Chapter 2
Effects of Climate Policy on the Economy: A Theoretical Perspective

2.1 Macroeconomic Objectives

The aspects which are relevant when assessing the economic and social compatibility are almost unlimited. Theoretical studies look at changes in the macroeconomic welfare. The topics examined in economic-policy analyses range from macroeconomic variables, regulatory frame conditions, income distribution, and structural change through to the conditions which can be derived with regard to social compatibility.

In order to reduce the analyses to be carried out to a manageable amount, it is necessary to concentrate on those problem areas where it is supposed that climate policy could have significant effects. Since climate policy involves sectorally overlapping measures with which considerable investment sums are induced, the impacts on the *macroeconomic variables* play an important role. Here, the impacts on the national or domestic product are often interpreted as a reference value for the macroeconomic welfare, since a continuous growth of the national product implies that the sum of the goods available for consumption is continuously increasing. Thus, the effects on the Gross Domestic Product (GDP) will be used to assess the macroeconomic impacts. However, in doing so it is important to keep the limitation of this indicator in mind. The national product – even without referring to the external costs of climate change[1] – is only a very indirect yardstick for measuring welfare. The following aspects have to be considered:

- The GDP measure does not express which share is allotted to the supply of commodities to the population. It is possible, for example, that consumption is reduced in spite of a constant national product, if investments increase as a result of climate protection.[2]

[1] When assessing the impacts of climate policy on the macroeconomic welfare, the avoided impacts of climate change also have to be taken into account. The assessment of policy consequences, however, concerns quantifying the macroeconomic effects of climate protection in order to be able to compare these with the benefits of climate protection policy. When the term "welfare" is used in this section, therefore, this does not include the external costs of climate change.

[2] From a theoretical point, any assessment of the welfare changes of a CO_2 reduction based on tangible goods supply should therefore also take into account the changes in aggregated private consumption.

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- The GDP measure does not reflect either a change in the commodity leisure or in non-market evaluated activities.
- Changes in GDP do not capture changes in the external costs. A climate policy does not only reduce greenhouse gas emissions, but also brings about a reduction of other external costs (e.g. emissions of air pollution). Likewise, to the extent that climate policy results in lower imports of fossil fuel from politically sensitive regions, climate policy also contributes to increase security of supply. These kinds of secondary benefits are neither included in the national product nor in the benefits of reducing the CO_2 emissions.[3]

The impacts on *employment level* constitute an essential topic when assessing social compatibility, especially in times of high unemployment. This variable is therefore subject to closer scrutiny, and is used as the second major indicator to assess the macroeconomic effects of climate policies.[4]

This section seeks to answer the question: due to which economic mechanism can the implementation of climate policy measures result in changes of the GDP and the number of jobs? Climate policy measures set off diverse adjustment reactions among individual companies and private households which precipitate as structural effects on a sectoral and regional level. The sum of these adjustment reactions and the subsequently caused impacts then result in changes of macroeconomic variables on the macroeconomic level. The various economic mechanisms describe which adjustment reactions and consequential effects are induced by climate policies. However, they are strongly influenced by the respective theoretical paradigm used. In line with the various schools of thought, price and cost effects, demand effects and innovation effects can be distinguished.

2.2 Price and Cost Effects

2.2.1 Effects of Changes in Prices and Costs

Price and cost effects stand at the forefront of neoclassical economic theory. The primary cost factors in the general economic discussion are the costs of labour (wages) and capital. With regard to climate policy, another cost factor is the cost occurring for supplying energy services. It is true that, in a macroeconomic context,

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[3] Accordingly, such effects would also have to be taken into account in an overall assessment of climate policy.

[4] Furthermore, sectoral or regional structural changes cause adjustment pressure in both growing and shrinking sectors and are therefore of considerable significance for both the social compatibility and when assessing the political enforceability of a climate policy. However, they are not included in Chap. 3 on macroeconomic effects, but are dealt with in Chap. 4.

these only comprise a small share of total costs, but they are strongly affected by changes in the energy supply or by climate protection.

If restrictions are placed on CO_2 emissions, the use of fossil fuels has to be reduced. If the cost burden increases as a result of this, various supply side effects will be triggered.[5] The same amount of labour is demanded for a lower real wage. Furthermore, substitutions in favour of other production factors take place, and, in general, the potential output is reduced. If the market mechanism on the labour market leads to lower real wages, a new equilibrium with full employment is reached. If this is not the case, unemployment will result. Furthermore, an increase in costs leads to disadvantages in international competition.[6] If, on the other hand, the climate policy brought about cost reductions, an increase of production and employment would result and international competitiveness would be improved. From these arguments it is clear that, within the scope of neoclassical theory, it is decisive for the direction these cost effects take whether a climate protection policy results in an increase or a reduction of the cost burden.

Neoclassical theory assumes, in general, that market mechanisms lead to an efficient allocation of resources. If such an efficient starting-point is assumed, a reduction of CO_2 emissions, in general, leads to a reduction of GDP.[7] In the scope of this static analysis, a different result can only come about if the assumption of an efficient starting-point is abandoned. The discussion of the effects of climate protection policy is therefore distinguished by the – often implied – characterisation of the starting situation. A *non-efficient starting situation* is accounted for on two different aggregation levels:

- The so-called no-regret potential is picked out as a central topic on a technology-based aggregation level.[8] It is argued that a considerable cost-efficient potential to reduce greenhouse gas emissions already exists under the given frame conditions. From this it is concluded that, to a certain extent, a reduction in greenhouse gas emissions would be possible without increasing the cost burden.
- Specifically with regard to the introduction of an energy or CO_2-tax, it is argued that a double dividend (emissions reduction plus increase in economic output) could be achieved if the tax revenue is used to lower other distorting taxes.

[5] See Lintz (1992, pp. 34–38) and Landmann (1984, pp. 181–190) based on the example of an increase in oil price.

[6] This effect is reduced if there are internationally agreed reductions such as those aimed at in the Kyoto Protocol. On the other hand, a first-mover advantage may result from unilateral (national) acts. See Sect. 2.3.3.

[7] In theoretical terms, an efficient starting-point is equivalent to a position on the production-frontier of an economy. Any increase in the output of one composite of the total output inevitably requires the reduction of at least one other composite, reducing welfare. If one neglects the problems that GDP is not able to account for all welfare changes (see Sect. 2.1), this is equivalent to a reduction in GDP.

[8] For a comprehensive definition of the no-regret potential see Ostertag (2003).

2.2.2 Existence of No-Regret Potentials

The existence of no-regret potentials is supported by comprehensive technology-based analyses in which cost-efficient saving possibilities can already be shown for numerous case examples under the given frame conditions.[9] Information deficiencies and investor's demand for very short term payback times are given as the main reasons for the existence of these untapped saving potentials.[10] Other obstacles cited include principal agent problems within companies as well as – especially relevant for housing construction – the non-appropriability of profits, which is caused by asymmetric information.[11] In addition to this, for the electricity sector, reference is made to the former kind of regulation of natural monopolies. They used to restrict measures of electricity conservation through degressive tariff designs on the one hand. On the other hand, electric utilities used their market power to frighten away environmentally-friendly independent electricity producers from entering the market.[12]

The concept of no-regret potentials was considerably extended and expanded to environmental protection in general by the work of Michael Porter.[13] He argues that a strict environmental protection policy can result in companies activating unused efficiency potentials and thus achieving competitive advantages (*free lunch hypothesis*). This theory is embedded in a concept of the international competitiveness of nations, which declares that the main factors of determination are found in the interaction of production factor availability, business strategies, demand conditions, industry clusters and supporting government action leading to changing frame conditions.[14] Intensive competition and the constant search for more efficient solutions are essential to achieve competitive advantages. In this sense, it can even be advantageous for a country if it starts off at a competitive disadvantage due to missing production factors, since this encourages innovations and avoids the squandering of resources. Increasing the stringency of environmental standards can work in a similar way: "The notion is that the imposition of regulations impels firms to reconsider their processes, and hence to discover innovative approaches to reduce pollution and decrease costs or increase output."[15]

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[9] See Grubb et al. (1993, pp. 403–432), IPCC (1995, pp. 309–312, 317–322), IPCC (2001, pp. 504–512).

[10] See Jaffe and Stavins (1994b, pp. 804–806), Sanstad and Howarth (1994, pp. 814–816), Metcalf (1994, pp. 821–823), Cameron et al. (1999, pp. 66–69). For a recent overview and conceptual framework on those barriers to energy efficiency, see Sorrell et al. (2004).

[11] DeCanio (1993, pp. 907–910), Cameron et al. (1999, p. 65). In the literature, this effect is known as the "investor-user dilemma". An investment by the owner in energy conservation cannot be transferred into higher basic rents, since new tenants can only estimate the energetic condition of a building at a high information cost.

[12] See e.g. Brunekreeft (2004).

[13] Porter (1990); Porter and van der Linde (1995).

[14] Berg and Holtbrügge (1997, p. 200).

[15] Jaffe et al. (1995, p. 155).

Both the results of bottom-up case studies, the associated explanations and Porter's reasoning are challenged theoretically. *"There is no free lunch"* is the counter-argument to the existence of a no-regret potential.[16] Basically, the arguments of the no-regret opponents whittle down to one or another form of hidden costs, which the proponents "forget" to account for.

In turn there is a whole series of counter arguments to this line of thought. The main ones are those which put forward a different theoretical starting-point. For example, in certain cases, the existence of no-regret potentials can be justified from the perspective of transactions cost economics and real options value theory.[17] In addition, numerous publications question the assumption of the utility maximising, rational behaviour of people and are emphasising – in addition to information and knowledge deficiencies – the competence and motivations of actors and putting forward the concept of *bounded rationality* instead.[18] In addition, from the perspective of evolutionary economics, the influences on the decision process at different levels have been highlighted and the assumption of fixed and transitive preferences has been challenged.[19] Finally, it is pointed out that decisions within companies are the result of a complex process, which is characterised by multifunctional network structures with differing objective functions, spillovers between the individual sectors and limited information processing abilities so that, at any time, there is the possibility to bring about substantial efficiency improvements.[20]

Thus, there are numerous arguments in the debate on the existence of no-regret potentials which are expressions of differing scientific paradigms. However, the existence or non-existence of no-regret potentials cannot be as clearly proven as the representatives of the respective positions would like to claim. Overall, the conclusion drawn from these models is that there are no strict behavioural assumptions: "The evidence and models surveyed suggest that a sensible rationality assumption will vary by context, depending on such conditions as deliberation cost, complexity, incentives, experience, and market discipline."[21]

For the assessment of climate protection policy, the consequence is that the existence of inefficiencies is a necessary but not sufficient condition for empirically significant no-regret potentials of a climate policy. In order for a climate protection policy to systematically reduce costs in proportion to other conceivable policy fields, the inefficiencies in energy consumption have to be particularly pronounced. In addition, there must be policies available to systematically and cost-effectively remove these inefficiencies. Thus, arguments are necessary which support the supposition

[16] See Palmer et al. (1995, p. 120).

[17] See Ostertag (2003).

[18] See Conslik (1996, pp. 669–683). In Simon (1997, p. 291), bounded rationality refers to "cognitive limitations of the decision makers".

[19] See Witt (1987, pp. 133–137), Vanberg (2001).

[20] Nelson (1995, pp. 51 ff). This argument is applied to energy and climate policy in the work of Dennis et al. (1990), Stern (1992), DeCanio and Watkins (1998a, b) as well as DeCanio et al. (2000, 2001).

[21] Conslik (1996, p. 692).

that inefficiencies exist, particularly with regard to decisions about energy saving investments. Alongside the already mentioned traditional reasons for market failure, a justification may exist in a form of bounded rationality which does not adapt fast enough to the changed frame conditions and therefore forfeits its efficiency, which may well have been present under the original conditions. The following aspects must be considered here:

- The company's energy supply is not at the centre of the corporate performance processes. In the sense of satisfying, the aspiration level consists mainly in securing supply at reasonable costs.
- During times of sinking energy costs, routines developed stating that a costly search for energy saving possibilities does not pay off anyway. This decision routine is plausible for the large number of companies in which energy consumption mainly occurs in ancillary services such as the supply of process heat or compressed air production and only constitutes a small share of the total costs.[22]
- This tendency is reinforced even more by the fact that energy-relevant investment decisions are often reinvestments, in which the decision is not made independently of decisions taken at earlier points in time. Thus, inefficient decisions in the past influence future decisions (good money is thrown after bad).
- Energy-relevant investments do not have to be made continuously, but often have a rather ad hoc nature. At the same time, these investments also often have a disproportionately long lifespan. On top of this are the complex environment and uncertainties with regard to future developments. Under these conditions it is especially plausible to have an orientation along decision routines which are difficult to dismantle, even more so since the drop in energy prices after the oil price crises seems to reinforce these kinds of decision routines.
- Policy measures which draw attention to the necessity to reduce CO_2 emissions in the future could help to change these decision routines independently of whether they alter relative prices or have a different leverage.[23] The altered decision routines establish themselves through social interaction. For measures to accelerate the diffusion of these routines, it is of considerable significance to select the respective multipliers and opinion leaders as the target group. This type of group- specific design can simultaneously limit the costs of the policy.

To sum up, the arguments presented above may be sufficient to explain why a certain no-regret potential exists. Such a no-regret potential also influences the shapes of the *cost curves* of a CO_2 reduction. If one assumes an efficient economy, every option with costs below zero will be realised. Thus, Point T in Fig. 2.1 will be realised. It characterises the theoretical cost minimum an efficient economy will reach.[24] If an additional restriction is added, such as a reduction of CO_2

[22] This argument is consistent with empirical results that relatively high unused saving potentials are found mainly in companies with low specific energy consumption. See Chap. 5.2 of this book.

[23] DeCanio (1999, pp. 291–292).

[24] As mentioned, external effects are excluded here.

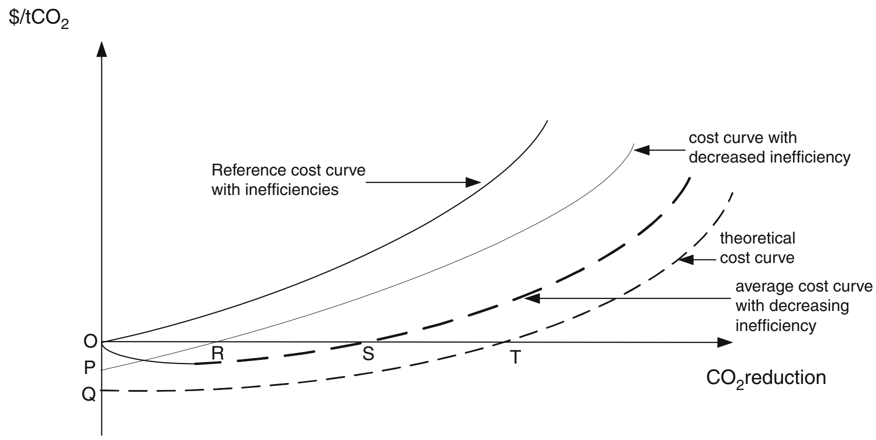

Fig. 2.1 Costs curves of CO_2 reduction including inefficiencies

emissions, this leads to an increase in costs. Thus, the theoretical (marginal) cost curve of CO_2 reduction has a positive slope to the right of starting point T.[25]

However, if it is assumed that inefficiencies exist in the reference case, there is another starting point. In contrast to an efficient economy, the emission reduction characterised by OT is not realised due to inefficiencies.[26] In an inefficient economy, the cost curve for the reference case starts in O, and the inefficiency is characterised by the area OQT. Thus, if one compares an inefficient economy with a perfect efficient economy, the theoretical no-regret-potential is equal to the emission reduction OT.

The arguments for the existence of a no-regret potential all relate to the inevitability of a certain amount of inefficiencies. Thus, the starting point for the analysis is point O on the reference (marginal) cost curve with inefficiencies. However, if it is possible to reduce the inefficiencies during the course of the climate policy, for example because decision routines are changing, the cost curve for the policy case is modified and shifts to the right towards the theoretical cost minimum curve. Nevertheless, it seems unrealistic that the theoretical cost minimum curve can be reached, not least because the measures to increase efficiency still incur costs, even in the most favourable case, or because the inefficiency is not completely removed. In Fig. 2.1, it is assumed that the inefficiencies are at least partially reduced. This corresponds to a (marginal) cost curve with decreased inefficiencies starting at point P.

However, the utilisation of a no-regret potential of climate policy is characterised by both a reduction of inefficiencies (leading to a shift of the marginal cost

[25] It can be assumed that increasing reductions of CO_2 will be associated with increasing marginal cost. Thus, the positive slope of the reduction curve is increasing.

[26] From the viewpoint of an efficient starting-situation, the CO_2 reduction costs are negative up to point T and the associated reduction is carried out. Correspondingly, the section of the cost curve relevant for an efficient starting situation does not begin until point T.

curve), and utilisation of technologies with increasing marginal costs (movement along a marginal cost curve). Combining both effects in one cost curve yields an average cost curve with decreasing inefficiency.[27] Starting from point O, there is a reduction in average costs until point R is reached, because this emission reduction is associated with negative marginal costs. The maximum efficiency gain is realised at point R (intersection of marginal cost curve with decreased inefficiency with the axis) and equals the area OPR below the marginal cost curve with decreased inefficiency. At the same time, the average costs curve reaches its minimum, if the emission reduction R is realised. However, the average costs are still below zero if emissions continue to be reduced. At point S, however, the reduction of average costs has been used up by the increase in marginal costs of the emission reduction beyond point R. The emission reduction OS realised in comparison to the reference case is the "no-regret" potential. It is defined as the emission reduction which can be realised without additional total costs compared to the reference case. However, in contrast to the situation characterised by OR, there is no reduction in total costs. Instead the increase in efficiency is used to realise further emission reductions.

With stricter environmental targets, however, measures at much higher costs have to be taken. The higher the targeted CO_2 reduction, the stronger the influence of the rising marginal costs of CO_2 reduction on the development of the average cost curve and the weaker the cost-reducing effect of decreasing the inefficiencies.

For the assessment of the economic impacts of climate policy, it is decisive at what amount the no-regret potential is estimated. Based on the estimations for North America and Europe up to the mid-90s, which were made primarily using technology-based energy system models, a no-regret potential equalling 10–30% of the CO_2 emissions was identified.[28]

When interpreting these results, it must be kept in mind that they generally refer to the maximum no-regret potential achievable under the assumed technological change,[29] i.e. to the range OT in Fig. 2.1. With regard to estimating the economic compatibility, it would however be necessary to estimate the potential OS, which is easily realisable through policy measures.[30] As long as there are no empirically sound, comprehensive estimates available, the no-regret debate ultimately remains

[27] In order to keep the argument simple, the explanation of Fig. 2.1 only assumes a singular decrease in inefficiency. If, however, the decrease in inefficiency happens continuously, the slope of the average cost curve decreases and it shifts towards the theoretical cost curve.

[28] Grubb et al. (1993, p. 470); the final conclusion of the IPCC is cited all over the world: IPCC (1995, p. 12): "Despite significant differences in views, there is an agreement that energy efficiency gains of perhaps 10 to 30% above baseline trends over the next two to three decades can be realised at negative to zero net cost." See Koomey et al. (1998), Loulou et al. (2000), Krause et al. (1999), Brown et al. (2000), IPCC (2001) for more recent statements.

[29] However, these estimates tend to underestimate the future technological change and are thus comparatively too pessimistic. See Jochem (1997b), Seebregts et al. (2000), IPCC (2001, p. 512).

[30] Here it would be necessary to substantially extend the prior energy systems models which were customary up to now to cover transaction costs and hidden costs and benefits. See Jochem and Diekmann (2001).

stuck in a "lasting controversy between believers and non-believers in the existence of a large untapped efficiency potential in the economy".[31]

2.2.3 Existence of a Double Dividend

One component of strategies to increase energy efficiency is usually an increase in energy prices through *an energy/CO_2 tax*, which is compensated for by lowering other taxes; i.e. is conceived as being revenue-neutral. Since the relative prices of the production factors are altered by the levying of almost any tax, excess burden of taxation occurs.[32] Partial analysis shows that this excess burden can be diminished if a tax is replaced by an energy tax and if the energy tax has a lower excess burden than the existing tax, i.e. it is less distorting. If this is the case, the result is a positive revenue recycling effect leading to a double-dividend of tax reform.[33] The taxes on labour are judged to have strong distortional effects. Thus, the chances are quite high that an ecological tax reform, which reduces the taxes on labour, will yield a double dividend. The reduction of the excess burden of taxation diminishes (weak double dividend) or even overcompensates (strong double dividend) the direct costs of CO_2 reduction.[34]

However, in more recent publications, the issue is raised that the probability of a double dividend is very strongly influenced by the interaction of climate policy with a pre-existing tax system characterised by distortions.[35] General equilibrium analysis holds that a reduction of CO_2 emissions leads to lower production and reductions in employment or real wages. Keeping total tax revenue constant requires an increase in tax rates. If these taxes have a distortionary effect, the overall excess burden increases still further. This effect is called the tax interaction effect. It is still possible that an ecological tax reform might induce a revenue recycling effect, if the eco-tax revenue is used to lower other distortionary taxes.[36]

[31] IPCC (2001, p. 506).

[32] The excess burden of a tax is the loss in welfare which occurs, because almost any tax leads to distorting changes in relative prices which induce substitution effects.

[33] See Schöb (1995). The first dividend consists of the reduction of the environmental burden, the second of the positive economic impacts.

[34] Deviating from this definition, which is based on Parry et al. (1999) and IPCC (2001, p. 472), sometimes an increase of employment is characterised as a weak second dividend in the literature, and an increase of the GDP as a strong second dividend.

[35] See Bovenberg and de Mooij (1994), Bovenberg and van der Ploeg (1994), Goulder (1995), Parry et al. (1999).

[36] Thus, it can be argued that climate policy instruments which lead to revenues, which are used to lower distortionary taxes, have more favourable economic effects than instruments without revenues (see Parry et al., 1999). According to this argument, for example, energy/CO_2 taxes or emissions trading systems with auctioned allowances would have to be favoured against an emissions trading system with a grandfathering scheme.

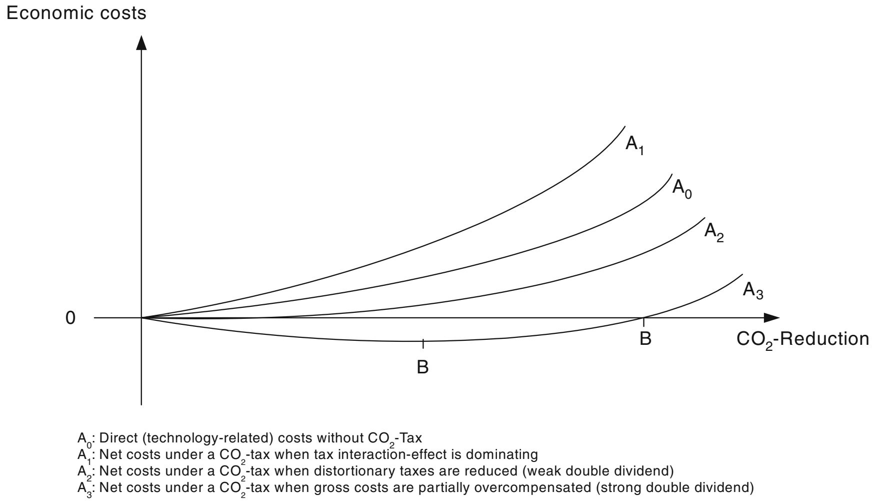

Fig. 2.2 Conceivable impacts of a CO_2/energy tax on the national economy (adapted from IPCC 2001, p. 513)

However, in order to reach a strong double dividend, the revenue recycling effect must outweigh the tax interaction effect.[37]

In several theoretical analyses, it is deduced that the tax interaction effect dominates the revenue recycling effect.[38] However, this result is not universally valid, but depends on the assumptions made, i.e. the role of labour as only source of income, or the magnitude of cross price elasticities of substitutes to the produced goods. It is certainly possible that, based on different assumptions, situations can be modelled in which a strong double dividend may still occur.[39]

Overall, it can be concluded that the existence of a double dividend is controversial and does not represent a definite result. Figure 2.2 makes this clear: depending on the assumptions selected, the theoretical modelling can result in the direct costs of climate protection shown in curve A_0 being increased, e.g. if tax interaction dominates (curve A_1). On the other hand, the direct costs can also be softened by a weak double dividend (curve A_2) or even partially overcompensated by a strong one (curve A_3).

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[37] IPCC (2001, pp. 472–473). These arguments are ultimately based on a second-best problem. Since several optimality conditions are violated, the removal of one inefficiency (revenue recycling effect) does not at the same time necessarily result in an improved allocation.

[38] See Bovenberg and de Mooij (1994), Parry et al. (1999).

[39] See Koskela et al. (2001, pp. 21–29), Parry and Bento (2000) and Bosello et al. (2001, pp. 15–17). Correspondingly, the argument is also put forward that the conditions for the existence of a double dividend are comparatively more favourable in many European countries than in the USA, IPCC (2001, p. 516). Furthermore, recent analyses argue that, under certain conditions, a double dividend may arise due to shifting the burden to international trade partners; see Smulders (2001).

These comments on ecological tax reforms refer to the impacts on the GDP. For effects on employment, the *substitution effects* have to be taken into account as well, which result from an energy/CO_2 tax financing the reduction of the taxes on labour – e.g. social security contributions. The production factor labour becomes cheaper in relation to the other production factors as a result of this reduction. Because of this change in the relative prices, an incentive then exists to employ more labour and substitute other production factors in this way. Whether employment increases under depends on whether these substitution effects are large enough to overcompensate the decreases in employment resulting from a drop in total production. It can be stressed that the impacts of an ecological tax reform on employment tend to be more positive than those on the GDP.

2.3 Innovation Effects

2.3.1 Policy-Induced Technical Change

Up until now, most analyses of the costs of climate protection assumed that technological change takes place without any impacts from the climate protection policy and that an autonomous increase in the energy efficiency of the national economy results over time.[40] If, however, due to the climate policy, additional technological change is induced, given emission reduction targets can be reached in a more cost-effective way.[41]

To what extent a climate policy can actually influence *the generation of new innovations* is of significance when assessing this effect. From the perspective of environmental economics, a corresponding innovation effect is assigned to market economic instruments.[42] Consequently, it can be reckoned that a climate policy which increases energy prices will result in corresponding effects. However it remains unclear how regulatory instruments effect the generation of innovations. They play an important role, for example, in the space heating sector, in which a considerable share of CO_2 reductions is to be achieved. Against the background of the innovation-hindering effect which is generally assigned to standard-based instruments by environmental economics,[43] the question arises of whether it is likely that any incentives to generate new technical solutions will occur. Answering this question is of considerable significance for the entire discussion of the costs of

[40] This corresponds to a shift of the production frontier, in which the marginal rate of transformation would be altered in a way that the amount of material goods per additional unit of emission abatement is reduced. Compared with the starting situation, each emission reduction target would then be compatible with a higher level of material goods production.

[41] Goulder and Schneider (1999, p. 218).

[42] See Sect. 5.1.

[43] See Sect. 5.1.

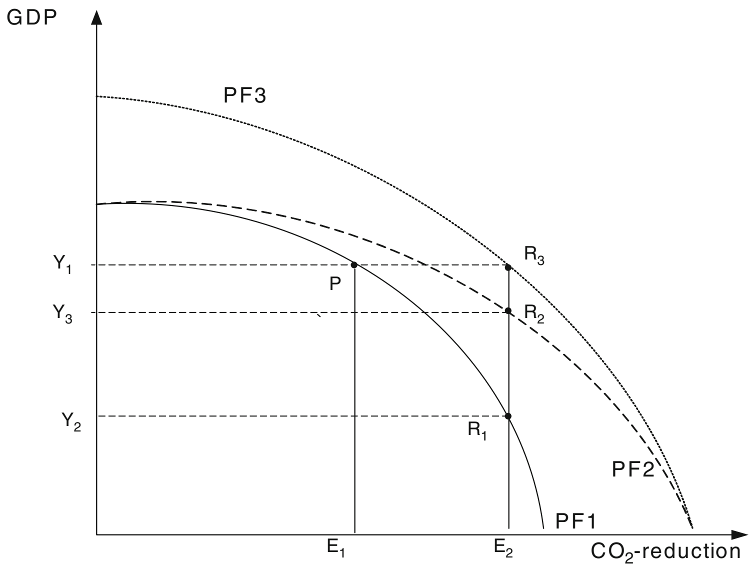

Fig. 2.3 Effects of technical change on the production frontier

climate protection because, according to the results of energy system analyses, high reduction capacities and clear, additional financial burdens are expected, especially in this sector. For the assessment of the direct additional costs, it is essential to know, in spite of the considerable significance of standard-based instruments in this sector, whether a *policy-induced technological change* can be reckoned with.[44]

In the theoretical analysis, the effects of a policy-induced technical change can be explained using the well-known concept of the production frontier (Fig. 2.3). In order to reach a predefined CO_2 reduction goal E_2, it is necessary to move on the production frontier from P to R_1. This leads to a reduction of GDP from Y_1 to Y_2. In Fig. 2.3, it is assumed that technical change is induced by a climate policy. This leads to a shift of the production frontier from PF1 to PF2. Thus, point R_2 on the new production frontier allows CO_2 emissions to be reduced by the same amount, but with less loss in GDP.

2.3.2 Productivity Effect of Investments in Climate Protection

Technical change in many cases is linked to investments having been made. New systems incorporate technical change and bring about a modernisation of the capital stock. The production possibilities of a national economy increase over time due to

[44] See Sect. 5.2 which deals with empirical results of climate policy induced technical change.

the growth and renewal of the capital stock. It has to be asked which impacts the *diffusion of climate protection technologies* – driven by a climate policy – have on this process. Here it is decisive whether climate protection technologies themselves show a productive effect in the sense of increasing the material goods output potential. This argument is also summarised in Fig. 2.3. If the investment in CO_2 reducing technologies has no productivity effects, this results in a shift of the production frontier from PF1 to PF2.[45] However, if such an investment also has productive effects at the same time, the production frontier shifts towards a curve such as PF3 instead. It is obvious that in such a case the economy is better off, because PF3 compared to PF2 allows any reduction in CO_2 emissions to be reached with a higher level of GDP.

However, the argument is more complex than this because it also has to be accounted for that climate protection investments crowd out other productive investments. Under the assumption of a constant total investment volume, the following two cases are conceivable:

- In the first case, it is assumed that climate protection does not show any productive impact. However, in case of a climate policy, total investments consist of both productive and climate protection investments. By investing in productive technologies, the production frontier is shifted towards a higher production of goods, but does not bring about any reduction in CO_2 emissions. According to this case, the investments in climate protection technologies do not have any productive impacts, i.e. they only reduce CO_2 emissions. Together, both types of investment result in a shift of the transformation curve towards higher goods production and lower CO_2 emissions. However, since the climate protection investments do not have any productive impacts themselves, under the ceteris paribus assumption of a constant investment volume, the productive investments of companies are then crowded out. Thus, the increase in productivity is lower compared to the development in which all investments are used for productive technologies. To sum up, in case 1, the macroeconomic productivity increase would be diminished by such a "technological crowding out".
- In the second case, again, both traditional productive investments and investments in climate protection are made. The same effect occurs for the traditional investments as in the first argument. The differences are to be found in the character of the climate protection technologies. Here, it is assumed that they also have a productive character. They thus increase – in contrast to the first argument – simultaneously the production possibilities of material goods. This effect occurs, for example, if the climate protection technologies represent new efficient production technologies which replace older production technologies burdened with higher emissions and lower productivity.[46] The crowding out of

[45] Such an assumption was implicitly made in the arguments about induced technological change in Sect. 2.3.1.

[46] Xepapadeas and de Zeeuw (1999, p. 167) refer to this as the "modernisation effect".

investments with productive effects derived under the ceteris paribus condition of a constant investment volume is then alleviated, or, in an extreme case, does not occur at all.[47]

The assumption of a constant investment volume can be abandoned if it is assumed that there is an *increase in the investment volume*.[48] Under this assumption, if climate protection investments have a productive character, this would be tantamount to a "technological crowding in" and an increased modernisation of the national economy would follow in its wake. This kind of effect takes place, e.g. if older production systems lose profitability due to the introduction of an eco-tax, and are taken out of service earlier than planned. This induces additional investments in new, more productive systems with lower emissions.[49]

The effects of technical change induced by the climate policy depend very strongly on which of the two hypotheses with regard to the productive impact of climate protection technologies is given greater weight. The hypothesis of a non- productive effect of investments in environmental protection is probably valid for end-of-pipe solutions which are added on to the production systems and tended to dominate environmental protection in the 1970s and 80s. On the other hand, it seems plausible that those investments which directly affect production (production-integrated environmental protection), and which have become more important, have more productivity-increasing effects than the end-of-pipe systems. First empirical results indicate that climate protection investments do indeed have a productive effect as well.[50] However, it is also clear that the magnitude of this effect depends on the technology, and that, in general, a substantial increase in productivity is induced only by some of the climate protection investments.

2.3.3 First Mover Advantage

Besides price competitiveness, which is influenced by cost effects, foreign trade successes are also determined by *quality competitiveness*. Above all for technology-intensive goods, which include climate protection technologies, high market shares depend on the innovation ability of a national economy and its early market presence. If there is a forced national strategy to reduce greenhouse gas emissions, these countries tend to specialise early in the supply of the necessary goods. If there is a

[47] This is the effect if climate protection investments result in the same increase in productivity as new productive investments.

[48] This kind of increase in investments could either take place at the expense of consumption or, in a Keynesian argumentation, be additionally induced (see Sect. 2.3.4).

[49] Xepapadeas and de Zeeuw (1999, pp. 173–174).

[50] Walz (1999). However, if a CO_2 reduction strategy moves towards separation and storage of CO_2, such an effect would not occur.

subsequent expansion of the international demand for these goods, these countries are then in a position to dominate international competition due to their early specialisation in this field.[51]

Being able to realise these kinds of first mover advantages requires other countries to follow suit. Given the growing demand for energy on the one hand, and the pressure to push for non-fossil fuels on the other, there is a high probability of this taking place. For first mover advantages to be realised, however, the domestic suppliers of climate protection goods have to be competitive internationally so that they themselves and not foreign suppliers meet the demand induced by the domestic pioneering role.[52] Taking the globalisation of markets into account, this requires that competence clusters are established which are difficult to transfer to other countries with lower production costs. These competence clusters must consist of high technological capabilities linked to a demand which is open to new innovations and horizontally and vertically integrated production structures. The following factors have to be taken into account when assessing the potential of countries to become a lead market in a specific technology:

- Lead market capability: It is not possible to establish a lead market position for every good or technology. One prerequisite is that competition is driven not by cost differentials alone, but also by quality aspects. This is especially valid for knowledge-intensive goods. In general, the technology intensity of climate protection technologies can be judged as being above average or even (e.g. photovoltaics) high tech. Other important factors are intensive user-producer relationships and a high level of implicit knowledge. These factors are not easily accessible to competitors, difficult to transfer to other countries and benefit from local clustering.[53] Two other important characteristics are high innovation dynamics and high potential learning effects. They are the key that a country which forges ahead technologically is also able realizing a degression in costs.
- Competitiveness of complementary industry clusters: Learning effects are more easily realised if the flow of (tacit) knowledge is facilitated by proximity and a common knowledge of language and institutions. The results of Fagerberg (1995b) can be explained in this way. He found strong empirical evidence that the international competitiveness of sectors and technologies is greatly influenced by the competitiveness of interlinked sectors. By and large, climate policy related technologies have very close links to electronics and machinery. Thus, it can be argued that countries with strong production clusters in these two fields have a particularly good starting point for developing a first mover advantage.
- The importance of the demand side can be traced to the work of economists from the 1960s.[54] There are various market factors which influence the chances of a

[51] Porter and van der Linde (1995, pp. 104–105), Taistra (2001, pp. 242–243). See also Blümle (1994).

[52] Ekins and Speck (1998, pp. 42–43), Taistra (2001, pp. 250–251).

[53] See Kline and Rosenberg (1986), Lundvall and Johnson (1994), Asheim and Gertler (2005).

[54] E.g. Linder (1961); see Hippel (1986), Porter (1990), Dosi et al. (1990).

country developing a lead market position.[55] In general, a demand which is oriented towards innovations and readily supports new technological solutions benefits a country in developing a lead market position. Another factor is a market structure which facilitates competition. The price advantage of countries is very important. Countries increasing their demand fastest are most able to realise economies of scale and learning effects. If one looks at the diffusion rate of the various forms of climate protection technologies in different countries, it can be seen that European countries have been forging ahead recently. Furthermore, the political goals for the EU will bolster this advantage in future. Nevertheless, there are also other countries which have recently increased their diffusion rates. If large markets, such as the U.S., China, India or Brazil, increase their use of mitigation technologies, this will cause a huge rise in absolute numbers which might also strengthen their price advantage.

- In addition to technological and market conditions, a lead market situation must also be supported by innovation-friendly regulation.[56] This is especially true for sustainability innovations in infrastructure fields such as energy, water or transportation. In these fields, the innovation friendliness of the general regulatory regime, e.g. with regard to IPR or the supply of venture capital, must be accompanied by innovation-friendly sectoral and environmental regulation resulting in a triple regulatory challenge.[57] There is a lot of additional research necessary to develop a clear methodology on how to analyse the innovation friendliness of regulation. One promising approach is a heterodox one which uses the sectoral systems of innovation approach as guiding heuristics. The first empirical case studies for renewable energies show how such an approach can be operationalised.[58] This approach also offers the opportunity to combines various paradigms. The effect of different instruments on innovation is a key question analysed within the neoclassical environmental economics paradigm. Other paradigms contribute to this question, e.g. transaction and evolutionary economics, which emphasise take a somewhat different look at decision making. They state that the decisions, e.g. with regard to financing renewable energy technologies, follow a different paradigm (e.g. other valuation of financial risks, bounded rationality with regard to alternative suppliers of electricity). Furthermore, the policy analysis approach of political scientists emphasises the long-term character of political goals, or the comparatively important role of green policies for voters, which are key supportive context factors favouring innovations.
- Since the Leontief Paradox and subsequent theories such as the Technology Gap Theory or the Product Cycle Theory, it has become increasingly accepted that international trade performance depends on technological capabilities.[59] This has been supported by recent empirical research, which underlines the

[55] Beise (2004), Beise and Cleff (2004).

[56] Blind et al. (2004).

[57] See Chap. 8.

[58] See Chap. 8.

[59] Posner (1961), Vernon (1966), Fagerberg (1994), Wakelin (1997), Archibugi and Michie (1998).

importance of technological capabilities for trade patterns and success.[60] Thus, the ability of a country to develop a first mover advantage also depends on its comparative technological capability. If one country has performed better in the past with regard to international trade than others, it has obtained key advantages on which it can build future success. Thus, trade indicators such as shares of world trade or specialisation indicators such as the Relative Export Advantage (RXA) or the Revealed Comparative Advantage (RCA) are widely used to compare the technological capability of countries. Furthermore, a country has an additional advantage in developing future technologies if it has a comparatively high knowledge base. Thus, patent indicators such as share of patents or the Relative Patent Advantage are among the most widely used indicators to measure technological advantages.

Empirical findings to support this hypothesis can be drawn from studies of trade relations using indicators based on patent or trade data.[61] For both types of indicators, the share of the most important countries at the world total was calculated (patent share, world export share). Furthermore, specialisation indicators (relative patent advantage (RPA); relative export advantage (RXA) and revealed comparative advantage (RCA) were calculated, in order to analyse whether or not the countries specialise on the climate protection technologies. They were formed in a way that the indicator shows values between −100 (extremely weak specialisation) and +100 (extremely strong specialisation):

- Relative patent advantage: for every country *i* and every technology field *j* the RPA is calculated according to

$$\mathrm{RPA}\,ij = 100 * \tanh \ln\,[(\mathrm{p}\,ij / \sum_i p_{ij}) / (\sum_j p_{ij} / \sum_{ij} p_{ij})]$$

- Relative export advantage: for every country *i* and every technology field *j* the RXA is calculated according to

$$\mathrm{RXA}\,ij = 100 * \tanh \ln\,[(\mathrm{ex}\,ij / \sum_i ex_{ij}) / (\sum_j ex_{ij} / \sum_{ij} ex_{ij})]$$

- The revealed comparative advantage includes both exports and imports into the analysis and is calculated for every country *i* and every technology field *j* according to

$$\mathrm{RCA}\,ij = 100 * \tanh \ln\,[(\mathrm{exij/\,imp}\,ij) / (\sum_j ex_{ij} / \sum_j imp_{ij})]$$

[60] Wakelin (1997), Fagerberg (1995a), Fagerberg and Godinho (2005), Blind and Frietsch (2005).

[61] For the relevant indicators, see Legler et al. (1992, pp. 89–93) and Grupp (1998), who assign the RCA in particular high significance for measuring technologically-determined foreign trade advantages.

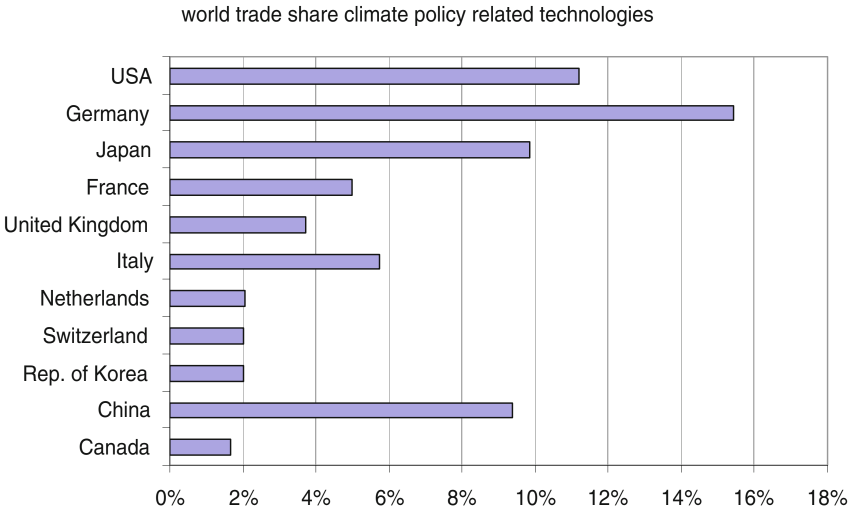

Fig. 2.4 World export shares of climate policy-related technologies in 2005 (Data: calculation of Fraunhofer ISI, Karlsruhe)

Climate protection technologies are neither a patent class nor a classification in the HS-2002 classification of the trade data from the UN-COMTRAD databank which can be easily detected. Thus, for each technology, it was necessary to identify the key technological concepts and segments.[62] They were transformed into specific search concepts for the patent data and the trade data. This required an enormous amount of work and substantial engineering skills. Furthermore, there is a dual use problem of the identified segments, and some segments – especially in the trade data – do not necessarily indicate that the technology is sustainable. In order to reflect that ambiguity the term climate relevant technology is used.

The importance of exports of climate policy related technologies can be seen from Fig. 2.4. World exports of climate policy related technologies are dominated by Germany, the U.S. und Japan. Furthermore, the other big EU countries play an important role. However, there are also new exporting countries entering the game, notably China and South Korea. Thus, it is very important to look at the technological basis behind these exports in the various countries.

The patent analysis reveals that climate policy related technologies have a considerable innovation dynamics. Between 1991 and 2004, the annual patent application in this field increased by 250%. The most important countries are the U.S., Germany, and Japan. However, over time, the share of the U.S. is shrinking. Germany's share remains largely unchanged, whereas Japan's share has been is increasing steadily (Fig. 2.5).

[62] This work extends the analysis of Legler et al. (2006) and DIW/ISI/Berger (2007) further by including additional climate policy related technologies into the analysis, and by moving from a stronger EU/OECD country oriented methodology towards including the total world market.

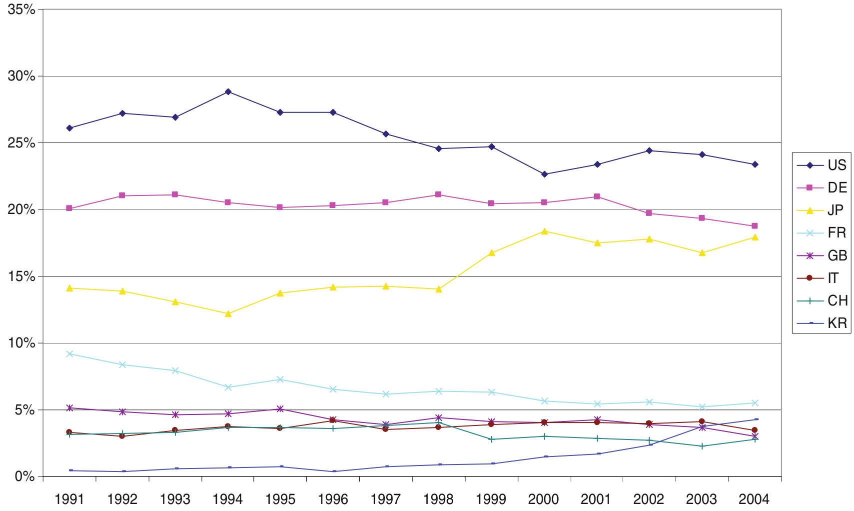

Fig. 2.5 Development of world patent shares of climate policy-related technologies (Data: calculation of Fraunhofer ISI, Karlsruhe)

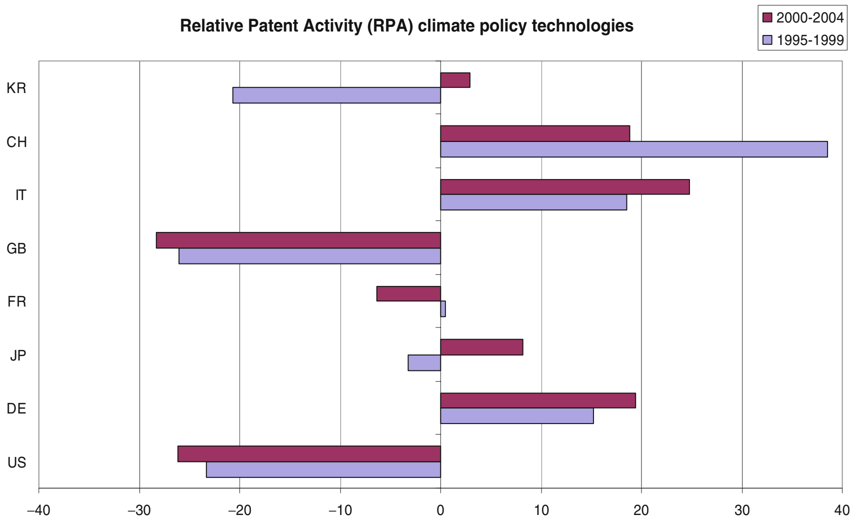

Fig. 2.6 Relative patent activity of climate policy-related technologies (Data: calculation of Fraunhofer ISI, Karlsruhe)

The shares at the absolute numbers do not account for the fact that the countries differ in size. Thus, in addition, specialisation measures are used which indicate whether or not a country is specializing on the technologies (Fig. 2.6). The numbers clearly indicate that Italy, Switzerland and Germany are very strong in the climate related patenting, However, in the last years, Japan has been able to specialise in this technology field too.

Another specialisation measure is related to the trade data itself. The most comprehensive indicator is the revealed comparative advantage. In addition to exports, it also takes the imports into account. A positive value indicates that the country has been specializing on the analysed goods, and vice versa. Figure 2.7 gives the results of the RCA for climate policy related technologies.

The data show that climate policy related technologies clearly form a very successful segment of the traditional industrialised countries. Germany, Japan, and even the US are showing positive RCA values. However, the data is not without caveats, especially if one looks at disaggregated data for single technologies. The RCA is difficult to interpret if imports are influenced by rapidly growing demand and domestic constraints to keep up capacity growth with increasing demand. The resulting surge in imports – and orientation of domestic producers on the home market – drive the RCA to negative level, even though the country might be very competitive. Such a situation has been taking place for wind energy in Germany, where demand outstripped national production capacities in the early 2000s. The latest data indicates, however, that the situation has been changing with regard to wind energy. Germany now not only holds about 30% of the patent applications in this technology field, but has been reaching positive RCA values too. Nevertheless, with regard to solar cells for photovoltaic, Germany is still having a negative RCA, due to an import surge from countries such as Japan. In other technological fields,

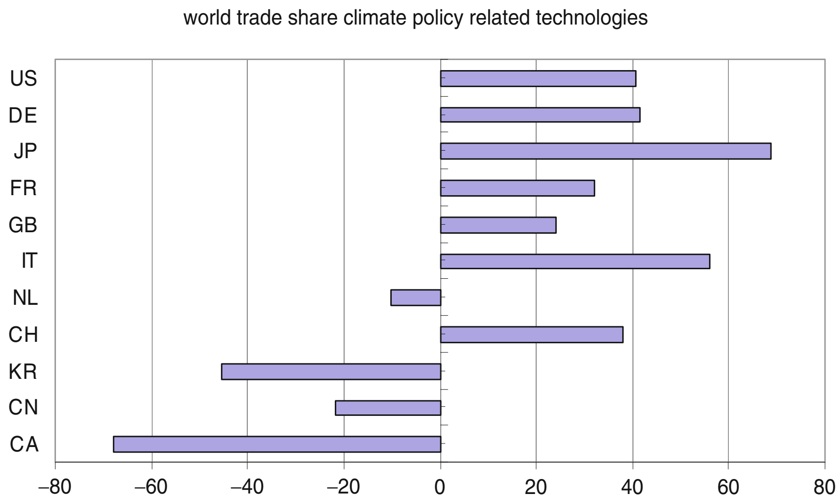

Fig. 2.7 Revealed comparative advantage of climate policy-related technologies in 2005 (Data: calculation of Fraunhofer ISI, Karlsruhe)

Germany has obtained positive RCA values for substantial times. This holds especially in the field of energy efficiency technologies, but also in supply oriented technologies such as carbon capture and storage (CCS).

Overall, it can therefore be assumed that Germany could profit from a first mover advantage in climate protection goods. However, it has not yet been possible to quantify more accurately the extent of such an effect, despite of all the progress with regard to measuring technological capability of the technologies. First, the measurement of the demand factors seems to be very case specific and stress the significance of demand conditions which are difficult to generalise. Secondly, and even more important, is the very high importance of an innovation friendly regulation especially for climate policy related technologies. Measurement of the intensity of the policy intervention – necessary for statistical analyses – is extremely difficult. Indeed, there is already significant disagreement on the mechanisms and the direction of influence of regulation on innovation, which underline the importance of additional research in that area.[63]

2.4 Demand Effects

There are two types of demand effects to be considered: First, the effect of structural changes between the components of final demand, and second the effect of an increase in aggregate demand on macroeconomic variables such as consumption and investment.

2.4.1 Structural Changes

A structural change in the component of final demand occurs if the climate policy triggers an increase in investment. Implementing a climate policy requires additional investments to increase mitigation capacities (direct positive impulses). At the same time, there is a drop in demand for both conventional energy carriers and conventional energy supply investments (direct negative impulses). With the exception of the case of a no-regret-potential, the costs for a climate policy are assumed to be higher than the capital and running costs for the conventional energy supply. Typically, a substantial share of the higher costs is transferred to the consumers. Thus, they have less income to spend on other consumer goods. Another possibility is the loss of tax revenues caused, for example, by tax exemptions for climate friendly technologies. Government then has to reduce other expenditures or increase revenues and will thus crowd out other investments or consumer spending. To sum up, compensatory effects occur within the structural adjustment mechanism

[63] See Chap. 8.

and, in the case of higher costs, negative consumption effects have to be accounted for when analysing structural shifts of demand.

Since numerous inputs from other sectors are necessary to supply the respective demand, the direct positive and negative impulses are carried forward as positive and negative *indirect effects* according to the production linkages of the industries involved. Thus the different positive and negative impulses lead to a different structural composition of the overall economy.

The argument so far has demonstrated the importance of the positive and negative demand impulses. It has been shown that it is the effect on the supply chain which influences the structural demand effects. They include the effects due to interlinkages between the production sectors. A more formal analysis reveals the following with regard to the overall effect on employment: The total production induced by an impulse is the sum of sectoral production p_k in all sectors *k*. The total employment which is induced by an impulse depends on the total domestic production in each sector in the value chain, and the labour intensity in each of these sectors. Furthermore, the total domestic production in each sector equals the overall total production of goods of each sector *k* minus the imports of each sector *k*. Thus, the total employment effect of an impulse can be written as:

$$employment = \sum_{k=1}^{K} p_k * (1 - import\ ratio\ k) * (labour\ intensity\ k) \quad \forall k = 1, \ldots, K$$

- The average import ratio, calculated for the complete value chain of an impulse, demonstrates which percentage of total production induced by the direct impulse is imported. The higher the import ratio, the lower the domestic production.
- The average labour intensity, also calculated for the complete value chain, demonstrates how many persons are employed per Euro of total domestic production induced by the direct impulse.

Thus, by comparing the labour intensities and the import intensities of the value chains of the positive and negative impulses of a climate policy, it is possible to get a first impression of the structural effects on employment. For energy-importing countries, it is significant that a considerable share of the negative demand effects – namely the reduction in demand for imported energy – takes effect not domestically but in the energy-producing countries. If a higher share of the climate policy investments is produced domestically, a net increase in domestic production results. If, in contrast, a considerable share of the energy is produced domestically, and a considerable share of the investments to reduce traditional energy consumption has to be imported, then a reduction in aggregated domestic demand results.

Figure 2.8 gives a first impression about the order of magnitude of import ratios of the value chain for impulses from different sectors and EU countries:[64] The average import intensity of the mineral oil product chain is by far the highest. On the

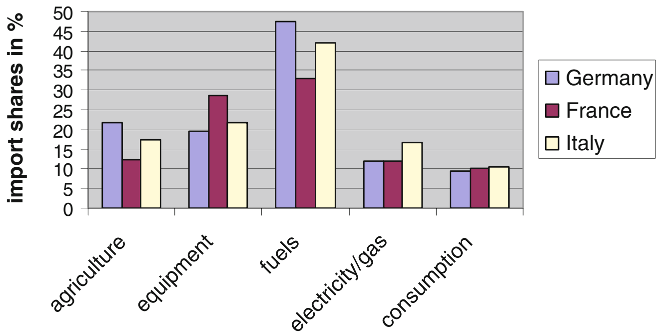

Fig. 2.8 Import shares of the complete value chain of various goods (Data: calculation of Fraunhofer ISI, Karlsruhe)

other hand, the total accumulated import of the value chain of electricity production is rather low. This reflects, among others, the important role of very capital-intensive nuclear power in France and Germany and the importance of German-based lignite in electricity production. The import shares of the value chain of average consumption are also quite low. They are an important indicator for the effect of impulses arising from the need to compensate for the additional costs. The value chains of the sectors most likely to benefit from climate policy strategies, e.g. investments in equipment or the agricultural and forestry sector (use of biomass) tend to have import shares which are in-between the value chains of the sectors they will substitute. Given these results, a substitution of conventional electricity production and oil products by renewable energy and more rational use of energy has no clear effect with regard to import substitution and depends on the specifics of the climate policy strategy which influences the composition of technologies.

The effect of structural changes in demand on labour intensity has to be accounted for, especially with regard to employment. An increase in employment results if the value chains of the sectors favoured by the climate policy have higher labour intensities than the value chains of the sectors favoured by the conventional energy supply. Typically, high labour intensities can be observed in the agricultural and forestry sectors. These result in an above average labour intensity of the associated value chains (see Fig. 2.9). The value chain of fuels production has low labour intensity, followed by the value chain of conventional electricity production. The

[64] These results are based on calculations performed with the international ISIS model which is based on the I/O-tables for various European countries. The author thanks his colleague Philipp Seydel from ISI for performing the model runs.

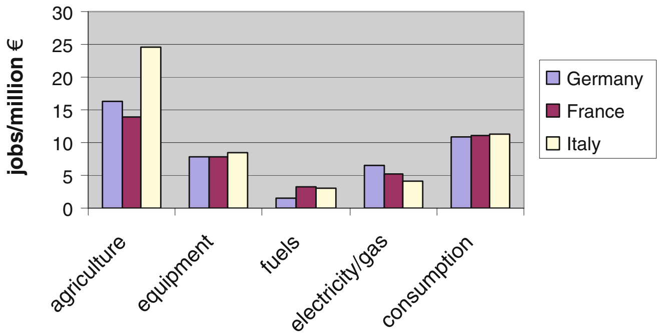

Fig. 2.9 Labour intensity of the complete value chain of various goods (Data: calculation of Fraunhofer ISI, Karlsruhe)

labour intensity of the investment sectors, by and large, is in between the labour intensity of fuels and electricity production. Thus, it can be assumed that the substitution of conventional energy supply by climate policy strategies generally leads to a modest increase in labour intensity. However, if the additional cost of the climate policy is very high, the value chain of consumption goods becomes increasingly important, because more and more of consumption must be sacrificed to cover the additional costs. The labour intensity of the value chain of consumption is above the one of the value chain for equipment. Thus, the effect of structural change towards labour intensive sectors becomes less prominent, the higher the cost difference of renewable energies to conventional energy supply.

2.4.2 Income Multiplier and Accelerator Effects

Demand-side effects are the cornerstone of the Keynesian model, which sees unemployment as caused by a deficit in aggregate demand. Assuming that the conditions for Keynesian unemployment are met, positive growth and employment effects are to be expected if climate policies result in an increase in the effective demand for goods.[65] This can lead to a self supporting increase in business activities triggered by mutually reinforcing income multiplier and accelerator effects. These effects depend on the economic conditions and the assumed reactions of the actors which are at the centre of the debate on Keynesian economics. An important assumption is that the demand from climate policies does not crowd out other segments of aggregate demand.

[65] For a theoretical presentation of environmental policy in the Keynesian model, see Lintz (1992, pp. 42–47).

However, some limitations have to be taken into account when considering this argument. The effect of Keynesian demand policy in the overlapping area of rational expectations, international goods and financial markets is substantially more complex than the mechanistic description above may suggest. Thus, the chances of success of a demand policy have been regarded with scepticism for some time.[66] It also has to be questioned whether the volume of demand changes to be moved by the climate protection would be sufficient for more than marginal effects of the business cycle. Limitations also result from the temporal links of the climate policy with a demand policy. A climate policy has to be designed for the medium to long term. In contrast, a demand policy has to be oriented on macroeconomic constellations. Only if these are favourable to a demand policy, can a climate policy induce positive macroeconomic effects in line with the impact mechanism described here.[67] On top of this, it is unclear whether the effects achieved due to an increase in demand can definitely be assigned to the climate policy. There would be no reason to mobilise the demand-increasing effects of the climate protection policy for employment policy reasons if the assumed potentials of a demand policy had already been tapped by other measures. It can be stated that climate policy cannot and should not be a substitute for other instruments of business cycle policy. Independently of this, it may give expansionary impulses which, depending on the macroeconomic constellation, bring about favourable effects, particularly since they might take effect virtually unnoticed by the formation of expectations under the disguise of environmental protection.

2.5 Combined Effects of the Impulses

In the previous sections impulses were discussed which are triggered by the various effect mechanisms. If one looks at the direction in which they work, a somewhat contradictory picture emerges (see Fig. 2.10):

- The cost and price effects resulting from the realisation of costly CO_2 reduction potentials have a clearly negative effect on the macroeconomic targets. These impulses are represented by a curve of type K_1 in Fig. 2.10.
- This picture becomes more sophisticated if, in addition, the existence of inefficiencies is considered. If a no-regret potential or a strong double dividend is assumed to exist, impulses result as shown in curve K_2. Caused by the increases in efficiency, a cost decrease results at first for the reduction of greenhouse gas emissions which has a positive impact on the macroeconomic targets. A neutrality of the cost impulse occurs if the total cost savings of the economic measures are equal to the total cost increases of the uneconomic ones. In the graph, this

[66] Landmann (1984, pp. 211–212).

[67] Conversely, it would be counterproductive for climate protection if climate policy had to be damped down in order to cool down an economy.

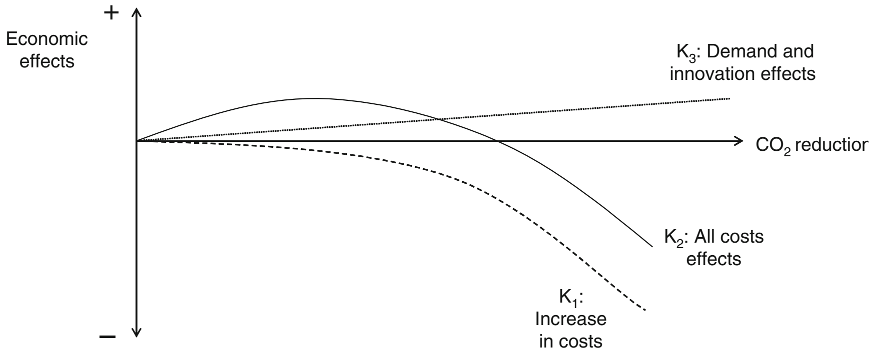

Fig. 2.10 Isolated effects of the impulses

corresponds to the point of intersection S of curve 2 with the abscissa. Up to this reduction of greenhouse gases, positive macroeconomic impulses emanate from the cost effects, only CO_2-reductions beyond this point trigger negative impulses in analogy to the above argument.

- The effects on the aggregate demand triggered by climate protection measures must be additionally taken into account. If one assumes a situation of underemployment corresponding to Keynesian perceptions, a demand impulse induced by climate protection measures is reinforced by the income effects. Under these assumptions, the effect of a climate protection policy can be symbolised by a straight line, K_3. Here, it is disregarded that the demand impulse could take place in a phase of the business cycle which is not appropriate for the given macroeconomic situation and, e.g. would trigger a wage-price-spiral or reactions of the central bank.
- In Sect. 2.3, it was argued that a climate policy could result in increasing productivity, increased generation of new technological solutions and the realisation of first mover advantages. The straight line K_3 in Fig. 2.10 symbolises the effect on national economy under the assumption that the positive innovation effects dominate the negative ones. However, it should be added that more detailed empirical analysis is required of both the existence and/or strength of these impulses.

It can be ascertained that the total impact results from the *interaction* of the various *mechanisms* and cannot be derived from the isolated observation of individual sub-effects. The intersection of curve 2 with the abscissa makes clear that the direction can change i.e. that moderate climate protection may bring about positive impacts, whereas there may be negative impacts from a very forced/accelerated climate protection. Another main point is that the direction of the effect not only depends on the climate protection policy itself, but also partly on how it is *embedded in the economic policy*. This is obviously the case for an energy tax, the effect of which on the national economy depends very heavily on the utilisation of the tax revenue and the interaction with the existing tax system. The size and direction of the income cycle effect also depends to a considerable extent on aspects external to the climate policy such as, e.g. whether a Keynesian under-employment situation exists, or the reactions of the bargaining parties and the central bank. Depending on the economic policy framework conditions, one and the same climate policy may thus have a different macroeconomic effect. Conversely, it can be argued that it is not actually the climate policy which generates these effects, but the economic policy per se. The climate policy here only acts as an additional motivation for implementing these measures – albeit as a motivation which is justified in itself, namely climate protection.

The arguments put forward so far concerned the isolated effects of the different economic mechanisms. Taken together, the combination of the different effects leads to a situation characterised in Fig. 2.11: Up to a certain point, a climate protection policy is likely to result in an increase in production. However, if more than a modest reduction of CO_2 emissions is aimed at, the negative effects become stronger and stronger leading to losses in production. The effects on employment are similar. However, if tax policies are used, with revenue being applied to lower the cost for labour, or if structural demand effects work in favour of more labour intensive sectors, the positive effects on labour demand are stronger and the negative effects start to prevail at a higher reduction level.

For policy making, the key aspect is how relevant the level of effects is from a political perspective. The following questions are particularly interesting:

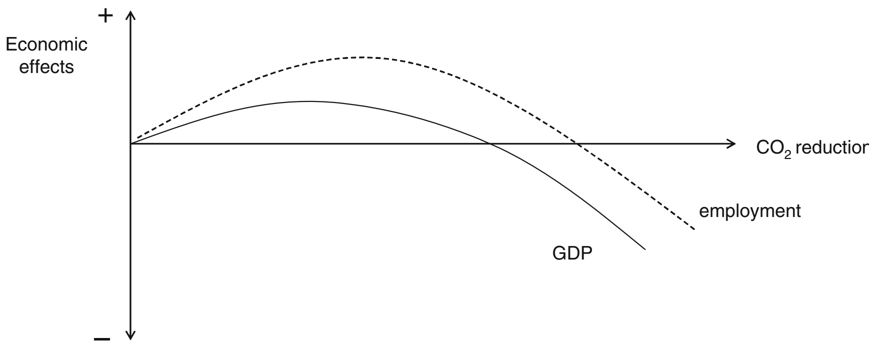

Fig. 2.11 Combined effects of the impulses

- At which level of CO2 reduction do positive effects occur; how big are they?
- Up to which level of CO_2 reduction are no severe macroeconomic losses to be expected?
- How big is the increase in employment if, for example, a CO_2 reduction is achieved which has no effect on production?

The theoretical analysis does not make any predictions about these kinds of questions. Thus, it is necessary to turn to the empirical macroeconomics of climate change.

Springer
http://www.springer.com/978-3-7908-2077-5

The Economics of Climate Change Policies
Macroeconomic Effects, Structural Adjustments and Technological Change
Walz, R.; Schleich, J.
2009, VII, 169 p., Hardcover
ISBN: 978-3-7908-2077-5
A product of Physica-Verlag Heidelberg