. The paper concludes that the case for environmental taxes compensated for by reduction in other preexisting taxes in developing countries seems strong and could represent an useful incentive to reforming existing taxes.

5. Conclusions

In this paper we have analyzed how different modeling strategies affect results concerning the possibility that well-designed environmental fiscal reforms achieve a double dividend, either in its strong form or as an employment double dividend. From, the above analysis several conclusions can be drawn.

In one sense there is too much theory, and too little empirical work. Papers generally consider taxes on an idealized theoretical pollutant or carbon taxes. It is important to assess the effects of taxes on various pollutants from the vantage point of a potential double dividend (see also Pezzey and Park, 1998). Similarly, the sectoral effects of environmental taxation may be very important. A role in fostering employment may be played by the shift of demand away from polluting sectors, which are typically capital intensive, toward cleaner industries, which are usually more labor intensive.

More generally, while theory provides only qualitative results, it also highlights the need for quantitative information on the EDD issue. In particular, much depends upon various elasticities whose sign and magnitude can only be revealed by empirical investigation. Moreover, in the light of the possibility of achieving a double dividend, more sensitivity analysis of both theoretical and empirical results stemming from different modeling strategies is strongly suggested.

A further remark is that in double dividend analysis, especially in its EDD conception, environmental taxes are the only market-based instrument considered in the literature. Very few exceptions can be found, such as those studying the employment impact of R&D and innovation subsidies designed to stimulate energy saving environmentally friendly technologies (see, for instance, Carraro and Galeotti, 1997b). By the same token, the study of trading emission permits, as an alternative to green taxes, appears to be promising for the double dividend (Norregaard and

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Reppelin-Hill, 2000). Here, monitoring and administrative costs are likely to play a prominent role (Park and Pezzey, 1998).

In summary, we believe that more work, especially on the empirical front, is needed on the double dividend issue. In particular, the main effects of fiscal reforms are distributional effects and the double dividend itself emerges only through relevant changes in income distribution. This issue is largely neglected by empirical literature.

Finally, from the perspective of the Old Continent, it should be borne in mind that an ecological tax reform is not a means of drastically reducing mass unemployment as it exists today in most European countries. Hence, it is important that researchers and especially policy makers avoid the risk of overconcentrating on the second dividend at the expense of the first. The double dividend debate arose in order to make policies of environmental protection more politically acceptable. This is the main goal of an environmental fiscal reform and other goals should not undermine its effectiveness.

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