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A public finance perspective on climate policy: Six interactions that may enhance welfare

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Abstract

Climate change economics mostly neglects sizeable interactions of carbon pricing with other fiscal policy instruments. Conversely, public finance typically overlooks the effects of future decarbonization efforts when devising instruments for the major goals of fiscal policy. We argue that such a compartmentalisation is undesirable: policy design taking into account such interdependencies may enhance welfare and change the distribution of mitigation costs within and across generations. This claim is substantiated by analyzing six interactions between climate policy and public finance that are insufficiently explored in current research: (i) reduced tax competition in an open economy, (ii) portfolio effects induced through climate policy, (iii) restructuring public spending, (iv) revenue recycling for productive public investment (v) greater intragenerational equity through appropriate revenue recycling and (vi) intergenerational Pareto-improvements through intertemporal transfers. We thereby structure the hitherto identified interactions between climate change mitigation and public finance and show that jointly considering carbon pricing and fiscal policy is legitimate and mandatory for sound policy appraisal.

Content

1. Introduction

Climate economics usually considers only inefficiencies directly related to climate change mitigation. It typically ignores interactions with other fiscal policy instruments, such as taxes, subsidies or public investment that are motivated by non-climate aims such as job creation, debt reduction, provision of infrastructure, health services, education or distributive justice. Vice versa, public finance typically ignores constraints and opportunities of future decarbonization when designing instruments for such major goals of fiscal policy.

However, some climate policy instruments would generate large revenue streams. Assume for a crude approximation that a carbon price of US\$15 per ton of CO_2 was applied to 6 billion tons of CO_2 emitted by the United States in 2005: This amounts to annual revenues of US\$90 billion, ignoring behavioral responses (Metcalf 2007; for more elaborate estimations, see Bauer et al. 2013, or Carbone et al. 2013). Given revenues of this magnitude and their distributional significance, interactions between climate policy and other fiscal policy instruments are non-negligible. These interactions also depend on the way these revenues are spent, and the distortions and scarcity rents created or affected by climate policy. Ignoring such interactions in climate economics may lead to inaccurate policy appraisal in two ways: first, the situation prior to a policy reform is inaccurately described because some important distortions are neglected; second, taking into account these distortions will attribute greater welfare gains to policy reform. Along similar lines, for public finance, taking the challenge of climate change mitigation into account may offer new solutions to well-known problems.

This article argues that standard welfare analyses of both climate change mitigation policy as well as fiscal policy neglect important interactions between the two that (1) lead to efficiency gains and (2) impact intra- and intergenerational distribution. We support this thesis by discussing six effects (listed below) that are insufficiently explored in current research. We structure the hitherto identified interactions between climate change mitigation and public finance by grouping them pairwise under the topics of public revenue-raising, public spending and distribution. Each effect is attributable to a coincidence of the climate externality with a second major externality or goal of public finance. Whenever such effects occur, taking them into account by an integrated design of fiscal- and climate policies may lead to welfare gains that would be forgone by separate treatment of the public finance topics and climate mitigation.

In contrast to well-known “double dividend” arguments of environmental taxation, all arguments but one are independent of the assumption of pre-existing inefficient taxes and most of the effects analyzed are unambiguously welfare-enhancing. We both summarize mechanisms that have already been described in the existing (if sparse) literature on public finance topics in climate policy (but were largely omitted in previous overviews on the fiscal dimension of climate policy, such as Jones et al. (2012) or de Mooij et al. (2012)), and discuss some previously unexamined effects. We conclude by discussing why it is methodologically legitimate to integrate climate change mitigation policies into public finance and outline potential implications for policy assessment.

After briefly reviewing the standard approach of climate economics as well as the double-dividend argument (Section 2), we first consider in the main part (Section 3) two effects related to the raising of public revenues via climate policy instruments. Both effects are also related to capital accumulation, one in an open economy, the other in a closed economy:

1. There are sizable welfare losses from international capital tax competition. These can be shown to be mitigated when climate policy revenues replace capital taxation in an open economy where capital is mobile (Section 3.1).

2. Climate policy inevitably creates new rents. If private capital is insufficiently accumulated, rent collection causes distortions that are beneficial (besides correcting the climate externality and collecting the rents for distributional

motives). These distortions increase aggregate efficiency by redirecting investment towards producible capital (Section 3.2).

We then consider the structure and the total level of public expenditures:

3. The provision of different combinations of public investment (at a given total level) affects both the direct costs of climate change mitigation and the strength of its general equilibrium effects. The degree to which direct climate policy is matched by a restructuring of public goods provision thus affects future productivity and macroeconomic efficiency (Section 3.3).

4. When government funding from other sources is lower than optimal, it can be beneficial that some climate policy instruments raise *additional* funds. We consider spending options with a positive aggregate effect, such as investment in underfinanced public capital stocks or public debt reduction (Section 3.4).

Finally, we consider issues of intra- and intergenerational (re)distribution due to climate policy:

5. If inequality (at a point in time) impairs economic performance, or if equality as such is considered to be a component of social welfare, there are welfare losses from high inequality. While the direct effect of climate policy on heterogeneous households is likely to be regressive, revenues from climate policy instruments can be used to more than offset this regressivity. This may be achieved by tax rebates for low-income households or public spending on education and local public goods (Section 3.5).

6. There are large intergenerational gains from using public finance instruments to redistribute the costs and benefits of climate change mitigation over time: If climate policy were combined with intergenerational redistribution so that future generations contribute to mitigation efforts, the net mitigation costs could be *negative* at each point in time, implying a Pareto-improvement across generations (relative to the no-policy case). Options for organizing such a transfer include changes to debt policy and to pension schemes (Section 3.6).

Our arguments are based on the premise that climate policy and additional non-climate effects should not be studied separately, but within a comprehensive public finance framework. The reason is that separate estimates cannot be directly added up due to the non-negligible general equilibrium effects that effective mitigation policies would cause. Our discussion addresses this as well as potential consequences for the evaluation of climate change mitigation policies, both in climate economics and public economics (Section 4).

2. Current assessments of climate change mitigation policies

This section summarizes two strands of literature on which our study builds: First, mitigation strategies have commonly been evaluated by so-called integrated assessment models. Our brief description of the main methods in Section 2.1 underlines the contrast between highly detailed modeling of climate change, its damages and technological mitigation strategies, and the simplified treatment of the policy space, which is confined to climate policy. Second, Section 2.2 covers the “double dividend” debate as the most prominent attempt to include interaction effects of carbon taxes with fiscal policy.

2.1 Integrated assessment modeling of optimal mitigation and second-best policies

Optimal climate change mitigation targets, pathways to implement them and the associated gross and net mitigation costs (without and with avoided damages from climate change) are commonly estimated with integrated assessment models (IAMs). These are numerical simulations that combine a model of the climate system with an economic model (typically a multi-sector neoclassical growth model). Two optimization approaches[1] can be distinguished by their

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[1] Alternatively to optimization with policy variables as controls, the effects of a given policy proposal can be simulated with IAMs to evaluate its

treatment of mitigation targets and damages due to climate change: cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA).

CBA in the context of climate change focuses on the optimal choice of a mitigation target, which is determined by weighing the opportunity costs of consumption foregone by investing into mitigation against the benefits of avoided damages from climate change, expressed as social costs of carbon, which are the economic damages resulting from a marginal increase in carbon emissions (the difference between costs and benefits gives the net costs, which are negative for the optimal mitigation path). In principle, this requires a detailed representation of a multitude of channels by which climate change may affect human welfare, such as a rising sea level, extreme weather events (storms, heat waves, droughts, …), water availability, the spread of diseases or agricultural yields (Reilly et al. 2013). Instead, stylized damage functions are standardly used to capture some of these effects (e.g. Hope 2006, Nordhaus 2007).[2] Thus, findings of different IAMs used for CBA depend on their respective modeling of market- and non-market damages, as well as the choice of the social discount rate, treatment of uncertainty and extreme outcomes, or substitution possibilities between physical capital and environmental services (Stern 2008, Ackerman et al. 2009, Weitzman 2009, Pindyck 2013).

CEA focuses on optimal strategies to achieve an exogenously given mitigation target (damage level). Only mitigation measures and gross policy costs, for instance, expressed as discounted consumption losses, are determined endogenously. Thus, the complexity of modelling climate damages is avoided; instead, high-emission sectors and mitigation technologies are represented in more detail. This also allows for a comparison of different assumptions about the availability of technologies to inform policy choices: for example, the "option value" of developing carbon-capture-and-storage or nuclear power for decarbonisation can be estimated (see for example Luderer et al. 2012, or Clarke et al. 2014 for an overview).

Thus, the representation of the climate system and emission-relevant economic sectors is often highly detailed in IAMs of either type - but other welfare-relevant aspects of the socio-economic system that have strong interactions with climate change and mitigation strategies, such as health or the distribution of income and wealth, are often only modeled in a crude and incomplete fashion, or not at all: For example, health is only considered in terms of negative effects of climate change, and mostly only as part of the motivation for very stylized aggregate damage functions. The distributions of income and wealth within countries are generally not considered.[3]

A more detailed representation of these non-climate aspects of welfare and related inefficiencies is important for both the identification of optimal mitigation strategies, and for the analysis of specific policies: First, the optimal mitigation paths and the related costs and welfare effects obtained from IAMs may change, since (1) there may be trade-offs (in a CBA) between investing in the low-carbon transition or for example poverty reduction (Dasgupta 2007), and (2) some non-climate objectives, such as health or distribution, are strongly affected not only by climate change itself, but also by the choice of mitigation measures (examples: local air pollution from electricity generation and transport, health effects of non-motorized transport, food prices affected by biofuel demand). Ignoring non-climate inefficiencies may lead~~s~~ to a too optimistic description of the situation without climate change mitigation, and ignoring the interactions with mitigation measures leaves out important welfare gains that can be attributed to it. For this study, this means that the welfare gains described occur relative to a baseline that contains more inefficiencies than standardly considered by IAMs.

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costs. This is called the evaluation approach (Weyant et al. 1996).

[2] A rare exception is Reilly et al. (2013), who explicitly model the health effect of higher ozone concentrations due to climate change.

[3] This refers to models for determining globally optimal GHG mitigation pathways. For related literature that does include distributional and health effects see, for example, Rausch et al. (2010) who analyze specific climate policy instruments for the USA with respect to their distributional effects; Thompson et al. (2014) additionally include health effects.

Second, it is even more important to take into account non-climate issues when practical GHG mitigation policies are considered in decentralized models, because limitations of climate- and non-climate policy instruments imply even more scope for interactions. It is common practice to analyze climate policy instruments (such as different forms of carbon pricing, emission standards or R&D support schemes for low-carbon technology) in second-best settings with another non-climate inefficiency, but the latter is usually directly related to emission-relevant sectors (such as imperfect coverage of carbon pricing schemes, or market failures in the energy sector related to innovation or imperfect competition). In such settings, it is generally preferable to use more than one policy instrument to address all sources of market failure, and to adjust these instruments to each other (Sorrell and Sijm 2003, Fischer and Newell 2008, Gillingham et al. 2009, Fischer and Preonas 2010, Mattauch et al. 2012, Kalkuhl et al. 2012 and 2013; Aldy et al. 2010 provide a good overview).

We argue that second-best analysis of climate policy should be systematically extended to include inefficiencies (and policies to correct them) that are neither related to climate change nor specific to emission-relevant sectors, but nevertheless have interactions with mitigation policies. Integrating them is important for the choice, design and evaluation of policy reform packages that involve both climate- and non-climate policies (see also Section 4).

2.2 Lower cost of public funds: The ”double dividend” of environmental tax swaps

There is one interaction of environmental and fiscal policies that has been discussed very prominently: the use of pollution tax revenues for cutting distortionary taxes elsewhere and potentially reaping a “double dividend” (Tullock 1967; see Pearce 1991 for an early application to climate policy). We summarize the argument because it is structurally similar to those brought up in the next section, and because this similarity makes clear how policy-relevant these new effects are, given the considerable political impact of the “classical” double dividend argument.

Assume some unspecified public spending requirement in a second-best setting where no lump-sum taxes but only distortionary taxes are available (this is the additional non-environmental inefficiency here), so the costs of raising public funds are non-zero. Then, if an environmental policy is introduced that not only corrects an externality (the first dividend), but also generates revenues, this could lower the cost of public funds (the second dividend) and thus the gross costs of environmental policy, because distortionary taxes could be reduced (“revenue recycling effect”). The claim that this constitutes an improvement over lump-sum recycling of the revenues to households is called the “weak” double dividend hypothesis, which is widely confirmed to hold (Goulder 1995a, Bovenberg 1999)[4].

More controversial is a stronger version of the hypothesis: an environmental tax swap does not only have lower, but even zero or negative gross costs. However, via general equilibrium effects, environmental taxes can also exacerbate the distortions from pre-existing taxes in factor markets that they are meant to reduce: Higher product prices reduce real factor returns, thus substituting an implicit for an explicit tax and causing a negative third effect on welfare, the so called “tax interaction effect” (Bovenberg and de Mooij 1994, Bovenberg and van der Ploeg 1994, Parry 1995). Due to the narrower tax base, this may more than offset the revenue recycling effect, thus *increasing* the gross costs and rendering a strong double dividend unlikely (the net costs including benefits from higher environmental quality are likely to remain negative).

For the case of a carbon tax, early numerical simulations supported these findings (Goulder 1995a, b; see also the review by Bosello et al. 1998).

However, some crucial assumptions of the original analysis have been challenged. We summarize three arguments that make the existence of a second, fiscal dividend of climate policy more likely:

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[4] Another case of a “double dividend” is the so-called employment dividend, where an environmental tax reduces involuntary employment (Carraro et al. 1996, Bovenberg 1999).

First, the strong double dividend hypothesis is more likely to hold if the initial tax system is inefficient, and if the environmental tax swap moves it closer to its non-environmental optimum. As summarized by Bovenberg (1999) and Goulder (2013), this includes situations when clean goods are better substitutes for leisure than dirty goods, but consumption is uniformly taxed; when taxation imposes different marginal excess burdens on different factors; when polluting activities are initially subsidized; when the environmental tax (partially) falls on Ricardian rents from a fixed factor used in the production of polluting goods (Bento and Jacobsen 2007); or when labor markets are imperfect (Koskela et al. 1998, Koskela and Schöb 2002, Schöb 2003). A related effect is the potential reduction of the informal sector (and broadening of the labor tax base) that may result from an environmental tax swap (Markandya et al. 2013).

Second, the studies above rejecting the strong double dividend hypothesis mostly rest on the assumption that environmental quality enters the utility function only, where it is (weakly) separable from consumption and leisure. This separability assumption has been challenged, either because environmental damages may shift consumption towards "defensive expenditures" (Schöb 1995, FitzRoy 1996), or because improved environmental quality implies better health and thus potentially higher labor supply (Schwartz and Repetto 2000; substantial positive health co-benefits of climate policy due to local air quality improvements have been found e.g. by Thompson et al. 2014). Each works in favor of a strong double dividend. A counter-effect is that improved environmental quality may also act as a complement to leisure, thus reducing labor supply (Bovenberg and van der Ploeg 1994).

Third, and maybe most importantly, it is unclear if environmental quality interpreted as the long-run climate is adequately modeled as a direct impact on utility only. If it is assumed on the contrary that environmental quality also serves as a public input to production, as is common in much of climate change economics (see for example Nordhaus 1993, Leimbach et al. 2010), a strong double-dividend also becomes more likely (Bovenberg and de Mooij 1997).[5] Barrage (2014) finds that neglecting climate change impacts on production and only focusing on direct utility losses leads to a carbon tax that is around 10% lower than optimal.

Overall, this underlines the importance of designing and analyzing climate policy in conjunction with the tax system due to fiscal interactions (Goulder 2013). But despite being in the focus of previous literature on interactions between environmental and other public economics, a distortionary tax system is by far not the only additional non-climate source of inefficiency, and its revenue-neutral restructuring not the only policy option that needs to be considered in a full assessment of the costs of climate policy. We now turn to additional effects that have been underappreciated so far.

3. Six reasons why climate change mitigation enhances welfare.

In this section we present six specific arguments for the thesis that interactions of climate change mitigation with other public policy objectives enhance welfare beyond the environmental improvement.

We first consider the advantages of a tax on carbon emissions for raising public revenues, both in an open economy subject to tax competition under capital mobility (Section 3.1) and in a closed economy when it affects investment behavior (Section 3.2).

Two further arguments concern public expenditures: the effect of *restructured* public spending on private abatement costs or general equilibrium effects (Section 3.3), and options to spend *additional* revenue from climate policy on productive public capital or for debt reduction (Section 3.4).

The final two arguments concern the intra- and intergenerational distribution of the costs of climate change: At any point in time, a carbon tax is likely to be regressive. However, its revenues may be so high that not only compensating

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[5] Goulder (1995a) notes that when environmental quality is an input to production, the notion of "gross costs" of tax reform as welfare costs without direct environmental benefits becomes ambiguous: "*In my view, [the result of Bovenberg and de Mooij (1994)], strictly speaking, does not provide support for the strong double-dividend notion because it involves benefit-side issues; this is not a case of negative gross costs.*" (p.169, ibid.)

measures could be financed, but even inequality reductions beyond that (Section 3.5). Over time, it might be possible to reallocate some of the future benefits of avoided climate damages to reduce current mitigation costs. When combined with such a transfer the correction of the climate externality should not lead to *net* costs to any generation (Section 3.6.). These distributive consequences of climate policy matter normatively, but also crucially affect political feasibility, which is a topic we only elaborate on briefly in this review.

Of course, this list is not exhaustive; the focus of this article is to point out in a structured manner when welfare impacts of climate policy have been underexplored, not to exhaustively review the field. Other non-climate inefficiencies which may interact with climate policy include informational asymmetries between the government and the private sector, horizontal and vertical externalities of public policies in countries with a federal structure (Keen 1998), labor market rigidities (Guivarch et al. 2011), tax-base effects related to the informal economy (Markandya et al. 2013), or weak institutions leading to tax evasion (Liu 2013). Cyclical climate policy or "Green Keynesianism" is another related field not considered here (Fischer and Heutel 2013, Harris 2013). Furthermore, not every effect will be relevant in every situation. To facilitate the selection of the most important effects for a specific policy package and economic environment, we emphasize the conditions under which each effect occurs.

3.1 Reduced international tax competition: Substituting rent taxation for capital taxation

The double dividend literature discusses a restructuring of the tax system in a closed economy. We now turn to another possibility for tax reform which is peculiar to the case of an open economy. If we assume that capital is internationally mobile[6], social welfare could be increased if the following effect is taken into account:

When governments use climate policy revenues to finance their budgets and in turn cut taxes on private capital, this improves the efficiency of the national tax system by reducing the interregional externality of tax competition, which is due to capital mobility.

This effect may arise when three premises regarding international capital flows hold. In the field of public economics, in particular the literature on horizontal fiscal federalism, a consensus has emerged that all these premises in fact hold true. The first is that capital is mobile internationally to a sufficiently high degree (Zodrow 2010). Second, this capital mobility restricts fiscal policy choices and causes a race-to-the-bottom in capital tax rates. Finally, this in turn leads to an inefficient underprovision of local public goods. The mechanism has been shown analytically by Wilson (1986) and Zodrow and Mieszkowski (1986). Empirically, the underprovision of local public goods is reflected e.g. in the observed underprovision of public infrastructure (Bom and Ligthart 2013; see also Section 3.3). Next to the more empirical survey by Zodrow (2010), other good overviews of the tax competition literature can be found in Wilson (1999) or Keen and Konrad (2013).

Thus, as long as capital markets are characterized by deep international integration, capital must be considered an inefficient tax base. In this international setting, taxation of fossil resources is preferable to capital taxation for three related reasons (Franks et al. 2015):

First, the supply of fossil resources is less elastic than the supply of capital, because the total stock of fossils is fixed, income from selling fossils is a rent and the resource owner will sell even at low prices, depending on buyers' behavior. Taking into account strategic behavior, it indeed turns out to be optimal to levy taxes on the use of fossil fuels and thus capture part of the resource rent.

Second, reductions of the rate of return on capital by a carbon taxes are smaller than for a capital tax. Since mobile capital chases the highest rate of return, a unilateral increase of the capital tax leads to capital flight. When instead a

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[6] In the context of the analysis of open economies and climate policy the field of carbon leakage has received great attention. In the present study we do not discuss carbon leakage, because the overlaps between climate change economics and public finance seem less important for this topic.

carbon tax is increased, then less fossil resources are used in the country. Fossil resources and capital are complementary to a certain degree, thus the return to capital also decreases. However, this indirect effect on the rate of return is weaker than the direct effect caused by capital taxation. Thus, there is relatively little relocation of capital to other countries when carbon taxes are increased unilaterally. More capital relocates under a comparable unilateral increase of capital tax rates.

Third, if revenues from fossil resource taxation finance a budget that contains productivity-enhancing public spending, e.g. on public infrastructure, this has a positive impact on rates of return to capital.

The efficiency result, that is, that carbon taxes are preferable to capital taxes, holds quite generally. Franks et al. (2015) exemplify this in a model of a global economy in which several regions compete for mobile capital and have to import fossil resources from an exporting region. They discuss two assumptions about the strategic behavior of the governments of the importing and exporting countries explicitly. First, the efficiency result holds irrespective of whether the resource importing countries cooperate among each other or not. Further, it does not matter whether the resource exporting countries can coordinate their actions to influence the resource price or not.

Concerning the first assumption, a buyers' cartel may exercise a kind of monopsony power to extract the resource rent (see e.g. Tahvonen, 1995; or Karp, 1984). We shall refer to this as the *monopsony effect*. It also occurs in the model of Franks et al. (2015). Moreover, they show how in the absence of cooperation among buyers, unilateral climate policy in the form of carbon pricing allows governments to appropriate part of the rent. Governmental expenditures enhance productivity, as shown e.g. by Bom and Ligthart (2013). Thus, as long as the effect of diminishing returns to scale does not dominate, it is optimal both from a global welfare perspective as well as from an individual country's perspective to unilaterally increase taxes. The productivity-enhancing properties of public spending align the incentives of competing resource-importing countries in a similar way as cooperation would do, such that a weak form of the monopsony effect may take place.

Second, when the governments of resource-exporting countries are assumed to interact strategically on the resource market, they will react to buyers' carbon taxation by increasing their taxes on resource exports with the effect of raising the consumer price of fossil resources. In that case, the rent that buyers may capture using the carbon tax is decreased. Nevertheless, the governments of importing countries may still capture a sufficiently large amount of the rent such that the carbon tax is superior to the capital tax.

Considering the environmental effects, Franks et al. (2015) find that an increase in both the buyers' and the sellers' taxes increases the consumer price and thus decreases the amount of resources sold. A green paradox, as brought up by Sinn (2008), does not occur. Resource sellers increase neither their rate of extraction nor the cumulative amount of extraction. Thus, substituting carbon taxes for capital taxes has beneficial environmental implications under all assumptions about strategic behavior mentioned above.

In sum, it is likely that for a wide range of assumptions about the strategic behavior of resource-buying and selling countries the unilateral substitution of carbon taxation for capital taxation increases social welfare. Through the above outlined mechanisms, such a substitution is not only attractive for countries with a strong preference for environmental protection; more importantly, it is highly relevant for countries which are exposed to the negative impacts of capital mobility and which are thus constrained by tight budgets (see also Section 3.4).

The study by Franks et al. (2015) implies that environmental and fiscal externalities such as tax competition should be studied within one integrated framework. Omitting the beneficial effects of a carbon tax on the problem of local public goods provision overstates the costs of climate change mitigation. If there is a pre-existing inefficiency, which is caused by capital tax competition, then unilaterally implementing a carbon tax enables governments to reap a double dividend of addressing climate change and alleviating tax competition.

3.2 Mitigated underinvestment: Inducing a "macroeconomic portfolio effect" by rent taxation

The arguments above considered cuts of non-environmental taxes in return for imposing a carbon price. This section considers an effect related to investment behavior under a carbon price, independent of the remaining tax system.

We argue here that the welfare effect of climate policy may exceed its environmental benefits if a carbon price on a flow of GHG emissions (or fossil fuel inputs) reduces the rent of an underlying stock that is part of a larger asset portfolio, and if the resulting rebalancing of this portfolio cures a non-climate inefficiency. Our example for such an inefficiency is the underaccumulation of producible capital due to imperfect intergenerational altruism.

The common argument in favor of a tax on rents – that it is non-distortionary – does not hold if there are alternative assets (Feldstein 1977), since saving behavior and thus portfolio composition change. However, it has been shown that this may actually constitute an efficiency and welfare improvement, e.g. for a tax on a fixed factor, "land", when some type of producible capital is underaccumulated (Petrucci 2006, Koethenbuerger and Poutvaara 2009, Edenhofer et al. 2013a). A similar effect occurs for the case of carbon pricing acting as a tax on rents from fossil fuel stocks (Siegmeier et al. 2014):

Assume that there is a finite stock of fossil resources which is fully owned, and that the extraction cost path is fixed, abstracting from new discoveries and uncertain technology improvements.

Then, without climate policy, the productive sector borrows physical capital and buys fossil fuel as input factors, while GHG emissions are free (but deplete the atmospheric reservoir). Capital yields interest payments and resource ownership yields the value of the extracted part of the stock, at a price reflecting extraction costs, the opportunity costs of extracting and selling the fuel later, and a scarcity rent (depending on demand elasticity, total supply and market structure). Households will divide their savings between capital and (ownership claims to) resources, balancing their portfolio according to a no-arbitrage condition on expected returns.

Now introduce climate policy in the form of a quantity instrument, specifically a permit scheme that directly controls the path of GHG emissions. For simplicity, assume that the government implements an upstream policy by perpetually issuing resource extraction permits, the total amount of which is exogenously given (e.g. reflecting an optimal mitigation pathway derived from an IAM, see Section 2.1). The fraction of the total resource stock that a household owns will also be the fraction of total extraction permits that this household obtains in each period.[7] Thus, households do not choose resource ownership and resource extraction independently, but the former implies the latter. Now, if the government decides to auction some or all of the permits instead of allocating them for free (or equivalently, to tax the revenues from permitted resource extraction), the resource stock owners' rent is transferred to the government. The expected returns and thus the value of the resource stock decrease, and households will direct more of their savings towards capital as the alternative asset until the no-arbitrage condition is restored due to the falling interest rate. If capital was initially underaccumulated, efficiency increases, and the welfare losses of climate change mitigation are reduced. Siegmeier et al. (2014) provide a formal proof for this "macroeconomic portfolio effect" in an overlapping-generations model with an exhaustible resource and publicly financed technological progress.

The argument also applies to implementations of climate policy via a carbon tax. However, a complicating factor in this case is that mitigation can only be enforced via a tax rate that decreases over time to provide an incentive for conservation (Sinclair 1992). Thus, the objectives of climate change mitigation and rent extraction for the public have to be weighed against each other. In contrast, a permit scheme has two policy parameters to optimally achieve both objectives: the quantity of permits and the share that is auctioned.

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[7] For simplicity, we assume that the structure of the portfolio of resource stocks (which may differ for example in terms of extraction costs) is identical across homogenous households.

In practice, the most important limitations will be that the permit scheme does not cover all global resource stocks, and that ownership claims to these stocks may not be freely tradable (as required for optimal portfolio adjustment). The latter concern may be addressed by implementing climate policy as a scheme of individual ownership claims to the stock of the atmosphere, which might change the political economy of climate policy (Siegmeier et al. 2014).

So far, we have neglected uncertainty, which is of central importance in the resource sector: The costs of exploration and extraction and research efforts to lower them, total supply of fossil fuels, and the costs of substitute technologies are generally highly uncertain. While the portfolio effect described above will still occur under uncertainty, additional effects are possible - among them a "second-order" portfolio effect may arise between equally risky investment opportunities: If climate policy extracts rents from the fossil resource sector, the attractiveness of investment into resource exploration endeavors or R&D in extraction technologies deteriorates vis-à-vis R&D in resource productivity or substitutes for fossil fuels, for example renewable sources of energy.[8] Lower investment in risky fossil resource projects is likely to increase extraction costs and decrease resource supply in the future, thus providing an additional incentive for improving resource productivity and reducing the costs of renewables.

Relaxing other simplifying assumptions such as ideal policy implementation and market structures may also affect the importance of the macroeconomic portfolio effect for the relative efficiency of specific carbon pricing schemes – but not its general occurrence whenever fossil resource stocks are one of several investment options.

3.3 Lower private abatement costs: Restructuring public spending

We now turn to public spending: This subsection discusses the implications of climate policy for the optimal composition of public spending; the next subsection considers its optimal level.

Our argument here is that the structure of public spending is insufficiently adjusted to policies that directly target GHG emissions, and vice versa. Efficient and effective climate policy consists of two parts: Direct measures (such as a carbon price) to induce private substitution of clean for dirty technologies, and "indirect", complementary adjustments of public spending (in particular on physical infrastructure) so that private abatement is less costly, because the utility and/or productivity of clean substitutes are enhanced. These two parts are typically not optimized together, although doing so would significantly lower total costs of climate policy and increase social welfare.

We highlight the importance of public spending for climate change mitigation, point out how this fact is neglected in mainstream analysis and practical implementations of climate policy, and summarize first insights and future challenges regarding the "integration" of direct and indirect climate policy.

The feasibility and costs of climate change mitigation depend on how fast different parts of the capital stock can be adapted to the use of low-carbon technologies, since almost 80% of today's emissions are directly related to producible capital, as they stem from burning fossil fuels and industrial processes (IPCC 2014a). Emissions are reduced by clean substitution of directly GHG-emitting devices such as power plants or vehicles, but the speed and costs at which this can be done also strongly depend on the (non-emitting) physical systems that complement them[9], such as the wider electricity system and transport infrastructure. These parts of the capital stock are often publicly financed or subsidized, and differ strongly between high- and low-emission scenarios, so the structure of public spending plays a key role for the low-carbon transition.

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[8] Although the funds withdrawn from such fossil resource projects could also be directed towards less risky assets altogether, it is plausible that some investors ("venture capitalists") will switch to risky alternatives, including R&D in renewable energy technologies which at the same time become more attractive under a credible political commitment to climate protection.

[9] The „carbon lock-in" literature discusses a wide range of sources of inertia in GHG-emitting activities, which may be interdependent in a "techno-institutional complex" (Unruh 2000). We focus here on technological dependencies only.

This can be illustrated by contrasting two studies: Davis et al. (2010) calculate emissions "committed" by already existing *directly* CO_2-emitting capital stocks, and find that using these devices to the end of their technical lifetimes (up to 40 years) could lead to a global warming of 1.3°C by 2060. They acknowledge the role of *non-emitting* parts of the existing capital stock for the inertia of the system, but do not model them. Guivarch and Hallegatte (2011) partly close this gap by additionally modelling transport infrastructure and asset location, which cause inertia in transport demand. They show that this implies committed emissions that are 35% higher in 2030 than those projected by Davis et al. (2010). Furthermore, they find that if this additional inertia as well as non-carbon GHG are accounted for, a 2°C warming target cannot be achieved by only regulating new investments (as could be erroneously concluded from Davis et al., 2010). Instead, even existing capital stocks need to be adjusted by retrofitting or premature retirement, including *"the drivers of energy services demand, and in particular modal shift and mobility needs linked to infrastructure and assets locations"* (Guivarch and Hallegatte 2011, p.804). Similar results could be expected from extensions for other high-emission sectors, in particular energy, where non-emitting capital stocks such as networks for electricity and gas transport or sea ports for coal and liquefied natural gas play a large role, for supply as well as demand.[10]

Despite its central role for decarbonisation, infrastructure spending has been neglected in the analysis, design and implementations of optimal mitigation pathways and climate policy to date. Most formal analytical or numerical models focus on directly GHG-emitting capital stocks and direct measures such as carbon pricing, without separate representations of infrastructure and other indirectly emission-relevant capital stocks. This implies the assumption that a social planner or an idealized government optimally adjusts the composition of publicly provided goods (that are complementary to GHG-emitting private goods) so that the costs of (private) direct abatement are minimal. However, Shalizi and Lecocq (2010) argue that carbon pricing does not provide a sufficient signal for efficient investment into (public or private) long-lived capital stocks more generally, and that dedicated mitigation programs targeting these stocks are required.

However, this is not what we observe – instead, direct policies and infrastructure policies are often inconsistent: For example, many European countries that ratified the Kyoto protocol (and participate in the European Emissions Trading System) have not directed public infrastructure spending away from roads and airports and towards rail (ITF 2014); commuter tax benefits persist in countries such as Germany, despite the important role of densification for transport emission reduction; while there is direct support for EV by price instruments in many European countries (Kley et al. 2010), public provision or support of electric vehicle charging infrastructure is rare, although the lack of charging infrastructure has been identified as a major obstacle to higher electric vehicle deployment (Sims et al. 2014). Efforts certainly fall far short of the adaptation of existing dirty capital stocks, or active policies to promote asset relocation, that Guivarch and Hallegatte (2011) consider necessary for reaching a 2°C target.

Two recent studies do consider integrated climate policy and point out the potential benefits. Waisman et al. (2012) use a second-best CGE where households and firms have imperfect foresight, and exogenously impose a specific set of adjustments of transport infrastructure and the related spatial asset distribution. They show numerically that this leads to significantly lower mitigation costs, in particular in the long run: Beyond the mid-2030's, estimated costs of mitigation are lowered by 50% and more (and the carbon price is also drastically lowered). However, since the complementary measures are ad-hoc and exogenous, their (second-best) optimal level cannot be elucidated. Siegmeier (2015) shows that if publicly provided goods affect the utility derived from private consumption goods, coupling an environmental tax

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[10] While infrastructure in the transport sector is still largely publicly owned, privatization in the energy sector has often included infrastructure such as electricity and gas networks, backup generation capacity, or gas storage. But since the energy sector for technological reasons suffers from a host of market failures, it remains heavily regulated: Prices and important physical infrastructure parameters (e.g. location, type and size of installations) are still generally controlled by government agencies, and subsidies are significant. Thus, even though changing the energy infrastructure may not be a pure public spending issue, it is still a subject of public policy due to the public good characteristics of many crucial system elements, so the main arguments of this section still apply.

swap with an adjustment in public goods provision may mitigate a negative effect on labor supply (the negative tax-interaction effect of the double dividend literature, see Section 2.2).

To realize these potentials by improved, integrated climate policy, a better understanding is needed of why governments have not optimally adjusted the structure of public capital stocks so far. Potential explanations include technological aspects (cf. Shalizi and Lecocq 2010): (1) uncertainty of technological development, which weighs particularly heavy for long-lived public capital, (2) economies of scale for incumbent technologies and network effects, combined with the longevity of existing capital stocks, (3) long lead times for investment into infrastructure. Furthermore, institutional aspects may play a role, such as (4) conflicting competences (vertical externalities) between several levels of government, or (5) competition (horizontal externalities) between neighboring localities.

In sum, it seems likely that better integration of instruments directly targeting GHG emissions and complementary adjustments of public spending could yield significant welfare improvements. More research is required to determine the optimal balance between these two elements of climate policy, in particular in various scenarios with deficits of market- and government institutions.

3.4 Optimal public spending level: Alleviating budget constraints

In this section, we consider policy reforms that are not revenue-neutral and discuss when and how additional revenues from climate policy may improve welfare by increasing the total *level* of public spending, or by debt reduction. We first argue that revenue- and spending side effects of climate policy may lead to a larger *optimal* public budget. We then introduce the additional inefficiency that that the public spending level is sub-optimally low. We argue that additional revenues raised by climate policy may offer an opportunity to increase the public budget (closer) to its optimal size. Specifically, we review some empirical evidence that public capital is underprovided, potential explanations for this observation, and why revenue from climate policy may offer a remedy. Finally, the related topic of using climate policy revenues for public debt reduction is discussed.

The impact of climate policy when the public budget was previously (second-best) optimal

An optimal reaction in terms of public spending to the introduction of a consistent, stringent climate policy would be to adjust to a new (probably higher) spending level, for two reasons:

First, a given level of public funds may be raised at a lower cost when climate policy raises revenue via carbon pricing (see revenue-side arguments in Sections 2.2, 3.1, 3.2).[11] Graphically, the curve of marginal costs of public funds is lower.

Second, the benefit that can be achieved at any level of public spending is likely to be higher under comprehensive climate policy: In some of the most emission-intensive sectors that require a transition to low-carbon technologies, public spending plays a particularly large role and will be more beneficial when it is adapted, e.g. infrastructure in energy and transportation (see Section 3.3). Public spending will also play a large role in adaptation to climate changes, and potentially in offsetting distributional effects of climate change (Section 3.5). Graphically, the curve of marginal benefits of public spending is higher.

Together, this implies a larger public budget: the marginal cost- and benefit curves intersect at a higher spending level.[12] The increase in public spending in this new optimum may of course also include spending options that are

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[11] Goulder (2013) points out that “green taxes” should not only be part of an optimal tax portfolio, but that even if the starting point is a sub-optimal distortionary tax system, additional revenue should come from a higher green tax rather than an “ordinary” tax, as long as the green tax is not “too large”.

[12] When public investment is financed by taxing the rents on fixed factors (along the lines of a Henry George Theorem, see Arnott and Stiglitz (1979)), it may even be possible to establish the socially optimal allocation, see Mattauch et al. (2013). However, given a situation in which there are two externalities, related to the climate and to productive infrastructure which is publicly funded, it is unclear if the social optimum can be reproduced by using the revenues from correcting the climate externality to finance the public investment.

unrelated to climate change, depending on the marginal benefit of each option.

Underprovision of public investment: why climate policy may help

Of course, the public budget is not always optimally sized in practice. There is evidence that public investment may be too low in many countries: Aschauer (1989) was the first to estimate a production function that includes public capital and found that public capital is undersupplied in the United States. Gramlich (1994) reviewed literature following up on Aschauer's study for the US and finds evidence for an undersupply at least for some types of public capital (e.g. urban transport infrastructure). More recently, Bom and Ligthart (2014) conducted a meta-regression analysis over 68 empirical studies for OECD countries. Their estimate for the output elasticity of public capital ranges from 0.08 (short-run effect of public capital broadly defined, at the national level) to 0.19 (long-run effect if only transport infrastructure and utilities at the regional level are included). Taking an approximate ratio of public capital to GDP of 0.5, this implies a marginal rate of return on public capital of 0.16 to 0.38. Comparing this to a depreciation rate of 0.1 and interest rate of 0.04, they conclude that public capital is indeed undersupplied.

We now consider four potential explanations for the non-optimal public budget, and why these problems may not apply or be weaker if additional revenues from climate policy are available:

First, public revenues may be too low due to weak institutions (this explanation will be more relevant for non-OECD countries). More specifically, institutions may be ineffective at implementing or enforcing conventional taxes, e.g. on income or consumption. Enforcing a carbon price may be less demanding, in particular when it is done upstream (fossil fuels consumption is relatively easy to measure). Political feasibility remains an issue though, since many implementations of a carbon price are visible to consumers (gasoline prices), and carbon pricing may affect rents from fossil fuels and/or existing energy- and carbon-intensive capital stocks.

Second, the existing allocation of other public funds may be inefficient in the sense that spending does not maximize net benefits. For example, when conventional taxes were introduced or increased in the past, political feasibility might have required the earmarking of revenues from specific taxes for specific spending (Wagner 1991). But even if the allocation of revenues from other taxes cannot be changed, the new revenues from climate policy can be allocated freely to different spending options, at least initially.[13]

Third, imperfect altruism towards future generations, or myopic politicians, may lead to high discounting of future benefits and thus to too little investment into projects with long-term benefits, which make up a substantial part of the public budget. If this were true, choosing stringent climate policy would be inconsistent, absent some mechanism that lets current generations benefit from future avoided damages (e.g. increasing asset prices, see Section 3.6). If climate policy was chosen nevertheless, it would under these circumstances more likely be designed in a revenue-neutral way, i.e. combined with cutting other distortionary taxes rather than an increase in the public budget – or at least a budget increase would probably not be in favor of projects with long-term benefits. Among the latter, mitigation policy still may stand the highest chances of realization, if the political momentum for climate policy is strong enough to lead to an "earmarking" of climate policy revenues for mitigation spending, as discussed above.

Fourth, even if investments with long-term benefits were supported for the sake of future generations, there may be a lack of fiscal tools for financing their high up-front costs, e.g. political limits on public debt such as a maximum ratio of total or new debt to GDP (if the limit is set by financial markets due to doubts about a country's creditworthiness, this

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[13] Of course, for the same political economy reasons that led to an earmarking of non-carbon pricing revenues, a climate policy package may also contain restrictions on how to use carbon pricing revenues, e.g. for spending on climate change mitigation measures. As long as public spending on mitigation is marginally productive – which is probably currently the case, given the weakness of climate policy – it still constitutes a welfare improvement, even though there may be better uses for at least some part of the funds. See Burtraw and Sekar (2014) for data on the use of revenues from currently existing carbon pricing schemes, or Brett and Keen (2000) for an attempt to explain earmarking of environmental taxes.

can often be traced back to weak institutions or inefficient political processes, which we already discussed above as the first two potential explanations of public underfunding). Then, additional revenues from climate policy may indeed offer more flexibility to invest in long-term projects. A related option that is discussed more prominently is using climate policy revenues for the reduction of public debt, which is covered next.

Public debt reduction

High levels of public debt have increasingly come into focus of policy makers, especially after their dramatic increase in developed countries as a result of the financial crisis. This is linked to the issue of climate change, as both are long-term challenges concerning many future generations.

Whether the existence of public debt in itself has a deteriorating effect on the economy is discussed controversially in the empirical literature (Kumar 2010, Herndon et al. 2013), and to our knowledge not clearly supported by theory. In our view, the literature on public debt and climate policy (Carbone et al. 2012, Ramseur et al. 2012, Rausch 2013) does also not give a genuinely new argument of why debt would by inefficient. Instead, the additional inefficiency that comes with the inclusion of public debt is represented through a government that fails to pay off the debt in an optimal way. This combines two effects that we treat in other sections:
First, debt reduction using revenue generated by climate policy can be less costly than financing it by other taxes - this is the classical double-dividend argument, as discussed in Section 2.2.
Second, revenue from climate policy can also help governments to optimize the intertemporal distribution of debt repayment – this is an argument regarding inter-generational distribution, worked out in more detail in Section 3.6.

For example, both effects are captured by Rausch (2013): Using a numerical model, he finds that a *revenue-neutral* inclusion of a carbon tax in the tax portfolio would entail a gross welfare loss. But since the availability of the carbon tax also opens the possibility to raise *additional* revenue [at lower marginal costs of public funds] which can then be used to reduce the public debt, future interest payments can be avoided and welfare improved (even before taking avoided climate damages into account). This obviously has strong implications for the inter-generational distribution of welfare, as both the benefits from avoided environmental damages and those from lower interest payments on public debt would accrue to future generations, leaving today's generations at a loss. It has been argued elsewhere that the opposite approach, leaving future generations with more public debt, but an improved environment may be a way to finance mitigation measures today (see Section 3.6).

3.5 Using carbon revenues for reducing inequality: the role of public investment

So far, we have considered interactions of climate policy and public finance at the aggregate level, both concerning the levying of revenue from limiting emissions as well as alternatives for spending these revenues – and tacitly made the assumption that households are homogeneous. *Distributive* effects both on the revenue-raising and spending side become important in two cases: First, if inequality of income or wealth is taken to be undesirable as such (reflected by a specific concept of social welfare); second, if some types of inequality lead to aggregate inefficiency (which is our focus here).

Climate policy is likely to be regressive (Bento 2013) and may thus increase inequality, which in turn could harm overall economic performance (Berg and Ostry 2011, Berg et al. 2011, Kumhof and Rancière 2010). Recent publications treating household heterogeneity and climate policy demonstrate that it is possible to reduce or even eliminate the regressivity of climate policies by a carefully chosen recycling of the revenues. There are several mechanisms for this: Most of the literature focuses on household transfers and cuts in distorting taxes and finds that regressivity can be reduced, or even eliminated (Bureau 2010, Metcalf 1999, Chiroleu-Assouline and Fodha 2009, Rausch 2010). In contrast, how the financing of public investment with climate policy revenues affects the regressivity of these policies and thereby the overall efficiency remains unexplored. We suggest that if inequality is indeed harmful to overall economic performance, then such a policy could be another reason for lower welfare losses from climate change mitigation. Alternatively, if inequality reduction is valued as such, whether or not it impacts aggregate efficiency, social welfare is increased by combining climate policy with appropriate revenue recycling options that may alleviate, not increase inequality.

We subsequently first explain why climate policy is often considered regressive and which remedies have been proposed for this. We find broad agreement in the literature that recycling the revenues through household transfers and tax cuts drastically reduces the overall regressivity. Second, we explore whether inequality reduces economic efficiency and we find that in particular inequality of opportunities is detrimental to overall economic performance. Third, we argue that this strengthens the case for public investment as another remedy for inequality of opportunity, notably investment in education (OECD 2012). Finally, we integrate the first and the third argument by raising the question to which degree the regressivity of climate policy could be offset by using its revenues specifically for public investment.

Environmental taxation: regressivity and remedies

Research on the equity impacts of climate policy has focused on factors that may make policy instruments regressive while neglecting the question of how revenue-recycling may achieve distributional goals (Bento 2013). Following Fullerton (2011), there are several reasons why environmental policies can be regressive: The two most important effects are that, first, low income households spend a larger portion of their income on products which require fossil inputs. Environmental policy would increase the price of these goods and thus be regressive. Second, unskilled workers might lose their jobs in the polluting industry, while jobs in the renewable sector preferably go to high-skilled workers.[14]

Bento (2013) reviews recent empirical literature and finds that environmental policies are likely to have a regressive effect. Furthermore there is wide agreement that the revenues from environmental policies can be used to mitigate these regressive effects (Bureau 2010, Metcalf 1999, Chiroleu-Assouline and Fodha 2009, Bento et al. 2009 Bureau 2010, Parry and Williams 2010). There may even exist ways to implement Pareto-improving environmental policies in a heterogeneous household setting.

Theoretical work that accounts for revenue recycling mainly focuses on households' transfers and cutting distorting taxes with climate policy revenues to mitigate regressivity: Chiroleu-Assouline and Fodha (2011, 2014) use an overlapping generations approach where agents have different income sources and skills, and thus income levels, as well as different time preference rates. They show that for any degree of progressivity of a carbon tax, there is a labor tax-cutting redistribution mechanism that renders the tax reform Pareto-improving. In their framework, climate policy is acting like a capital tax and the regressivity of this tax is not caused by any of the drivers listed above, but rather by the design of the pre-existing labor tax system.

Klenert and Mattauch (2014) and Klenert et al. (2014b) also confirm that redistribution of the carbon tax revenue can make an (otherwise regressive) carbon tax reform Pareto improving. In contrast to previous work, they explicitly take into account that the poorer a household, the more of its income it spends on carbon-intensive subsistence goods, thus addressing the first concern about inequality regarding environmental policies raised above.

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[14] Other distributional effects of environmental policies are: First, for capital-intensive abatement technologies, environmental policies would drive up the demand for capital. This would depress wages which would have a regressive effect since low-income households receive most of their income from wages. Second, when pollution permits are grandfathered to firms, scarcity rents are created, which again go to the high-income firm owners (Parry 2004). Third, low-income households may attach a lower value to environmental quality and care more for goods like food and shelter. Thus high-income households would benefit more from avoided damages. Fourth, avoided damages to capital increase the present value of capital, for example of an oceanfront house. Since capital owners are already better off, this policy would also have a regressive effect.

Rausch et al. (2010) look at a broader range of revenue redistribution mechanisms, such as transfers and tax cuts, in a more detailed general equilibrium model which is calibrated to the US economy. They find that the tax itself can have a slightly progressive effect, due to the dependence of poor households from transfer payments, which are unaffected by climate policies. Accounting for revenue recycling renders the tax reform even more progressive.

Does inequality reduce economic efficiency?

The conventional view of economic theory is that inequality reduction as a policy goal reduces the overall efficiency of an economy due to losses in the redistribution process (Okun 1975). In particular, Kaldor (1955), based on the observation that rich households save more than poor households, comes to the conclusion that redistributive policies would thus lead to less capital accumulation. In the context of environmental taxation, Metcalf (1999) and Parry and Williams (2010) point out that there is a trade-off between efficiency and the degree of reduced regressivity: more efficient environmental policies tend to be more regressive.[15]

However, the conventional view neglects that there are two fundamentally different types of inequality: inequality of *opportunity* is caused by factors which are beyond an individual's personal responsibility, like the economic situation of the parents (Roemer 1993). In contrast, inequality of *returns to efforts* gives incentives to households to work harder. The conventional view is correct with respect to inequality of returns to efforts as it increases an economy's growth rate; however inequality of opportunities decreases it (Marrero 2010). High levels of inequality of opportunity are usually coupled to low social mobility, a fact which is also known as the ''Great Gatsby Curve'' (Corak 2013).

Berg and Ostry (2011) and Berg, Ostry, and Zettelmeyer (2011) look at growth in the long term and find that a trade-off between equity and efficiency might not exist. It rather seems that in countries with low economic inequality, the length of periods of strong economic growth, so called “growth spells”, is increased. Moreover, Kumhof and Rancière (2010) claim that increased inequality and debt-to-income ratios can trigger economic crises, based on an analysis of the economic crises in the U.S., 1929 and 2007, which both were foreshadowed by a strong increase in wealth and welfare inequality.[16]

Additionally, inequality has been found to increase the risk of civil conflicts (Østby 2008, Østby and Strand 2013, Cederman et al. 2011), which in turn reduce growth.

Reducing inequality while promoting efficiency: the role of public spending

High inequality of opportunity makes health care, education and other factors unaffordable for some parts of the population. This situation can partially be alleviated by public spending (OECD 2012). A short-term impact of education on inequality of opportunity can in particular be expected from measures such as further training of unemployed or continued education for more senior workers in order to include or keep them in the labor market as well as language courses for immigrants.

Additionally, public investment in physical infrastructure is known to promote efficiency and growth (Romp and de Haan 2007, Agenor 2013), but the empirical literature regarding its effect on inequality is inconclusive: while some studies find that investment in infrastructure, which is financed by distorting taxes, reduces inequality (Calderon and Chong 2004, Calderon and Serven 2004, Lustig and Ortiz-Juarez 2011, Jacoby 2000), there is also evidence for increased inequality through public spending (Artadi and Sala-i Martin 2003).

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[15] Burtraw and Sekar (2014) highlight that treating efficiency and equity as two objectives between which a government needs to strike a balance reflects a view where the atmosphere is owned by the state. In contrast, *”if one views the property right to atmosphere resources as inherently assigned to individuals and held in common, the issue of how to use the economic value created from introducing a price on carbon might be viewed as illegitimate, at least from the perspective of the resource owner“* (ibid., p. 4f).

[16] Additionally, it is debated whether inequality harms aggregate welfare by increasing health and social problems – independently of its impact on economic growth (Wilkinson and Pickett 2009). A part of the debate is summarized in Noble (2009) and Liebig (2012).

The theoretical literature is similarly ambiguous: Chatterjee and Turnovsky (2012) show in a growth model with heterogeneous dynastic agents that government spending *increases inequality* in welfare and wealth in the long run. Glomm and Ravikumar (1994) find that income tax-financed public spending is *neutral* on the income distribution. Mattauch et al. (2014) and Klenert et al. (2014a) show in a heterogeneous-agent model that Pareto-improving public spending can have a distribution-neutral effect when it is financed by a tax on consumption, and even an *inequality-reducing* effect when financed by a tax on capital. In their model, agents are distinguished by their saving motive, their time preference and their source of income. These assumptions are well founded in the empirical literature[17] and are necessary to reproduce a realistic wealth distribution (De Nardi 2004, De Nardi and Yang 2014).

Financing public investment by carbon pricing

Combining the aspects discussed above raises two additional points: First, instead of directly redistributing revenues from carbon taxes (to mitigate their regressivity) or cutting distortionary taxes (which could also enhance inequality, see Klenert et al. (2014b)), governments could also invest in infrastructure to enhance growth. The resulting higher living standards of most households may alleviate inequality of opportunity directly. Second, climate policy revenues could be used for public investments that specifically reduce intra-generational inequality. What is unclear in both cases is the size of the inequality-reducing effect that climate policy revenues alone could finance. Future work on this would need to model household heterogeneity to reflect both the regressivity of environmental taxation as well as differential benefits from public investment. If the result was that for inequality reduction, public investment is preferable to direct financial benefits to poor households, then discussions of mitigating the regressive nature of environmental policies should focus on this option.

3.6 Intergenerational distribution: fiscal strategies for Pareto-improving climate policy

Climate change is fundamentally an intertemporal problem: If climate policy is to avert dangerous anthropogenic interference with the climate system, then substantial mitigation costs arise today, but much higher benefits through avoided damages occur in the future.

So the *net* costs of climate change could be lower at each point in time, if climate policy were combined with intergenerational redistribution: Future generations as the main beneficiaries of mitigation measures could be made to bear some of today's mitigation costs by a transfer to present generations. The resources for financing low-carbon infrastructures and emission reductions could thus be mobilized from future generations who have higher benefits from climate protection than the current population.

Such a transfer may be welfare-enhancing because it could achieve a *Pareto-improvement,* that is, negative net costs of climate policy in this context. Combining climate policy with intergenerational transfers that make it Pareto-improving could be a politically feasible solution to the climate problem: Given the standstill in international negotiations, Pareto-improving climate policy would separate the solution of the climate problem from the more general (and politically even more difficult) considerations of intergenerational justice (Broome 2012). It differs from socially optimal climate policy by violating the optimal intergenerational distribution of welfare, but could potentially imply negative net costs of climate policy at each point in time.

But is Pareto-improving climate policy possible? Could intergenerational transfers from people yet unborn to those alive be implemented by fiscal policy? Recently different possibilities for such transfers have been explored. The

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[17] Attanasio (1994), Dynan et al. (2004) and Browning and Lusardi (1996) demonstrate that the savings motive varies across income classes. Quadrini (1997), Diaz-Gimenez et al. (2011) and Wolff (1998) highlight the role of different income sources and Lawrance (1991) show that households' time preference rate decreases the more wealth they own.

remainder of this section first clarifies the above argument about Pareto-improving climate policy and then discusses suggestions for organizing an intergenerational transfer from the future to the present.

There is universal agreement about the basic economics of the climate problem: Climate change is a market failure as the emission of greenhouse gases are an externality. Economic theory holds that the correction of this externality comes at no cost. Some theorists have thus claimed that there really are no costs of climate change if those who will benefit from mitigation pay for it (Foley 2009, Broome 2010, 2012). However, climate change is an externality spread out over time so that rather than saying that there are no (net) costs of climate change, it seems more apt to conclude that there are net costs of climate change mitigation today, while higher benefits occur in the future. Thus only by arranging for an intergenerational transfer from the future beneficiaries of climate policy to the present generation that has to bear the costs of low-carbon investments, a Pareto-improving solution to the climate problem could be reached: no generation would need to pay more for climate change mitigation than the benefits it will receive. But only when climate mitigation policy is thus complemented by carefully designed transfer measures should there not be net costs to the present generation.

Recent research has considered two options for organizing intergenerational transfers: Diminution of capital stocks, and higher returns for current holders of assets such as fixed factors of production. An earlier strand of research has investigated a third option: public debt. Most of these options cannot be examined in representative agent models, so that modelling is usually carried out using overlapping generation models.

First, an obvious possibility for a transfer from future to current generations would be that current generations leave future generations less (private or public) capital in return for a cooler world (Foley 2009, Broome 2012). Rezai, Foley and Taylor (2012) use a variant of the DICE model (Nordhaus 1993) to examine the possibility of financing mitigation with resources diverted from other investments. They find that implementing the social optimum compared to a true business-as-usual scenario[18] leads to higher consumption for all future people except those living in the first decade. Moreover, a more equity-conscious social planner, mimicking an intergenerational transfer, would want to allocate more consumption to the first decade, leading to a Pareto improvement for all generations. However a mechanism to achieve this based on tax policy instruments is not described.

On the contrary, Below et al. (2013) propose a mechanism based on pay-as-you-go (PAYG) pensions between generations, using an overlapping-generations model. Therein, the old generations are compensated for their mitigation efforts by the respective young generation alive at the same time through a PAYG transfer payment. With this transfer scheme extending far into the future, a mitigation policy that is Pareto-improving for all generations can be achieved.

This result may be very sensitive to the way of modeling the PAYG transfers. Governments usually must rely on distortive taxation, typically on wage income, to finance the transfers which results in additional welfare losses. Below et al. (2013) collect the PAYG pensions in a lump-sum fashion, which makes the proposed mechanism less useful for real-world fiscal policy.

A second possibility to organize an intergenerational transfer builds on the idea that climate change mitigation will change the value of current assets: their future returns will differ from a business-as-usual scenario due to fewer damages to production in the future. Karp and Rezai (2014) demonstrate in a stylized overlapping-generations model that if agents live for two periods, capital is a fixed production factor and agents only own assets when they are old, a Pareto-improving transfer is possible in the following sense: If the mitigation of an externality requires investments today, all generations' welfare is improved except that of the current young. Their welfare can also be improved if the current old compensate them with a share of their increased asset value. If addressing a generic externality requires investments today, all generations' welfare is improved except that of the current young. Their welfare can also be

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[18] In which agents are deprived of mitigation instruments and do not see themselves capable of influencing the level of emissions.

improved if the current old compensate them with a share of their increased asset value. Karp and Rezai (2014b) confirm this result for a non-fixed capital stock with adjustment costs between investment and consumption as well as standard dynamics of the atmospheric stock.

Numerical simulations confirm this for non-fixed capital stocks with adjustment costs in investment and realistic dynamics of the atmospheric stock (Karp and Rezai 2012b).

However, one may doubt whether such a model captures the relevant features of asset-holders behavior. The premise that future generations would pay today's proprietors higher prices for assets if future rents were higher due to mitigation measures today seems credible. But then rational proprietors today would welcome or execute investment in climate-friendly infrastructure, which largely does not conform to the current economic reality. Possible reasons for this mismatch include free-riding behavior, commitment problems, lack of information and imperfect foresight or time inconsistency.

An even simpler explanation may be that the direction of the price change of the asset crucially depends on how mitigation is represented in such a model. In a setting similar to that employed by Karp and Rezai (2014), Schultes et al. (2014) model the price changes of an asset that is traded across generations, land in their case, when future returns that accrue to this asset change in response to mitigation. They demonstrate that returns to land can rise or decline in response to mitigation, depending on how mitigation technology and land enter production. The price of land may thus also rise or fall. In such a model, today's asset owners may have an incentive not to invest in mitigation, if the mitigation options and the role of land for production interact in such a way that mitigation devalues their assets.

A third, earlier line of enquiry has focused on constructing an intergenerational transfer by debt policy. When the Ricardian equivalence does not hold, it is possible to compensate current generations for their welfare losses from mitigation by transfer payments that are financed by increasing public debt. For instance Bovenberg and Heijdra (1998, 2002) find that environmental tax policy can be Pareto-improving when combined with public debt in a continuous overlapping generation model. However their results hinge on a number of assumptions of which it is unclear whether they are a credible representation of the climate problem. Environmental degradation depends on the size of the capital stock, and harms utility, not production. Mitigation is only possible through either taxation (and thus reduction) of capital (Bovenberg 1998) or public abatement spending (Bovenberg 2002). These modeling assumption make it difficult to compare these earlier results to contemporary findings.

In summary, climate change mitigation in principle does not require sacrifices from the current generation in order to benefit future generations if these could be made to bear some of the costs of decarbonization. The net costs of climate change mitigation for the near future could thus be lower or even non-existing if an appropriate Pareto-improving intergenerational transfer can be realized. On a theoretical level, recent research has identified several options open to fiscal policy to organize such a transfer, although the robustness of the proposed mechanisms is unclear. On a practical level, political feasibility of committing long into the future to elaborate intergenerational transfers may well be doubted and is a topic for further research.

4. Discussion: Why interactions between climate policy and public finance matter; Implications for policy evaluation

The thesis defended in this article – the interactions between public finance and policies lead to lower welfare gains relative to treating the two fields in isolation – is dependent on two premises. The first premise concerns the framework of economic policy evaluation: Climate policy happens in a world with multiple market failures and pre-existing distortions (for instance due to taxes) which are in turn influenced by climate policy. We assume that models designed to evaluate climate policy should take these into account. Otherwise effects that might substantially change the outcome of the evaluation will be missed. The second premise concerns the benchmark of evaluation: Compared to standard discounted utilitarianism, if (intragenerational) equality is valuable as such (see Section 3.5.) one may find that welfare gains are larger compared to evaluations under discounted utilitarianism. Seeking intergenerational Pareto-improvements instead of intertemporal optimality (see Section 3.6.) reinforces this conclusion. The following discussion to defends the first premise and justify why it is appropriate to consider the welfare effects of climate change in a framework that also includes other fiscal policy objectives.[19]

Why is it appropriate to study the costs of climate change within a public finance framework?

From a practitioner's perspective, there is a straightforward answer to this question: Whenever substantial interactions between two distinct fields exist, one should include these interactions into policy appraisal. This is particularly true if such interactions become tangible in terms of large financial flows, as is the case for interactions between climate change mitigation and public finance: If mitigation efforts yield revenues that can form a substantial part of national budgets (see Section 1), policy-makers will *de facto* be concerned with the interactions of climate policy with fiscal policy.

To the theorist, such an answer may seem naïve. We discuss – and rebut – two major objections to the practioner's perspective. The first objection concerns the legitimacy of treating certain economic phenomena together and not in isolation. The second is the doubt that through the advent of a "new" problem to be addressed by policy, addressing existing imperfections becomes any more feasible or actually yields a genuine benefit.

Regarding the first objection, the question to which degree abstraction, simplification and isolation is warranted in economic theory is arguably the most important methodological problem for economics (Hausman 2013). Hence whether merging two previously unrelated subfields is considered an improvement over previous research may fundamentally depend on one's basic methodological commitments. Examining these for the case of merging climate policy with major topics of public finance is beyond the scope of this article. However, the thesis that embedding analyses of climate policy in a public finance framework results in non-negligible effects for both fields is a theoretically very modest claim. We do not know of any metaphysical, methodological or normative controversy (see Mäki (1992); section 10) that would provide arguments for or against merging the two fields; on the contrary doing so is likely to yield sounder policy advice. Current greater interest (or earlier lack thereof) in linking the fields of public finance and climate change mitigation may thus need to be discussed differently: first, evidence for the fact that linking the two fields would yield truly non-negligible effects is provided by relatively recent studies (Metcalf 2007, Bauer et al. 2013, Carbone et al. 2013) that show that ambitious climate protection will yield substantial revenues for government budgets. Second, economic research is typically conducted with a narrow focus on the essentials of a problem, sometimes at risk of missing some of its broader implications. Already Tullock (1967), who may have been the first to note a potential double dividend of environmental taxation, remarks that *"economists, like everyone else, sometimes keep ideas in watertight compartments. Fiscal policy has normally been dealt with quite separately from the problem of externalities"* (p.643). Goulder (1995; footnote 3) reinforces this claim when writing that *"the neglect of these interactions reflects a tradition in the field of public finance, where theoretical analysis of pollution taxes […] has generally been kept separate from the analysis of ordinary distortionary taxes"*. Combet (2013) and Combet and Hourcade (2014) defend a view similar to that of this article for the case of interactions of climate policy with the social security system. The reply to the first theoretical objection thus bolsters the intuition implicit in the practitioner's perspective.

Regarding the second objection, the theorist will wonder why the advent of stricter climate policy will impact the success of policy to address other externalities. Why would the introduction of climate policy imply that other unrelated real-world imperfections should suddenly be addressed *in combination with* the climate policy instrument? If public

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[19] For extensive discussions about the appropriateness of discounted standard utilitarianism for evaluating climate change and alternative welfare criteria concerning intra- and intergenerational equity, see, e.g. Dasgupta (2001), Roemer (2011), Broome (2012). As there is a very prominent debate within climate change economics about the benchmark for evaluating policies, our discussion is limited to a justification of the first premise.

spending is non-optimally composed, inequality imperfectly addressed, public debt at non-optimal levels, etc., there should be reasons independent of climate policy why this is so and a reason why this may be changed if climate policy is enacted. One answer to this objection comes from economic theory; another answer from political economy.

The theory of second-best allocations stresses that in a situation in which one externality is not corrected, the optimal allocation on all other markets differs from the first–best allocation (Lipsey and Lancaster 1956). Thus if one moves from a situation in which the climate externality is unaddressed to one in which it is addressed, in general some other regulated market equilibria should be changed as well to achieve the first-best outcome. Some of the effects considered in Sections 2 and 3 indeed confirm that adjusting policy measures supposed to address distortions independent of climate policy does have beneficial effects when stricter climate policy is introduced.

A different answer to this objection complements the practitioner's perspective by infusing it with political economy. Politically, it is typically more feasible to design tax reforms that combine various public finance measures tailored to win the support of special interest groups (Grossman and Helpman 2001) and voters (Castanheira et al. 2012). In particular, the government may be constrained by not being able to raise non-environmental, distortionary taxes on political grounds, even if levying these taxes to increase government spending would increase total productivity. Poterba (1993) stresses this point: *"On reflection the [double dividend argument] may make more sense. If there is a causal link between enacting a carbon tax and cutting particular other taxes, perhaps because of political constraints on raising existing taxes, and if there are no other ways to enact changes in these other taxes, then it is appropriate to consider how the funds are used in evaluating the net benefit from a carbon tax"* (p.55).

Recent work in climate economics has been impacted by similar, but even broader considerations: Opinions differ on whether to include beneficial side-effects of climate change mitigation that are not of fiscal nature, often labelled "co-benefits" (Haines et al. 2009, West et al. 2013, Ürge-Vorsatz et al. 2014) – such as improved health through reduction of local air pollution and increased model share of non-motorized transport, or energy security – into cost assessments of climate policy (Nemet et al. 2010, Kolstad et al. 2014, Edenhofer et al. 2014a).[20] Arguments in favor of the inclusion of co-benefits in policy appraisal based on welfare theory are similar to those already given for fiscal interactions of climate policy (greater realism of effects of climate policy; sounder policy advice). We conclude the discussion of merging analyses of fiscal and climate policy by indicating why the two principal objections prominent in the co-benefit debate do not apply to fiscal side-effects of climate change mitigation.

A first principal objection against accounting for non-fiscal co-benefits is that studies of their magnitude do not happen in a framework suitable for welfare analysis. This may be the case for studies mostly analyzing a specific sector in one location, although some studies do assess the welfare effects of policy options (IPCC 2014a). This is an objection less acute for fiscal co-benefits of climate change mitigation such as those scrutinized in Section 3 as research on interactions of mitigation policy with other fiscal policy has typically been analyzed in general equilibrium contexts.

A different objection against the inclusion of co-benefits in cost assessments of climate policy is that the uncertainty around some side effects of climate policy is too great to include them into policy appraisal. Even if many co-benefits are said to be less uncertain than future mitigation benefits, estimates of the uncertainties might still be incommensurable (Nemet et al. 2010, West et al. 2013). A further worry is that these effects are difficult to monetize (Ürge-Vorsatz et al. 2014). Whether or not this critique is legitimate (Edenhofer et al. 2013b, Edenhofer et al. 2014b, Stechow et al. 2014), it does not apply to public finance co-benefits: Estimates of the revenue from carbon taxation and of the size of other fiscal interactions are both relatively robust and such estimates are already expressed in monetary terms.

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[20] The effects studied in Section 3 can be seen as "co-benefits" of climate change mitigation if the term is to include all beneficial side effects of climate policy. However as some of the effects mentioned in this article are non-incremental and /or have intertemporal ramifications, it is at present unclear how to incorporate them into the framework on co-benefits recently proposed by the IPCC (Kolstad et al. 2014).

5. Conclusion: Implications for Policy Assessment

This article highlighted the close links between climate change mitigation and other, allegedly conflicting objectives of economic policy such as financing public investment or reducing tax competition and inequality. These links include, but go far beyond the idea of a potential “double dividend” of substituting environmental for distortionary taxes. It has been shown that the welfare effects of climate policy should be assessed in a comprehensive public finance framework, and that this reveals efficiency gains. There may also be more flexibility in terms of the intra- and intergenerational distribution of costs, helping to avoid potential conflict over carbon tax reforms.

We conclude by highlighting some consequences for the assessment of climate policy and public finance research:

Concerning the assessment of climate policy, IAMs have generally been designed to include as many effects relevant climate change mitigation as possible[21]. Some of the arguments given above to support the thesis of this article have been endorsed by the integrated assessment community to justify the inclusion of as many technological options as possible for the assessment of climate policy (Schneider 1997). If such assessments have a direct policy impact this may even be mandatory to prevent ’cherry picking‘ by lobby groups, that is the willful exclusion of relevant, but unwelcome effects. However, climate policy assessments have predominantly focused on technological options (Millner 2013, Staub-Kaminski et al. 2014), neglecting interactions with public finance (Howarth 2006). The contribution of this article thus underlines that integrating the above interactions of climate policy with topics in public finance could change results of climate policy assessments significantly.

Furthermore, IAMs have also been accused of insufficiently analyzing climate policy under welfare conceptions different from standard discounted utilitarianism (Howarth 2000, Llavador et al. 2011, Millner 2013). Regarding the significance of the two alternative welfare criteria employed in this article, intragenerational inequality reduction as an end in itself and intergenerational Pareto-improvements, it may thus be enlightening to conduct an assessment of climate policy with IAMs from these different viewpoints. There is preliminary evidence that applying these alternative welfare criteria indeed leads to markedly different evaluations of climate policy (see Rausch et al. (2011) for inequality reduction; Rezai et al. (2012) for Pareto-improvements).

Public finance vice versa typically neglects issues of climate policy, presumably because the field is unaware of the high fiscal revenues to be expected from ambitious climate policy. Exceptions are the classical double-dividend discussion (Goulder 1995, 2013) and a few applications to the problem of tax competition (Eichner and Runkel 2012; Habla 2014; Franks et al. 2015). But in an economy that will be significantly constrained by (mitigated or unmitigated) climate change (IPCC 2014a) the field should take ramifications of climate policy into account more, as the analysis of the major effects above has shown. The contribution of this article could thus also be seen as a first attempt to structure the mitigation effects to be included into a public economics of a climate-constrained world.

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[21] For instance, they have even been defined to *“, … (2) constructively force multiple dimensions of the climate change problem into the same framework, and (3) quantify the relative importance of climate change in the context of other environmental and non-environmental problems facing mankind”* (Kelly and Kolstad 1998 (summarizing Weyant et al. 1996), p.3).

References

Ackerman F., S.J. DeCanio, R. Howarth, and K. Sheeran (2009). Limitations of integrated assessment models of climate change. *Climatic Change*, Vol. 95: 297-315.

Agénor, P.R. (2013). Public Capital, Growth and Welfare: Analytical Foundations for Public Policy. *Princeton University Press*, Princeton.

Aldy, J., A.J. Krupnick, R.G. Newell, I.W.H. Parry and W.A. Pizer (2010). Designing Climate Mitigation Policy. *Journal of Economic Literature*, Vol. 48(4): 903-934.

Alesina, A. and D. Rodrik (1994). Distributive Politics and Economic Growth. *The Quarterly Journal of Economics*, Vol. 109(2): 465-490.

Arnott, R. J., and J. E. Stiglitz (1979). Aggregate land rents, expenditure on public goods, and optimal city size. *Quarterly Journal of Economics,* Vol. 93(4): 471-500.

Artadi, E. V. and X. Sala-i Martin (2003). The Economic Tragedy of the XXth Century: Growth in Africa. *NBER working paper series*, No. 9865.

Aschauer, D.A. (1989). Is public expenditure productive? *Journal of Monetary Economics*, Vol. 23: 177-200.

Attanasio, O.P. (1994). Personal saving in the United States. *In: Poterba, J. M. (Ed.), International Comparisons of Household Saving*, pp. 57-124, The University of Chicago Press, Chicago.

Barrage, L. (2014). Optimal dynamic carbon taxes in a climate-economy model with distortionary fiscal policy. *Working paper*, retrieved from www.lintbarrage.com on 28/12/2014.

Bauer, N.,I. Mouratiadou, G. Luderer, L. Baumstark, R.J. Brecha, O. Edenhofer and E. Kriegler (2013). Global fossil energy markets and climate change mitigation - an analysis with ReMIND. *Climatic Change, online first*.

von Below, D., F. Dennig and N. Jaakkola (2013). Consuming more and polluting less today: intergenerationally efficient climate policy. *Unpublished manuscript*, retrieved from: http://www.princeton.edu (4/3/2014).

Bento, A.M. (2013). Equity Impacts of Environmental Policy. *Annual Review of Resource Economics*, Vol. 5: 181-196 .

Bento, A.M. and M. Jacobsen (2007). Ricardian rents, environmental policy and the 'double-dividend' hypothesis. *Journal of Environmental Economics and Management*, Vol. 53: 17-31.

Bento, A. M., L.H. Goulder, M.R. Jacobsen and R. H. V. Haefen (2009). Distributional and Efficiency Impacts of Increased US Gasoline Taxes. *American Economic Review,* Vol. 99(3): 667-699.

Berg, A.G. and J.D. Ostry (2011). Inequality and Unsustainable Growth: Two Sides of the Same Coin? *IMF Staff Discussion Note*.

Berg, A.G., J.D. Ostry, and J. Zettelmeyer (2012). What Makes Growth Sustained? *Journal of Development Economics*, Vol. 98(2): 149-166.

Bom, P.R.D. and J.E. Ligthart (2014), What have we learned from three Decades of Research on the Productivity of Public Capital? *Journal of Economic Surveys*, Vol. 28(5): 889-916.

Bosello, F., C. Carraro and M. Galeotti (1998). The double dividend issue: Modeling strategies and empirical findings. *Environment and Development Economics*, Vol. 6(1): 9-45.

Bovenberg, A.L. (1999). Green tax reforms and the double dividend: an updated reader's guide*. International Tax and Public Finance*, Vol. 6(3): 421-443.

Bovenberg, A.L. and L.H. Goulder (1996). Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analysis. *The American Economic Review*, Vol. 86: 985-1000.

Bovenberg, A.L. and B.J. Heijdra (1998). Environmental tax policy and intergenerational distribution. *Journal of Public Economics*, Vol. 67: 1-24.

Bovenberg, A.L. and B.J. Heijdra (2002). Environmental Abatement and Intergenerational Distribution*. Environmental and Resource Economics*, Vol. 23: 45-84.

Bovenberg, A.L. and R.A. de Mooij (1997). Environmental tax reform and endogenous growth. *Journal of Public Economics*, Vol. 63: 207-237.

Bovenberg, A.L. and F. van der Ploeg (1994). Environmental Policy, Public Finance and the Labour Market in a Second-Best *World. Journal of Public Economics*, Vol. 55: 349-390.

Brett, C. and M. Keen (2000). Political uncertainty and the earmarking of environmental taxes. *Journal of Public Economics*, Vol. 75: 315-340.

Broome, J. (2010). The most important thing about climate change. In: *Boston, J., A. Bradstock and D. Eng (eds.). Public Policy: Why Ethics Matters*. Canberra: ANU E Press, 2010: 101-116.

Broome, J. (2012). Climate matters. Ethics in a warming world. *New York: W.W Norton*.

Browning, M., and A. Lusardi (1996). Household Saving: Micro Theories and Micro Facts. *Journal of Economic Literature,* Vol. 34(4): 1797-1855.

Bureau, B. (2010). Distributional effects of a carbon tax on car fuels in France. *Energy Economics*, Vol. 33(1): 121-130.

Burtraw, D. and S. Sekar (2014). Two world views on carbon revenues. *Journal of Environmental Studies and Sciences*, Vol. 4(1): 110-120.

Calderon, C. and A. Chong (2004). Volume and quality of infrastructure and the distribution of income: an empirical investigation. *Review of Income and Wealth*, Vol. 50(1): 87-106.

Calderon, J. and L. Serven (2004). The Effects of Infrastructure Development on Growth and Income Distribution. *World Bank Publications*, No. 270.

Carbone, J.C., R.D. Morgenstern and R.C. Williams III (2012). Carbon Taxes and Deficit Reduction. *Working paper*, May 2012.

Carbone, J.C., R.D. Morgenstern, R.C. Williams III and D. Burtraw (2013). Deficit Reduction and Carbon Taxes: Budgetary, Economic, and Distributional Impacts. *Resources for the future*. Report.

Carraro, C., M. Galeotti and M. Gallo (1996). Environmental taxation and unemployment: Some evidence on the 'double dividend hypothesis' in Europe. *Journal of Public Economics*, Vol. 62(1-2): 141-181.

Carraro, C. and M. Galeotti (1997). Economic growth, international competitiveness, and environmental protection: R&D innovation strategies with the WARM model. *Energy Economics*, Vol. 19: 2-28.

Castanheira, M., G. Nicodème, and P. Profeta (2012). On the political economics of tax reforms: survey and empirical assessment. *International Tax and Public Finance,* Vol. 19(4): 598-624.

Cederman, L.E., N.B. Weidmann and K.S. Gleditsch (2011). Horizontal Inequalities and Ethnonationalist Civil War: A Global Comparison. *American Political Science Review*, Vol. 105(3): 487-89.

Chatterjee, S. and S. J.Turnovsky (2012). Infrastructure and Inequality. *European Economic Review*, Vol. 56(8): 1730-1745.

Chiroleu-Assouline, M. and M. Fodha (2009). Double Dividend and distribution of welfare: advanced results and empirical considerations. *Économie International*, Vol. 120(4): 91-107.

Chiroleu-Assouline, M. and M. Fodha (2011). Environmental tax and the distribution of income among heterogeneous workers. *Annals of Economics and Statistics/Annales d'Économie et de Statistique*, pp. 71-92.

Chiroleu-Assouline, M. and M. Fodha (2014). From regressive pollution taxes to progressive environmental taxation. *European Economic Review*, Vol. 69: 126-142.

Clarke L., K. Jiang, K. Akimoto, M. Babiker, G. Blanford, K. Fisher-Vanden, J.-C. Hourcade, V. Krey, E. Kriegler, A. Löschel, D. McCollum, S. Paltsev, S. Rose, P.R. Shukla, M. Tavoni, B. van der Zwaan, and D. van Vuuren (2014). Assessing Transformation Pathways. In: *Edenhofer, O. et al. (eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.

Combet, E. (2013). Carbon Taxation and Social Progress*. Global Union Research Network. Discussion Paper No. 17*.

Combet, E. and J.-C. Hourcade (2014). Carbon Tax, Pensions and Public Deficits: The hidden costs of the compartmentalization of expertise. *Mimeo.*

Corak, M. (2006). Do Poor Children Become Poor Adults? Lessons from a Cross Country Comparison of Generational Earnings Mobility. *Emerald Group Publishing Limited*.

Dasgupta, P. (2001). Human Well-Being and the Natural Environment. *Oxford University Press*.

Dasgupta, P. (2007). Commentary: The Stern Review's Economics of Climate Change. *National Institute Economic Review,* Vol. 199: 4–7.

Davis, S.J., K. Caldeira and H.D. Matthews (2010). Future CO2 emissions and climate change from existing energy infrastructure*. Science*, Vol. 329: 1330-1333

De Mooij, R.A., I.W.H. Parry and M. Keen, eds. (2012). Fiscal Policy to Mitigate Climate Change: A Guide for Policymakers. *The International Monetary Fund.*

De Nardi, M. (2004). Wealth Inequality and Intergenerational Links. *Review of Economic Studies,* Vol. 71(3): 743-768.

De Nardi, M. and F. Yang (2014). Bequests and Heterogeneity in Retirement Wealth*. NBER Working Paper Series* 20058.

Diaz-Gimenez, J., Glover, A. and J.-V. Rios-Rull (2011). Facts on the Distributions of Earnings, Income, and Wealth in the United States: 2007 Update. *Federal Reserve Bank of Minneapolis Quarterly Review,* Vol. 34(1).

Dynan, K. E., J. Skinner and S.P. Zeldes (2004). Do the rich save more? *Journal of Political Economy,* Vol. 112(2): 397-444.

Edenhofer, O., M. Jakob, F. Creutzig C. Flachsland, S. Fuss, M. Kowarsch, K. Lessmann, L. Mattauch, J. Siegmeier and J. C. Steckel (2014a). Closing the Emission Price Gap. *Mimeo.*

Edenhofer, O., S. Kadner, C. von Stechow, G. Schwerhoff and G. Luderer (2014b). Linking Climate Change Mitigation Research to Sustainable Development. In: *Atkinson, G., S. Dietz, E. Neumayer, M. Agarwala (eds.). Handbook of Sustainable Development.* Second Edition. Edward Elgar.

Edenhofer, O., L. Mattauch and J. Siegmeier (2013a). Hypergeorgism: When is Rent Taxation as a Remedy for Insufficient Capital Accumulation Socially Optimal? *CESifo Working Paper* No. 4144.

Edenhofer, O., K. Seyboth, F. Creutzig and S. Schlömer (2013b). On the Sustainability of Renewable Energy Sources. *Annual Review of Environment and Resources,* Vol. 38 (1): 169-200.

Eichner, T. and M. Runkel. (2012). Interjurisdictional Spillovers, Decentralized Policy making, and the Elasticity of Capital Supply. *American Economic Review* , Vol. 102 (5): 2349–57.

Feldstein, Martin S. (1977). The surprising incidence of a tax on pure rent: A new answer to an old question*. Journal of Political Economy*, Vol. 85(2): 349-360.

Fischer, C. and R.G. Newell (2008). Environmental and technology policies for climate mitigation. *Journal of Environmental Economics and Management*, Vol. 55(2), 142-162.

Fischer, C. and L. Preonas (2010). Combining Policies for Renewable Energy: Is the Whole Less Than the Sum of Its Parts? *International Review of Environmental and Resource Economics*, Vol. 4: 51-92.

Fischer, C. and G. Heutel (2013). Environmental macroeconomics: Environmental policy, business cycles, and directed technical change. Annual Review of Resource Economics, Vol. 5: 197-210.

FitzRoy, F. (1996). Environmental Taxes, Non-Separable Externalitities and Real Wages. *Working Paper*, University of St. Andrews.

Foley, D. (2008). The economic fundamentals of global warming. In: *Harris, Jonathan M. and Neva R. Goodwin (eds.). Twenty-First Century Macroeconomics: Responding to the Climate Challenge*. Northampton: Edward Elgar.

Franks, M., O. Edenhofer and K. Lessmann (2015). Why finance ministers may favor a carbon tax, even if they do not believe in climate change. *Mimeo.*

Fullerton, D. and G.E. Metcalfe (1998). Environmental taxes and the double dividend hypothesis – did you really expect something for nothing? *Chicago-Kent Law Review*, Vol. 73(1): 221-256.

Fullerton, D. (2011). Six distributional effects of environmental policy. *Risk Analysis*, Vol. 31(6): 923-929.

Fullerton, D. and G.E. Metcalf (2001). Environmental controls, scarcity rents, and pre-existing distortions. *Journal of Public Economics*, Vol. 80: 249-267.

Gillingham, K., R. G. Newell, and K.L. Palmer (2009). Energy efficiency economics and policy. *Annual Review of Resource Economics*, Vol. 1(1): 597–619.

Glomm ,G., and B. Ravikumar (1994). Growth-Inequality Trade-Offs in a Model with Public Sector R&D. *The Canadian Journal of Economics*, Vol. 27(2): 484-493.

Goulder, L.H. (1995a). Environmental taxation and the double dividend: a reader's guide. *International Tax and Public Finance*, Vol. 2(2): 157-183.

Goulder, L.H. (1995b). Effects of carbon taxes in an economy with prior tax distortions: An intertemporal general equilibrium analysis. *Journal of Environmental Economics and Management,* Vol. 29: 271-297.

Goulder, L.H. (2013). Climate change policy’s interaction with the tax system. *Energy Economics*, Vol. 40 (Supplement 1): S3-S11.

Gramlich, E.M. (1994). Infrastructure investment: A review essay. *Journal of Economic Literature*, Vol. 32(3): 1176-1196.

Grossman, G. M., and E. Helpman (2001). *Special interest politics*. MIT Press.

Guivarch, C., R. Crassous, O. Sassi and S. Hallegatte (2011). The costs of climate policies in a second best world with labour market imperfections. *Climate Policy*, Vol. 11(1): 768-788.

Guivarch, C. and S. Hallegatte (2011). Existing infrastructure and the 2°C target. *Climatic Change*, Vol. 109: 801-805.

Habla, W. (2014). Non-renewable Resource Extraction and Interjurisdictional Competition across Space and Time. Mimeo.

Haines A., A. J. McMichael, K. R Smith, I. Roberts, J. Woodcock, A. Markandya, B. G Armstrong , D. Campbell-Lendrum, A.D. Dangour, M. Davies, N. Bruce, C. Tonne, M. Barrett and P. Wilkinson (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. *The Lancet,* Vol. 374(9707): 2104-2114.

Harris, J.M. (2013). Green Keynesianism: Beyond Standard Growth Paradigms. *Global Development and Environment Institute Working Paper 13-02*, Tufts University.

Hausman, D.M. (2013). Philosophy of Economics. In: Edward N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy (Winter 2013 Edition)*, retrieved from: http://plato.stanford.edu/archives/win2013/entries/economics/ (4/4/2014)

Heijdra, B.J. and L. Meijdam (2002). Public investment and intergenerational distribution. *Journal of Economic Dynamics and Control*, Vol. 26(5): 707-735.

Heijdra, B.J, J.P. Kooiman and J.E. Ligthart (2006). Environmental quality, the macroeconomy, and intergenerational distribution. *Resource and Energy Economics*, Vol. 28(1): 74-104.

Herndon, T., M. Ash and R. Pollin (2013). Does high public debt consistently stifle economic growth? A critique of Reinhart and Rogoff. *Cambridge Journal of Economics*, Vol. 38(2): 257-279.

Hope, C. (2006). The Marginal Impact of CO2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC’s Five Reasons for Concern. *Integrated Assessment*, Vol. 6(1): 19-56.

Howarth, R. B. (2000). Climate Change and Relative Consumption. In: *Jochem, E., J.A. Sathaye and D. Bouille (eds.). Society, Behaviour, and Climate Change Mitigation. Advances in Global Change Research 8.* Springer.

Howarth, R. B. (2006). Optimal environmental taxes under relative consumption effects. *Ecological Economics,* Vol. 58(1): 209-219.

IPCC (2014a). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.). *Cambridge University Press*, Cambridge and New York.

IPCC (2014b). Summary for Policymakers. In: *Edenhofer, O. et al. (eds.). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.

ITF (2014). International Transport Forum, data on road and rail infrastructure investment, retrieved from http://stats.oecd.org on 20/11/2014

Jacoby, H. G. (2000). Access to Markets and the Benefits of Rural Roads. *The Economic Journal*, Vol. 110(465): 713-737.

Jones, B., M. Keen and J. Strand (2012). Fiscal implications of climate change. *The World Bank, Policy Research Working Paper 5956*.

Kaldor, N. (1955). Alternative Theories of Distribution. *Review of Economic Studies*, Vol. 23(2): 83-100

Kalkuhl, M., O. Edenhofer and K. Lessmann (2012). Learning or Lock-in: Optimal Technology Policies to Support Mitigation. *Resource and Energy Economics*, Vol. 34(1): 1-23.

Kalkuhl, M., O. Edenhofer and K. Lessmann (2013). Renewable energy subsidies: Second-best policy or fatal aberration for mitigation? *Resource and Energy Economics*, Vol. 35: 217-234.

Karp, L. (1984). Optimality and consistency in a differential game with non-renewable resources. *Journal of Economic Dynamics and Control*, Vol. 8(1): 73-97.

Karp, L. and A. Rezai (2014). The Political economy of environmental policy with overlapping generations. *International Economic Review,* Vol. 55(3): 711-733.

Karp, L. and A. Rezai (2014b). Asset prices and climate policy. *Mimeo*.

Keen, M. (1998). Vertical tax externalities in the theory of fiscal federalism. *IMF Staff Papers*, Vol. 35(3): 454-485.

Keen, M. and K.A. Konrad (2013). The Theory of International Tax Competition and Coordination. *Handbook of Public Economics*, Vol. 5: 257-328.

Kelly, D.L., and C.D. Kolstad (1999). Integrated assessment models for climate change control. *International yearbook of environmental and resource economics*, pp. 171-97.

Klenert, D. and Mattauch, L. (2014). The distributional incidence of a carbon tax reform - Accounting for subsistence levels of basic goods with non-homothetic preferences. *In preparation.*

Klenert, D., L. Mattauch, O. Edenhofer and K. Lessmann (2014a). Infrastructure and Inequality: Insights from Incorporating Key Economic Facts about Household Heterogeneity*. CESifo Working Paper*, No. 4972.

Klenert, D., Schwerhoff, G. and Edenhofer, O. (2014b). The Distributional Incidence of a Carbon Tax Swap - The Double Dividend of Redistribution. *In preparation.*

Kley, F., M. Wietschel and D. Dallinger (2010). Evaluation of European electric vehicle support schemes. *Working papers on sustainability and innovation No. S7/2010*, Fraunhofer ISI, Germany.

Koethenbuerger, M. and P. Poutvaara (2009). Rent taxation and its intertemporal welfare effects in a small open economy. *International Tax and Public Finance*, Vol. 16: 697-709.

Kolstad C., K. Urama, J. Broome, A. Bruvoll, M. Cariño Olvera, D. Fullerton, C. Gollier, W.M. Hanemann, R. Hassan, F. Jotzo, M.R. Khan, L. Meyer and L. Mundaca (2014). Social, Economic and Ethical Concepts and Methods. In: *Edenhofer, O. et al. (eds.). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Koskela, E., R. Schöb and H.-W. Sinn (1998). Pollution, Factor Taxation and Unemployment. *International Tax and Public Finance*, Vol. 5: 379-396.

Koskela, E. and R. Schöb (2002). Optimal Factor Income Taxation in the Presence of Unemployment. *Journal of Public Economic Theory*, Vol. 4(3): 387-404.

Kumar, M.S. and J. Woo, (2010). Public Debt and Growth. *IMF Working Paper*.

Kumhof, M., R. Rancière and P. Winant (2013). Inequality, Leverage and Crises: The Case of Endogenous Default. *International Monetary Fund*, No. 13-249.

Lawrance, E. C., 1991. Poverty and the Rate of Time Preference : Evidence from Panel Data. *Journal of Political Economy,* Vol. 99(1), 54-77.

Leimbach, M., N. Bauer, L. Baumstark and O. Edenhofer (2010). Mitigation costs in a globalized world: climate policy analysis with ReMIND-R. *Environmental Modelling and Assessment*, Vol. 15(3): 155-173.

Liebig, S. (2012). Richard Wilkinson and Kate Pickett (2009): The Spirit Level. Why More Equal Societies Almost Always Do Better. Allen Lane, London. [Review] *Social Justice Research*, Vol. 25(1): 102-107.

Lipsey, R. and K. Lancaster (1956). The general theory of second best. *The Review of Economic Studies*, Vol. 24(1): 11-32.

Liu, A.A. (2013). Tax evasion and optimal environmental taxes. *Journal of Environmental Economics and Management*, Vol. 66(3): 656-670.

Llavador, H., J.E. Roemer and J. Silvestre (2011). A dynamic analysis of human welfare in a warming planet. *Journal of Public Economics*, Vol. 95(11): 1607-1620.

Luderer, G., V. Bosetti, M. Jakob, M. Leimbach, J.C. Steckel, H. Waisman and O. Edenhofer (2012). The economics of decarbonizing the energy system - results and insights from the RECIPE model intercomparison. *Climatic Change*, Vol. 114: 9-37.

Lustig, N., L.F. Lopez-Calva and E. Ortiz-Juarez (2011). The decline in inequality in Latin America: How much, since when and why. *Society for the Study of Economic Inequality (ECINEQ), Working Paper Series*, 211, 2011-211.

Mäki, U. (1992). On the method of isolation in economics. *Poznan Studies in the Philosophy of the Sciences and the Humanities* (special issue Idealization IV: Intelligibility in Science), Vol. 26: 319-354.

Markandya, A., M. González-Eguino and M. Escapa (2013). From shadow to green: Linking environmental fiscal reforms and the informal economy. *Energy Economics*, Vol. 40(S1): S108-S118.

Marrero, G.A. and J.G. Rodríguez (2013). Inequality of opportunity and growth. *Journal of Development Economics*, Vol. 104: 107-122.

Mattauch, L., F. Creutzig and O. Edenhofer (2012). Avoiding Carbon Lock-In: Evaluating Policy Options for Advancing Structural Change. *Climatecon Working Paper 1-2012*.

Mattauch, L., O. Edenhofer, D. Klenert and S. Bénard (2014). Public Investment when Capital is Back - Distributional Effects of Heterogeneous Saving Behavior. *CESifo Working Paper* No. 4714.

Mattauch, L., J. Siegmeier, O. Edenhofer and F. Creutzig (2014). Financing Public Capital through Land Rent Taxation: A Macroeconomic Henry George Theorem. *CESifo Working Paper*, No. 4280.

McCollum, D.L., V. Krey, K. Riahi, P. Kolp, A. Grubler, M. Makowski and N. Nakicenovic (2013). Climate policies can help resolve energy security and air pollution challenges. *Climatic Change*, Vol. 119(2): 479-494.

Metcalf, G.E. (1999). A Distributional Analysis of Green Tax Reforms. *National Tax Journal*, Vol. 52(4): 655-681.

Metcalf, G.E. (2007). A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change. *Discussion Paper 2007-12, Hamilton Project, Brookings Institute*.

Millner, A. (2013). On welfare frameworks and catastrophic climate risks. *Journal of Environmental Economics and Management*, Vol. 65(2): 310-325.

Mirrlees, J.A. and N. Stern (1972). Fairly good plans. *Journal of Economic Theory*, Vol. 4(2): 268-288.

Nemet, G. F., T. Holloway and P. Meier (2010). Implications of Incorporating Air-quality Co-benefits into Climate Change Policymaking. *Environmental Research Letters,* Vol. 5(1) : 014007.

Noble, H. (2009). Comments on the Spirit Level Controversy. *Radical Statistics*, Vol. 104: 49-60.

Nordhaus, W.D. (1993). Rolling the 'DICE': An optimal transition path for controlling greenhouse gases. *Resource and Energy Economics*, Vol. 15: 27-50.

Nordhaus, W.D. (2007). A Review of the Stern Review on the Economics of Climate Change. *Journal of Economic Literature*, Vol. 45(3): 686-702.

OECD (2012). Chapter 5: Reducing income inequality while boosting economic growth: Can it be done? *In: Economic Policy Reforms 2012: Going for Growth.* OECD Publishing.

Okun, A.M. (1975). Equality and efficiency, the big tradeoff. *Brookings Institution Press*.

Østby, G. (2008). Horizontal Inequalities, the Political Environment and Civil Conflict: Evidence from 55 Developing Countries. In F. Stewart (ed.): Horizontal Inequalities and Conflict: Understanding Group Violence in Multiethnic Societies. *World Bank Publications*.

Østby, G. and H. Strand (2013). Horizontal Inequalities and Internal Conflict: The Impact of Regime Type and Political Leadership Regulation. In: *K. Kalu, U.O. Uzodike, D. Kraybill, and J. Moolakkattu: Territoriality, Citizenship, and Peacebuilding: Perspectives on Challenges to Peace in Africa.* Adonis & Abbey Publishers Limited.

Parry, I.W.H. and R.C. Williams III (2010). What are the Costs of Meeting Distributional Objectives for Climate Policy? *The B.E. Journal of Economic Analysis & Policy*, Vol. 10(2): 1-35

Parry, I.W.H. (1995). Pollution Taxes and Revenue Recycling. *Journal of Environmental Economics and Management*, Vol. 29: S64-S77.

Parry, I. W. H. (2004). Are emissions permits regressive? *Journal of Environmental Economics and Management*, Vol. 47(2): 364-387

Pearce, D. (1991). The Role of Carbon Taxes in Adjusting to Global Warming. *The Economic Journal*, Vol. 101 (407): 938-948

Petrucci, A. (2006). The incidence of a tax on pure rent in a small open economy. *Journal of Public Economics*, Vol. 90(4-5): 921-933.

Pindyck, R.S. (2013). Climate Change Policy: What Do the Models Tell Us? *Journal of Economic Literature*, Vol. 51(3): 860-872.

Poterba, J.M. (1993). Global warming policy: A public finance perspective. *The Journal of Economic Perspectives,* Vol. 7(4): 47-63.

Quadrini, V. (1997). Understanding the U.S. Distribution of Wealth. *Federal Reserve Bank of Minneapolis Quarterly Review,* Vol. 21(2): 22-36.

Ramseur, J.L., J.A. Leggett and M.F. Sherlock (2012). Carbon Tax: Deficit Reduction and Other Considerations. *Report of the Congressional Research Service*, September 2012.

Rausch, S., G.E. Metcalf, J.M. Reilly, and S. Paltsev (2010). Distributional Implications of Alternative U.S. Greenhouse Gas Control Measures. *The B.E. Journal of Economic Analysis & Policy*, Vol. 10(2) (Symposium).

Rausch, S., G.E. Metcalf and J.M. Reilly (2011). Distributional Impacts of Carbon Pricing: A General Equilibrium Approach with Micro-Data for Households. *Energy Economics*, Vol. 33: S20-S33.

Rausch, S. (2013). Fiscal consolidation and climate policy: An overlapping generations perspective. *Energy Economics,* Vol. 40: S134-S148.

Reilly, J., S. Paltsev, K. Strzepek, N.E. Selin, Y. Cai, K.-M. Nam, E. Monier, S. Dutkiewicz, J. Scott and M. Webster (2013). Valuing climate impacts in integrated assessment models: the MIT IGSM. *Climatic Change*, Vol. 117: 561-573.

Rezai, A., D.K. Foley and L. Taylor (2012). Global Warming and Economic Externalities. *Economic Theory,* Vol. 49: 329-531.

Roemer, J.E. (1993). A Pragmatic Theory of Responsibility for the Egalitarian Planner. *Philosophy & Public Affairs*, Vol. 22(2): 146-166.

Roemer, J. E. (2011). The ethics of intertemporal distribution in a warming planet. *Environmental and Resource Economics*, Vol. 48(3): 363-390.

Romp, W. and J. de Haan (2007). Public capital and economic growth: A critical survey. *Perspektiven der Wirtschaftspolitik,* Vol. 8(S1): 6-52.

Schneider, S.H. (1997). Integrated assessment modeling of global climate change: Transparent rational tool for policy making or opaque screen hiding value-laden assumptions? *Environmental Modeling and Assessment,* Vol. 2 (4): 229-249.

Schöb, R. (1995). Ökologische Steuersysteme. Umweltökonomie und optimale Besteuerung. *Campus.*

Schöb, R. (2005). The double dividend hypothesis of environmental taxes: a survey*. In: Folmer. H. and T. Tietenberg (eds.). The international yearbook of environmental and resource economics 2005/2006*, pp. 223-279. Edward Elgar.

Schultes, A., M. Leimbach and O. Edenhofer (2014). Should landowners oppose climate change mitigation? – A general equilibrium analysis of damages on land." *Mimeo*.

Shalizi, Z. and F. Lecocq (2010). Climate Change and the Economics of Targeted Mitigation in Sectors with Long-Lived Capital Stock. *The World Bank, Policy Research Working Paper 5063*.

Siegmeier, J., L. Mattauch and O. Edenhofer (2014). Portfolio effects and climate policy. *Mimeo*.

Siegmeier, J. (2015). Restructured public spending can take the edge off green tax reforms. *Mimeo*.

Sims R., R. Schaeffer, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M.J. Figueroa Meza, L. Fulton, S. Kobayashi, O. Lah, A. McKinnon, P. Newman, M. Ouyang, J.J. Schauer, D. Sperling, and G. Tiwari (2014). Transport. In: *Edenhofer, O. et al. (eds.). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Sinclair, P. (1992). High does nothing and rising is worse: carbon taxes should keep declining to cut harmful emissions. *The Manchester School*, Vol. 60: 41-52.

Sorrell, S. and J. Sijm (2003). Carbon Trading in the Policy Mix. *Oxford Review of Economic Policy*, Vol. 19(3): 420-437.

Staub-Kaminski, I., A. Zimmer, M. Jakob, R. Marschinski (2014). Climate policy in practice: A typology of obstacles and implications for integrated assessment modeling. *Climate Change Economics,* Vol. 5 (1).

von Stechow, C., D. L. McCollum, K. Riahi, J. Minx, S. Mirasgedis, O. Lah, C. Robledo-Abad, J. Roy, E. Hertwich and J. Jewell (2014). Assessing the diverse literature on integrating global climate change mitigation goals and multiple development objectives. *In preparation*.

Stern, N. (2007). The economics of climate change: the Stern review. *Cambridge University Press.*

Tahvonen, O. (1995). International CO2 Taxation and the Dynamics of Fossil Fuel Markets. *International Tax and Public Finance*, Vol. 2(2): 261-278.

Thompson, T., S. Rausch, R. Saari and N. Selin (2014). A Systems Approach to Evaluating the Air Quality Co-benefits of US Carbon Policies. *Nature Climate Change*, forthcoming.

Tullock, G. (1967). Excess benefit. *Water Resources Research,* Vol. 3(2): 643-644.

Ürge-Vorsatz, D., S. Tirado Herrero, N.K. Dubash, and F. Lecocq. 2014. Measuring the Co-Benefits of Climate Change Mitigation. *Annual Review of Environment and Resources,* Vol. 39(1):549-582.

Waisman, H., C. Guivarch, F. Grazi and J.C. Hourcade (2012). The IMACLIM-R model: infrastructures, technical inertia and the costs of low carbon futures under imperfect foresight. *Climatic Change*, Vol. 114: 101-120.

Weitzman, M.L. (2009). On Modeling and Interpreting the Economics of Catastrophic Climate Change. *Review of Economics and Statistics,* Vol. 91(1): 1-19.

West, J. Jason, S. J. Smith, R. A. Silva, V. Naik, Y. Zhang, Z. Adelman, M. M. Fry, S. Anenberg, L. W. Horowitz, und J.-F. Lamarque. (2013)=. Co-benefits of Mitigating Global Greenhouse Gas Emissions for Future Air Quality and Human Health“. *Nature Climate Change,* Vol. 3(10): 885-889.

Wagner, R.E., ed. (1991). Charging for Government: User Charges and Earmarked Taxes in Principle and Practice. *Routledge, London.*

Weyant, J., O. Davidson, H. Dowlabathi, J. Edmonds, M. Grubb, E.A. Parson, R. Richels, J. Rotmans, P.R. Shukla, R.S.J. Tol, W. Cline and S. Fankhauser (1996). Integrated Assessment of Climate Change: An Overview and Comparison of Approaches and Results. In: *J. P. Bruce et al. (eds.), Climate Change 1995: Economic and Social Dimensions of Climate Change*. Cambridge University Press, pp. 367-439.

Wilkinson, R. and K. Pickett (2009). The Spirit Level: Why Equality is Better for Everyone. *Penguin.*

Wilson, J.D. (1986). A Theory of Interregional Tax Competition. *Journal of Urban Economics*, Vol. 19(3): 296-315.

Wilson, J.D. (1999). Theories of Tax Competition. *National Tax Journal*, Vol. 52(2): 269-304.

Wolff, E. N. (1998). Recent Trends in the Size Distribution of Household Wealth. *Journal of Economic Perspectives,* Vol. 12(3): 131-150.

Zodrow, G.R. (2010). Capital Mobility and Capital Tax Competition. *National Tax Journal*, Vol. 63 (4, Part 2): 865-902.

Zodrow, G.R. and P. Mieszkowski (1986). Tiebout, Pigou, Property Taxation, and the Underprovision of Local Public Goods. *Journal of Urban Economics*, Vol. 19: 356-370.