Modelling the economy-wide effects of unilateral CO_2 pricing under different revenue recycling schemes in Austria - Searching for a triple dividend

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Abstract

In this paper we identify policy implications for implementing carbon pricing in Austria, taking into account model structure uncertainty (see Kirchner et al., 2024). Methodologically, we compare the results of two macroeconomic models, DYNK (a New Keynesian model) and WEGDYN_AT (a neoclassical general equilibrium model), to evaluate the effects of carbon pricing under different revenue recycling options. Specifically, we examine the model results with respect to their findings regarding a potential triple dividend, that we define as a simultaneous materialization of i) a reduction in CO_2 emissions, ii) positive effects on GDP and employment, and iii) distributionally progressive effects in household consumption possibilities. Accounting for model structure uncertainty improves the robustness of our results; at least within the macroeconomic frameworks applied here. Our results confirm the tradeoff between equity and efficiency identified in previous analyses. In the New Keynesian model, we find evidence for a triple dividend for a combination of the recycling options of non-wage labor cost reductions and lump-sum per-capita transfers (“climate bonus payments”).

Keywords: carbon pricing, revenue recycling, macroeconomic impacts, distributional impacts, model comparison, Austria

1. Introduction

In line with increasing ambition of emission reduction targets, carbon pricing in recent years has gained in attention all over the world (World Bank, 2022). It is widely recognized in the literature as a critical tool for reducing greenhouse gas (GHG) emissions, as it incentivizes lower-cost abatement options, and is especially regarded effective in leveraging lower-cost abatement options (IPCC, 2022). In the European Union (EU), the practice has been well established since 2005 for emission-intensive industry and energy supply, in the form of the EU Emission Trading System (EU ETS); for other sectors not covered by this scheme (non-ETS sectors), carbon pricing has been implemented nationally in about half of the Member States, mostly in the form of carbon taxes. Austria has just recently, in October 2022, introduced a national emission trading system with a fixed price for transport and buildings. Starting in 2027, a (separate) EU-wide emission trading system will be established for these sectors in accordance with Directive 2023/959/EC (European Commission, 2023).

Research argues for carbon pricing as an essential cornerstone in a broader mix of climate policy instruments, since it can contribute to reducing emissions by incentivizing lower carbon activities (e.g. Neuhoff, 2011; Baranzini et al., 2017; Mattauch et al., 2020). According to economic theory, carbon pricing is both effective and efficient, often outperforming other instruments (Fischer and Newell, 2008; Goulder and Parry, 2008). Ex-post analyses of the effects of carbon pricing confirm a dampening effect on emissions (e.g. Andersen, 2004; Murray and Rivers, 2015; Andersson, 2019). A recent meta-study by Green (2021) shows that most estimates for reductions in annual emissions resulting from carbon pricing fall in the range of 0 and 2%, with outliers of up to 17% per year. There is also increasing empirical evidence indicating that carbon pricing in the context of a revenue-neutral environmental tax reform can result in a double dividend[1], i.e. at the same time can achieve reductions in CO_2 emissions and positive (or non-negative) effects on macroeconomic indicators, if revenues are used to reduce distortionary taxes (e.g. Freire-González, 2018).[2]

Recently, a growing body of literature has emerged examining the achievement of distributional goals in addition to the double dividend (e.g. Verde and Tol, 2009; Rausch et al., 2011; Kosonen, 2012; Goulder et al., 2019), also reflecting that the issue of fairness in the context of climate policies and the energy transition is gaining in importance in public debate.[3] Against this background, microsimulation studies assessing the distributional impact of carbon pricing and revenue recycling have also become more prevalent. For high-income countries, studies generally suggest that carbon pricing tends to be

[1] The concept of the double dividend of environmental tax reform goes back to Pierce (1991). Goulder (1995) defined three forms of the double dividend, a strong, an intermediate and a weak double dividend. A strong double dividend denotes that an environmental tax reform including a reduction on distortionary taxes results in negative, or at least zero, gross cost. The weak double dividend refers to higher cost savings if tax revenues are recycled via reductions in distortionary taxes as compared to recycling via lump-sum payments.

[2] In isolation, the introduction of carbon pricing would result in a deterioration of macroeconomic indicators, as they do not account for the social cost of carbon.

[3] In this context, Ohlendorf et al. (2021) point at differences in model outcomes related to the type of model used: They expect CGE models to more likely yield progressive outcomes for carbon taxes since they assume them to especially affect capital-intensive industries. As a result, capital income of richer households would decrease implying a more progressive distribution impact of carbon pricing. The meta analysis conducted by Ohlendorf et al. (2021), however, does not confirm an impact of studies considering general equilibrium effects on the direction of distributional effects.

regressive for heating fuels and/or electricity and provide mixed evidence[4] regarding the tax burden for transport fuels, with the combined impact mostly found to be regressive (Callan et al., 2009; Flues and Thomas, 2015; Berry, 2019; Douenne, 2020; Tovar Reaños and Lynch, 2022; van der Ploeg et al., 2022). Moreover, they highlight the relevance of horizontal distribution, i.e. differences between households with similar incomes. However, the results also suggest that the regressivity of carbon pricing can be offset by recycling (a portion) of the revenues back to households via transfers.

For Austria macroeconomic studies corroborate that carbon pricing can contribute to reducing CO_2 emissions and confirm the tradeoff between equity and efficiency for the choice of the revenue recycling option (Table 1): While reducing labor costs can boost GDP and employment, it is not effective in increasing low household incomes or equality. Recycling via lump-sum payments, by contrast, can enhance equality and improve consumption opportunities particularly for low-income groups, but is not sufficient to balance negative impacts of carbon pricing on GDP and employment. A recent microsimulation study by Eisner et al. (2021) confirms that carbon taxes in Austria tend to be regressive (for heating fuels and electricity), but shows that regressivity can be cushioned by transfer payments, enhancing equality and mitigating negative welfare effects.

Table 1. Estimated effects of carbon pricing in Austria under different compensation mechanisms

	No compensation	**Lump-sum payments**	**VAT Reductions**		**Reductions in Labor Costs**	**Green Spending**	**Multiple Compensation Measures**	
Reduction of CO_2 emissions	[5],[7]	[2],[3],[4],[5]	[4],[5]		[4],[5]	[3],[6]	[1],[2],[3],[5],[7]	
GDP growth	[5],[7]	[3],[4],[5]	[4]	[5]	[4],[5]	[3],[6]	[1],[2],[3],[7]	[5]
Employment	[5],[7]	[3],[5]		[5]	[4],[5]	[3]	[7]	[1],[2],[3],[5]
Increase in low household incomes	[5]	[2],[4],[5]	[4]	[5]	[4],[5]	no data	[2]	
Progressive distributional effects	[5]	[2],[4],[5]	[4]	[5]	[4],[5]	no data	[2]	[5]

White: positive effect, black: negative effect, grey: neutral. Sources are: [1] Goers and Schneider (2019), [2] Großmann et al. (2019), [3] Großmann et al. (2020), [4] Mayer et al. (2021), [5] Kirchner et al. (2019), [6] Kratena and Schleicher (1999), [7] Schneider et al. (2010).

The objective of this paper is to analyze policy scenarios for implementing carbon pricing in combination with revenue recycling mechanisms in Austria and to improve the robustness of simulation results by considering structural model uncertainty. Since macroeconomic modelling results on the effects of carbon pricing in environmental fiscal reform vary not only due to differences in scenario assumptions and the underlying data used but also due to differences in the modeling approach (see also the companion paper to the present study, Kirchner et al., 2024)[5], we compare the results of two macroeconomic models – the Dynamic New Keynesian model DYNK and the Wegener Center Recursive Dynamic Computable General equilibrium (CGE) Model WEGDYN_AT. Thereby, we examine the model results

[4] On average over 21 OECD countries, Flues and Thomas (2015) find a rather proportionate burden for transport fuels, as do Callan et al. (2009) for Ireland. Studies for France (Berry, 2019; Bureau, 2011) find that carbon pricing is also regressive in the case of transport fuels.

[5] The working paper of Kirchner et al. (2024) is currently available for download at https://farecarbon.joanneum.at/wp-content/uploads/2024/02/FARECarbon_Working_Paper_No_1.pdf. Depending on the journal's guidelines it will be deleted if the working paper is accepted for publication.

with respect to their findings regarding a potential triple dividend. We define this triple dividend as (1) a reduction in non-ETS CO_2 emissions, (2) positive/non-negative changes in Gross Domestic Product (GDP) and the unemployment rate, and (3) increases in consumption possibilities of low-income households and achievement of progressive outcomes, as compared to a baseline scenario without carbon pricing (and associated revenue recycling).[6]

The contribution of our paper lies in the identification of options for revenue recycling of carbon pricing for Austria that are robust in the sense that they are independent of the choice of the macroeconomic modelling framework considered here. Such model comparison approaches have already been applied in selected studies in energy and climate policy analysis (Jansen and Klaassen, 2000; Bach et al., 2002; Edenhofer et al., 2010; Kober et al., 2016; Meyer and Ahlert, 2019; Böhringer et al., 2021). Building on Kirchner et al. (2024), which provides a detailed examination of model structure uncertainty and impact chains of the macroeconomic models, our particular emphasis lies on the assessment of the effects of a broad range of recycling options.

The paper is structured as follows: In section 2, we describe the policy scenarios and briefly introduce the models used in our analysis. We then present the simulation results (section 3). In section 4, we discuss the policy implications of our results as well as limitations and potential extensions of our analysis, while the last section concludes.

2. Methods

2.1 Macroeconomic Modelling

Two macroeconomic models are applied to study the effects of the carbon pricing and recycling policies in Austria, DYNK and WEGDYN_AT. The two models were chosen since they follow different state-of-the-art modelling philosophies, involving different impact chains regarding both carbon pricing and revenue recycling that are described in detail in the companion paper (Kirchner et al., 2024). Due to differences in the modelling approach, the assessments of different policies by the two models might differ, not only in terms of magnitude of the estimated effects but sometimes also in direction (see also Table 1 above). We will therefore contrast the findings by the two models to identify similarities pointing at more robust options for the design of carbon pricing and revenue recycling options.

The dynamic New Keynesian model DYNK is a macroeconomic model covering the economic activities of multiple sectors in a single region (Kirchner et al., 2019; Sommer and Kratena, 2019). Its modelling approach bears some similarities with Dynamic Stochastic General Equilibrium (DSGE) models, as it explicitly describes an adjustment path towards a long-run equilibrium. The term 'New Keynesian' refers to the existence of a long-run full employment equilibrium, which will not be reached in the short run, due to institutional rigidities. Depending on the magnitude of the distance to the long-run equilibrium, the reaction of macroeconomic aggregates to policy shocks can differ substantially. DYNK is

[6] Pereira et al. (2016) analyzed the potential of a carbon tax for achieving a triple dividend (defined as a reduction in carbon emissions, a restoration of economic growth, and fiscal consolidation) for Portugal. Distefano and D'Alessandro (2023) for Italy assessed the potential of carbon taxation in reaping even a quadruple dividend, comprising improvements in macroeconomic performance (GDP and employment), public indebtedness, carbon emissions, and income inequality.

an input-output (IO) model in the sense that it is demand driven, as all that is demanded is produced. In the DYNK model, the treatment of demand is especially elaborated and captures consumption (private and public), investment and exports, which are endogenous, explained by consumer behavior. Domestic consumption is represented by 20 household types (income quintiles x four areas of residence by population density) that differ in income and consumption structures. Monetary flows of the IO structure of the model are linked to physical satellite accounts data for energy and GHG emissions. A detailed technical description of the DYNK model is provided in the supplementary material to Kirchner et al. (2019)[7].

WEGDYN_AT is a recursive-dynamic Computable General Equilibrium (CGE) model of the small open economy Austria (see e.g. Mayer et al., 2021; Dugan et al., 2022). It is calibrated to the Social Accounting Matrix for the year 2014 and comprises 81 economic sectors. Special focus is on the coverage of energy technologies (bottom-up technology detail for electricity, heat and gas generation), transportation (12 distinct modes of transport) and household representation (12 types based on income quartile and area of residence). In contrast to New Keynesian models, CGE models depict the economy as a closed system of monetary flows of goods and services in equilibrium. In response to an economic shock (e.g. carbon pricing), output levels and relative prices adapt immediately until a new equilibrium is reached. In terms of closures, WEGDYN_AT assumes a fixed saving rate and a fixed current account balance. On the labor market, WEGDYN_AT models unemployment via a minimum wage; i.e. if real wage rates would fall below the minimum wage, people would reduce labor supply, thereby creating scarcity such that nominal wages would rise again. This adjustment process leads to a state in which the real wage rate is equal to the minimum wage. Foreign trade is illustrated via the “Armington assumption” (Armington, 1969) of product heterogeneity (i.e. imported and domestic goods are imperfect substitutes). Welfare is measured as Hicksian equivalent variation, depicting real consumption possibilities of households. The price of foreign exchange is set as numéraire. A detailed description of the WEGDYN_AT model is provided in the supplementary material to Mayer et al. (2021)[8].

2.2 Policy Scenarios

We analyze the effects of carbon pricing and four pure (and two mixed) options for the recycling of revenues (see Table 2 for an overview). For all recycling scenarios revenue neutrality is assumed, i.e. all revenues generated by carbon pricing are used for the recycling measures. The recycling scenarios were chosen based on two deliberations: First, they should be able to significantly mitigate the impacts of carbon pricing on vulnerable households and/or cushion negative impacts on competitiveness for industry. Second, a reasonable implementation of the scenarios in the models applied here should be feasible. Since the two macroeconomic models cannot adequately model green spending – i.e. investments in energy efficiency, renewable energy sources, etc. – without additional technology-rich single

[7] https://ars.els-cdn.com/content/image/1-s2.0-S0301421518307535-mmc2.pdf [accessed 2023-12-20]

[8] https://ars.els-cdn.com/content/image/1-s2.0-S0140988321005181-mmc1.pdf [accessed 2023-12-20]

sector models, we refrain from analyzing this recycling option.[9] In the following we provide a more detailed reasoning for the selection and definition of the scenarios, and their underlying assumptions.

Table 2: Assumed development of carbon prices in €/t CO_2 and revenue use scenarios

	EU ETS		National Carbon Pricing		
	ETS price (baseline*)		Non-ETS price (scenario A)		Revenue Recycling Scenarios
	nominal	real	nominal	real	
2022	50	46	30	27	▪ Climate Bonus Recycling (**CBR**)
2023	linear increase		35	31	▪ Non-wage Labor Cost Reductions (**LCR**)
2024	…		45	40	▪ Mix of Climate Bonus & Non-wage Labor Cost Reductions (**MIX**)
2025	69	60	55	48	
2026-2029	linear increase		linear increase		▪ Value Added Tax Reductions (**VTR**)
2030	**102**	**83**	**90**	**73**	

Note: Real prices refer to the price level 2015; *ETS price already active in baseline to isolate effects of non-ETS CO_2 pricing. The revenue use scenarios in grey (MIX) is modelled only with the DYNK model.

2.2.1 Carbon pricing scenarios

In the carbon pricing scenarios, a national carbon price is defined for fossil fuels used in sectors currently not covered by the EU ETS (non-ETS sectors). The EU ETS captures emissions from emission-intensive industry, energy supply, and aviation. The non-ETS carbon price hence applies primarily to transport and buildings (heating) as well as industry/manufacturing that is not included in the EU ETS. The emissions from these non-ETS sectors account for approximately 29% of Austrian greenhouse gas emissions, of which roughly three quarters are energy-related CO_2 emissions that will be covered by the national carbon price.[10]

With respect to the carbon price level, we focus on a moderate development of the national carbon price (Table 2): We start from the national carbon price that the Austrian government implemented for transport and buildings in September 2022 (Austrian Government, 2022). The Austrian carbon price

[9] For analyzing the effects of green spending as a further recycling option, the macroeconomic models would have to be linked with bottom-up models containing a detailed representation of the respective technologies and an accurate depiction of investment decisions of firms, households, and the public sector. Moreover, information on the distributional dimension of the individual measures would be required, e.g. which income quantiles would benefit most from an expansion of public transport.

[10] So far, carbon pricing has been implemented nationally in about half of the Member States, mostly in the form of carbon taxes. The tax rates applied in the countries range between less than €1/t CO_2 for the Polish carbon fee and about €120/t CO_2 for the Swedish carbon tax and largely focus on CO_2 emissions from the use of fossil energy sources that are not covered by the EU ETS. The Nordic countries (Finland, Sweden, and Denmark) and Poland have been global frontrunners in the area of carbon pricing, introducing their schemes already in the early 1990s. In 2022, with €30/t CO_2 the Austrian (and respectively German) carbon price was the eight highest among all 15 EU Member States (World Bank, 2022).

takes the form of a national emissions trading system with a fixed price during the first four years of operation as in Germany, which means that it is identical to a carbon tax. For the period between 2022 and 2025, the following price path has been defined: The carbon price starts at €30 per t CO_2 in 2022 and is increased to €35 in 2023, €45 in 2024 and €55 in 2025.[11] From 2026 on, the fixed price in the national emissions trading system is to be replaced by the market price. We follow the development path of the implemented Austrian carbon price until 2025; afterwards we assume a linear price increase to €90 per t CO_2 in 2030 (in nominal terms).

For sectors covered by the EU ETS, we assume that the carbon price of €50 for 2022 increases by the growth rates assumed in the MIX-CP scenario in the European Commission's Impact Assessment of the "Fit for 55" Package (European Commission, 2021).

As sensitivity analysis, we provide the results for an alternative national carbon pricing scenario with an ambitious carbon price (scenario B), for which we assume a carbon price of €50 for 2022 that is linearly increased to €156 in 2030 (see Appendix B).[12] As expected, since only the level of the carbon price differs in both scenarios the model outcomes show the same direction but on a higher magnitude.[13]

2.2.2 Options for revenue recycling

Reduction in non-wage labor costs (LCR)

The first recycling scenario models a reduction in non-wage labor costs[14] equivalent in size to the revenue from carbon pricing. The main rationale behind the choice of this scenario is that it represents a step towards a socio-ecological reform of the tax structure, shifting the tax base from labor to environmental taxes. European labor markets are characterized by a high tax wedge between the effective consumption wages of employees and the effective labor costs of firms (OECD, 2022). Reductions in the taxation of labor are seen as an important option to support employment and to improve fairness

[11] While the Austrian emissions trading system follows the German model in many respects, it contains a major deviation in the form of a price stabilization mechanism. This provides for the increase in the CO_2 price to be adjusted if energy prices rise or fall significantly. If, in year t, energy prices rise or fall by more than 12.5% year-on-year in the first three quarters, the price increase planned for year t+1 is halved or doubled. For example, in 2023 the price would be €32.5 instead of €35 if the price index for fossil fuels in the first three quarters of 2022 is more than 12.5% higher than in the previous year. By contrast, if the index falls by more than 12.5%, the CO_2 price for 2023 would rise to €37.5. The CO_2 prices set for subsequent years would remain unaffected by such adjustments. They would only be adjusted in the event of a renewed undercutting or overshooting.

[12] The price level of €50 chosen for the first year is based on the carbon price in the EU ETS for 2021. The development of the price then follows the same growth rate as the level of the EU ETS carbon price in the European Commission's Impact Assessment of the "Fit for 55" package (European Commission, 2021).

[13] Note that also the higher carbon price in scenario B is, in respect to the whole economy, still moderate. Very high prices, by contrast, would push the models to their boundaries (e.g. a price of €500/tCO_2), with potential non-linear effects (e.g. sectors might collapse or strong trade effects might show up).

[14] Non-wage labor costs include social security contributions paid by the employer as well as different payroll taxes levied in Austria such as the municipal tax on payroll, the contribution to the Chamber of Commerce and the contribution to the Family Burdens Equalization Fund (*Familienlastenausgleichsfonds* – FLAF). Our scenario focuses on a reduction on non-wage labor costs in general and not only on social security contributions, as the DYNK and WEGDYN_AT models do not distinguish between different components of non-wage labor costs.

(European Commission, 2017, 2022a). Austria has one of the highest tax wedges on labor in the EU and among OECD countries, with an implicit tax rate on labor of 40.8%.[15] Social security contributions and payroll taxes paid by employers represent the largest cost factor, with an implicit tax rate of 18.6%.

Part of the expected positive macroeconomic effect associated with this recycling option stems from an assumed increase in competitiveness for the economy. Recycling the revenue from carbon pricing by reducing non-wage labor costs is equivalent to a budget-neutral 'fiscal devaluation', i.e. a unilateral fiscal policy that mimics the effects of a nominal exchange rate devaluation (Farhi et al., 2014). The reduction in labor costs reduces the prices for goods produced in the country, resulting in a shift in terms-of-trade that makes home goods cheaper relative to foreign goods.[16] In a model-based comparison of different tax reform options for the Austrian economy, Berger et al. (2019) come to the conclusion that a reduction in employer labor costs (by € 2 billion, corresponding to 0.55% of GDP) provides a more modest impulse to GDP and employment than reductions in income or corporate taxes of equal magnitude. On the other hand, the study by Berger et al. (2019) highlights that a reduction in non-wage labor costs has the most favorable outcome with respect to the employment of low-skilled labor and can thus contribute to reduce inequality between socioeconomic groups.

Reduction in the value added tax (VTR)

Second, we analyze a scenario that models a reduction in the value added tax (VAT). According to the European Union's common system of VAT, Member States may apply a maximum of two reduced tax rates of at least 5% to specific goods or services (Directive 2006/112/EC). A standard rate of at least 15% has to apply to all other goods and services. Austria has a standard VAT rate of 20% and two reduced rates of 10% and 13%. In our scenario, we further reduce the 10% rate that applies to a diverse range of essential goods and services, including food, medicines, books, newspapers, public transport, and rents. This scenario is of interest because reducing the VAT can be expected to offset the negative effect of carbon pricing on the consumption possibilities of households. A reduction in the VAT generates first and foremost an income effect, as consumers benefit from the reduction to the cost of living (Barrell and Weale, 2009). A permanent VAT rate reduction can be regarded as a positive permanent income shock for private households. The reduction in the VAT should also have progressive distributional effects, with a stronger effect on low-income households, because the share of indirect taxes in total income increases with decreasing household income. In Austria, the tax burden of VAT amounts to 16.4% of equivalized gross household income in the bottom income decile but only to 4.2% in the highest income decile (Rocha-Akis et al., 2016).[17]

[15] On average across the EU, in 2022 the implicit tax rate on labor was 38.1%, and social security contributions and payroll taxes paid by employers accounted for almost half of this tax burden (European Commission, 2022b).

[16] The introduction of the national carbon price will have an opposite effect, i.e. making home goods more expensive relative to foreign goods. The net effect on the terms of trade will i.a. depend on the emission and labor intensity of export goods in relation to other goods.

[17] Calculations for Germany, for instance, show that a reduction in the standard rate of VAT by one percentage point would reduce the tax burden of households on average by 0.43% of net household income, with a reduction of 0.60% in the lowest and 0.33% in the highest income decile (Bach and Isaak, 2017). A reduction of the reduced tax rate for food and local public transport would have even stronger progressive distributional effects.

Climate bonus payments (CBR)

As a third recycling option, lump-sum payments to all Austrian households are analyzed. While low-income households usually spend a higher share of their income on energy, particularly for heating, in absolute terms their expenditures tend to be below the average (Menyhért, 2022). If the revenues from carbon pricing are redistributed in a revenue neutral way via lump-sum payments, households with lower incomes therefore benefit relatively stronger, and will usually be overcompensated for the increase in prices. According to the literature, this option can increase the support for an ecological tax reform (Klenert et al., 2018; Carattini et al., 2019). However, in contrast to climate bonus payments that focus on low-income households, unspecific lump-sum payments are naturally characterized by limited social accuracy (Callan et al., 2009; Verde and Tol, 2009; Bureau, 2011; Farrell, 2017; Berry, 2019; Douenne, 2020). So far, eco-bonus payments independent of the household income level have for instance been introduced in Switzerland (Mildenberger et al., 2022), while lump-sum payments targeted to compensating low-income households are for example used in British Columbia (complementary to a reduction in income taxes, Beck et al., 2016). Climate bonus payments are also the option chosen by the Austrian government as recycling option.[18]

Combination of Reductions in Non-wage Labor Costs and Climate Bonus Payments (MIX)

In addition to these pure revenue recycling options, we consider a combination of reductions in non-wage labor costs and climate bonus payments. As described above, households with lower incomes benefit relatively stronger from lump-sum climate bonus payments and will usually be overcompensated for the price increase. However, the lump-sum payments are not effective in mitigating the negative impacts of unilateral carbon pricing on competitiveness. Using revenues from carbon pricing for labor tax reductions, by contrast, can boost competitiveness, but might not be effective in mitigating negative impacts on lower-income households. This scenario hence aims at dissolving tradeoffs between equity and efficiency inherent to the different recycling options.

2.2.3 Factors influencing the impact of recycling options

The actual impact of different policy measures on the targeted outcome dimensions, especially of a reduction in labor costs and VAT, will depend on a range of structural and more contingent characteristics of the economy. The impact of a VAT reduction will depend on the pass-through to consumer prices, which in turn may vary depending on the type of good but also on the business cycle, as we can expect businesses to have a higher propensity to pass on the tax reduction to consumers in a downturn and when consumption is subdued (Benedek et al., 2015). Analyzing data for a large sample of European countries covering the period 1999 to 2013, Benedek et al. (2015) find that durables tend to have higher pass-through rates than non-durables and that the pass-through for changes in the standard VAT rate is significantly higher than for changes in reduced rates. Studies of specific reforms, such as the VAT reductions in the UK in 2008, in Ireland in 2011, in Germany in 2020 as well as the VAT increase implemented in Japan in 2014, consistently show substantial pass-throughs to consumer prices and

[18] All revenues raised by the national carbon price (from households and businesses) are recycled back to households via this measure. Climate bonus payments do not differ according to household income but according to the region of residence. This is, however, not modelled here.

significant effects on consumer spending (Blundell, 2009; O'Connor, 2013; Cashin and Unayama, 2016; Bachmann et al., 2021).

A reduction in labor costs can be expected to raise labor demand and thus reduce unemployment (Bassanini and Duval, 2006; Mooij and Keen, 2012). How a reduction will exactly affect labor utilization and economic performance, however, will largely depend on the characteristics of the economy (Coenen et al., 2008). The elasticities of labor supply and labor demand are of crucial importance in this respect because they determine the extent to which a tax relief for employers will result in higher wages or higher employment. Higher demand or supply elasticities will cause larger responses to tax changes (Hofer et al., 2015). Countries with high labor supply elasticities can expect a stronger positive impact on employment from any tax reduction (European Commission, 2013). For the same reason, we can expect tax reductions to have a stronger employment effect on low-wage workers, as these workers are the ones with higher labor supply elasticity (Attinasi, et al., 2016). Empirical evidence indicates that labor cost reductions have modest overall effects on the supply decisions of men but a stronger impact on married women, single mothers and low-skilled men (Eurofound, 2017). The precise effects of a reduction in non-wage labor costs can also be influenced by labor market institutions. Collective bargaining, which limits the flexibility with which wages react to tax changes, is expected to increase the impact of a tax change on employment (Ku et al., 2020). In this respect, it can be noted that Austria is characterized by a particularly high level of collective bargaining coverage (Visser, 2016).

3. Results

In the description of results of the macroeconomic models we focus on the following four main indicators to provide an indication of the potential of a triple dividend of carbon pricing in Austria: (1) changes in non-ETS CO_2 emissions, (2) changes in real GDP, (3) changes in the unemployment rate, and (4) changes in real household consumption[19] by income groups (and region, differentiated by population density). For differences with regard to other indicators, please refer to the companion paper (Kirchner et al., 2024).

Our results show that the implementation of carbon pricing effectively reduces emissions in all carbon pricing scenarios in both models. The range of effects and the different recycling options are illustrated in Figure 1 for carbon price scenario A.[20] The decrease in emissions reflects on the one hand a shift to low emission options, but on the other hand also reductions in economic performance due to a deterioration in productivity, competitiveness and reduced consumption opportunities as a result of increased prices. Depending on the recycling scenario, the full effect on emissions is partly offset by increasing output or income.

[19] Please note that this indicator corresponds to the indicator for real private household consumption used in the companion paper Kirchner et al. (2024).

[20] In carbon price scenario B, the decline in emissions is stronger due to the higher carbon price. However, the additional emission reductions are not proportional to the increase in the carbon price, since cost-effective emission reduction potentials are increasingly exploited (see Appendix A).

When comparing the reductions in emissions estimated by the two macroeconomic models, DYNK and WEGDYN_AT, some (small) differences become apparent. According to DYNK, the reduction in emissions is lower than according to WEGDYN_AT, and there is little variation between the different recycling options: Emissions are reduced by about 5.4% in 2030 compared to the baseline scenario without CO_2 pricing in all simulations with DYNK. By contrast, WEGDYN_AT predicts savings between 6.7% and 7.2%, depending on the recycling option (see also Table A. 1 in Appendix A). The smallest decrease is observed in the case with a reduction in non-wage labor costs, where an increase in economic activity partially offsets the decrease in emissions.

The stronger overall emission reductions and the higher variations between the scenarios underscore the (Neo-classical) CGE framework of WEGDYN_AT where reactions are stronger – e.g. via substitution processes in production and consumption – and represent a long-term equilibrium. In contrast, DYNK, emphasizes the short-term effect of demand-side policies.

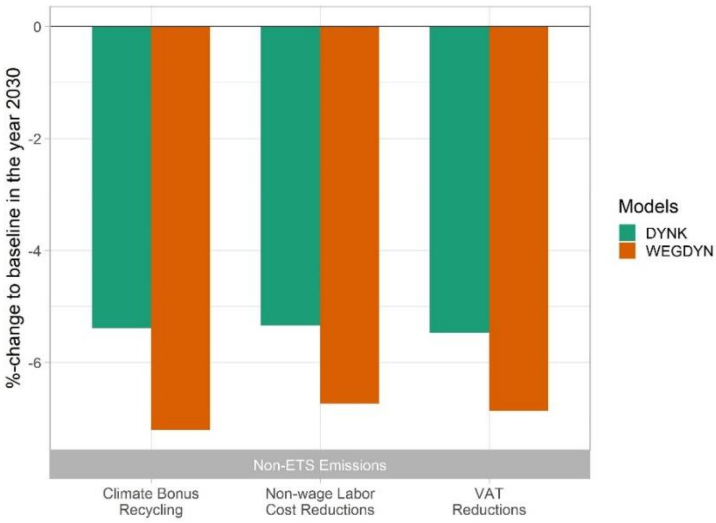

Figure 1. Effects of the policy scenarios (carbon price scenario A + recycling options) on non-ETS CO_2 emissions compared to the baseline scenario without non-ETS carbon pricing in 2030

With respect to the macroeconomic effects, the model results point in the same direction in all three scenarios, but differ in magnitude, especially for climate bonus recycling (see Figure 2 and Table A. 1 in Appendix A).

As expected, both models find positive macroeconomic effects when revenues from carbon pricing are used to reduce non-wage labor costs (LCR), since employment and competitiveness of the Austrian economy increase[21] and distortionary taxes are reduced: In carbon price scenario A, real GDP in 2030 is by (almost) 0.1% higher in both the DYNK and the WEGDYN_AT simulations, compared to the baseline scenario without carbon pricing. With respect to changes in the unemployment rate DYNK finds a

[21] Most notably, lower labor costs result in higher employment demand, with positive impacts on wages and private consumption. Moreover, the production price decrease due to the reduction in non-wage labor costs overcompensates the price increase caused by higher demand.

reduction by 0.5pp compared to the baseline without carbon pricing in 2030 and WEGDYN_AT shows a decline by 0.4pp. The stronger decline in DYNK reflects that the decrease in labor costs is only slightly dampened by short-term (rather small, because rigid) wage increases due to rising labor demand. In WEGDYN_AT, by contrast, the positive impact on employment is more significantly dampened by long-term macroeconomic feedback effects.[22]

Using revenues for climate bonus payments (CBR), by contrast, results in lower GDP and a higher unemployment rate compared to the baseline. Higher consumption expenditures in this case are not sufficient to compensate the negative impacts of carbon pricing, i.e. lower productivity due to price distortion and price increases as well as a deterioration in the trade balance[23]. For carbon price scenario A, GDP losses are estimated in the range of -0.1% (DYNK) and -0.6% (WEGDYN_AT) compared to the baseline without carbon pricing in 2030, while the unemployment rate increases by 0.1pp and 1pp, respectively. The main reason why unemployment (and thus GDP) reacts much stronger in WEGDYN_AT is that the CGE model allows for more flexibility – in this case stronger substitution effects – and thus a stronger shift away from labor.

The VAT recycling option leads to a roughly neutral GDP effect in DYNK and a positive effect in WEGDYN_AT (+0.14% compared to the baseline without carbon pricing in 2030). With respect to the unemployment rate, a small reduction by about 0.06pp compared to the baseline scenario without carbon pricing in 2030 is found in DYNK while the rate decreases by 0.12pp in WEGDYN_AT. In DYNK, a reduction in VAT has an immediate positive impact due to price decreases; the strengthening of domestic production can neutralize the negative effects on the trade balance that are less pronounced than in the case of climate bonus payments. The reduction of the unemployment rate reflects the positive impact on the domestic provision of basic goods entailing higher labor demand than the supply of fossil fuels. The reduction in the unemployment rate in WEGDYN_AT, by contrast, is mainly driven by the development of the real wage rate, which is influenced by consumer prices. As consumer prices are lower, so does the real wage rate increase, leading people to supply more labor to the market (until the minimum real wage rate is reached again). The real GDP effect is positive due to higher employment and lower consumer prices.

[22] I.e. due to the decrease in labor costs, a shift from capital to labor occurs. As the demand for capital falls, price would decrease in a first round effect, which again increases capital demand elsewhere in the economy, which somewhat cushions the shift from capital to labor in the new equilibrium.

[23] I.e. a decrease in exports due to worsening of the terms of trade and an increase in imports due to the import intensity of private consumption.

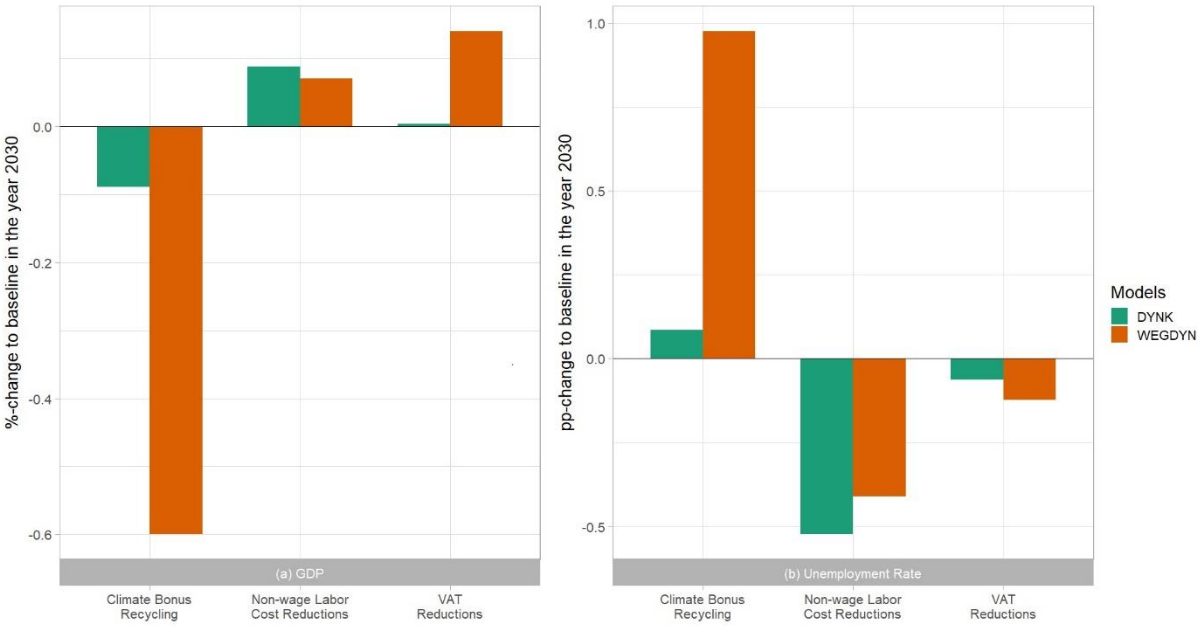

Figure 2. Effects of the policy scenarios (carbon price scenario A + recycling options) on real GDP and the unemployment rate compared to the baseline scenario without carbon pricing in 2030

To investigate the distributional impact of the different policy scenarios, we take a closer look at changes in real consumption possibilities across the household income distribution. As we can see from Figure 3, model choice can have a considerable impact on the assessment of revenue recycling options. Detailed results are provided in Tables A. 2 and A. 3 in Appendix A.

Climate bonus payments and reductions in value added tax return similar results across models. Revenue recycling through a per-capita lump-sum transfer (climate bonus) leads to strong positive consumption effects for low-income households and to a clear progressive distributional pattern with negative effects at the top of the income distribution in both DYNK and WEGDYN_AT. The relative stimulus to real consumption possibilities associated with this recycling option is, however, greater in DYNK (with an effect compared to the baseline ranging from +1.6% for low-income households to -0.3% for high-income households) than in WEGDYN_AT (+0.7% to -1.0%). This difference in magnitude and range arises from the fact that in DYNK capital income reacts less sensitive and affects private households less strongly than in WEGDYN_AT. In WEGDYN_AT capital rents decline relatively strong due to a lower demand for capital (as we observe a shift to labor demand), which reduces particularly the income of high-income (Q4) households (as they have a higher share of capital income).

The VAT reduction scenario produces unambiguously positive results in terms of real consumption possibilities in both models. In DYNK, reducing the value-added tax of essential goods and services leads to a combination of lower prices and higher incomes that generates a positive and almost uniform increase in consumption possibilities across all household income quintiles (between +0.4% and +0.5% compared to the baseline). In WEGDYN_AT, the increase in households' real consumption is weaker than in DYNK due to nominal income losses resulting from a lower nominal wage rate and capital rent that work against the lower household consumer price. Losses in capital income are most pronounced for Q4-households, which also explains the smallest increase in real consumption for this group.

Unlike the other two recycling options, the reductions in non-wage labor costs bring to the fore more pronounced differences in model structure between DYNK and WEGDYN_AT. As we have seen, a reduction in non-wage labor costs leads to a positive stimulus on economic output and a reduction in unemployment in both models. Regarding the distributional implications of this option, however, DYNK and WEGDYN_AT produce a contrasting picture. The labor cost reduction scenario leads to minor, negative deviations from the baseline in DYNK, with virtually no change in the lowest quintile and a progressive reduction in consumption possibilities of up to -0.2% at the top of the income distribution. In WEGDYN_AT, the effect is regressive, increasing from -0.1% in the first to +0.2% in the fourth quartile. These differences in outcome are modest in absolute terms, but they highlight how different model assumptions can impact the assessment of recycling options. In WEGDYN_AT, for the higher income quartiles, Q3 and Q4, higher capital and labor income dominates the increase in the consumer price index and leads to positive changes in real consumption; for the two lower income quartiles Q1 and Q2 the increase in the consumer price index dominates the somewhat higher nominal income (which comprises a larger share of transfers and lower shares of factor income than for Q3 and Q4), resulting in a decrease in real consumption.

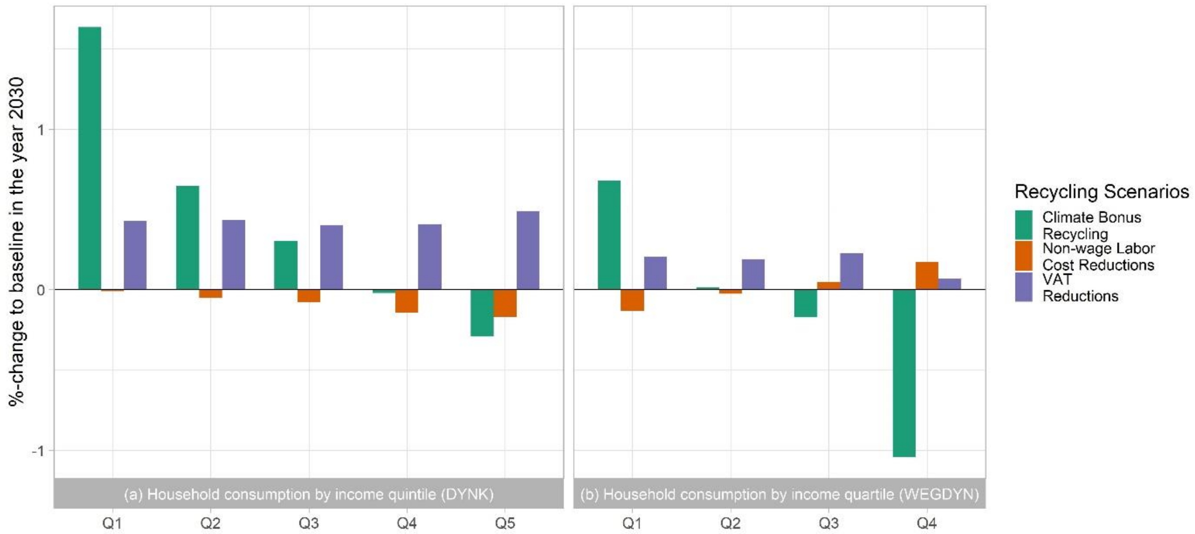

Figure 3. Effects of the policy scenarios (carbon price scenario A + recycling options) on real consumption by household income class (quintiles in DYNK, quartiles in WEGDYN_AT)

Extending carbon pricing to non-ETS sectors is likely to affect households asymmetrically across regions. This is primarily because of differences in energy consumption patterns for transport and housing associated with the degree of urbanization, but also because of regional differences in economic structure and labor markets. The distributional impact of different revenue recycling options should therefore also be assessed from a regional perspective. While both DYNK and WEGDYN_AT allow to distinguish several types of regions, based on population density, for reasons of space here we limit our analysis to contrasting results for the most urban and the most peripheral regions (Figure 4). Tables with the complete results can be found in Appendix A. The two models show that the regional impact of carbon pricing and revenue recycling options is not straightforward. Overall, in DYNK households in lesser populated areas are affected more negatively by carbon pricing than households in urban areas. This is in line with the expectation that, in rural areas, households rely more heavily on individual motorized transport and often face higher heating costs, thus shouldering a higher share of the carbon pricing. None of the revenue recycling scenarios, while cushioning the negative effects or generating positive effects for all households, reverses this general pattern. The results essentially show level differences between urban and peripheral regions, confirming the distributional impacts discussed in the previous paragraphs. In WEGDYN_AT, on the contrary, differences between regions are less pronounced and, in the CBR scenario, it is urban households rather than those in the rural areas that face less favorable outcomes.[24] This is especially true for the climate bonus payments scenario, which has a negative net effect on consumption possibilities in urban areas, except for the households in the bottom income quartile, while the effect is positive in the rural regions except for the two top quartiles. In the VAT reduction scenario, in contrast, the outcome is almost identical along the household income distribution, regardless of regional differences.

[24] More adverse effects for urban households can be explained by the dominance of the regressive income channel effect over the progressive expenditure channel effect. Hence, while consumer prices always rise least for urban households, changes in income work in the opposite direction.

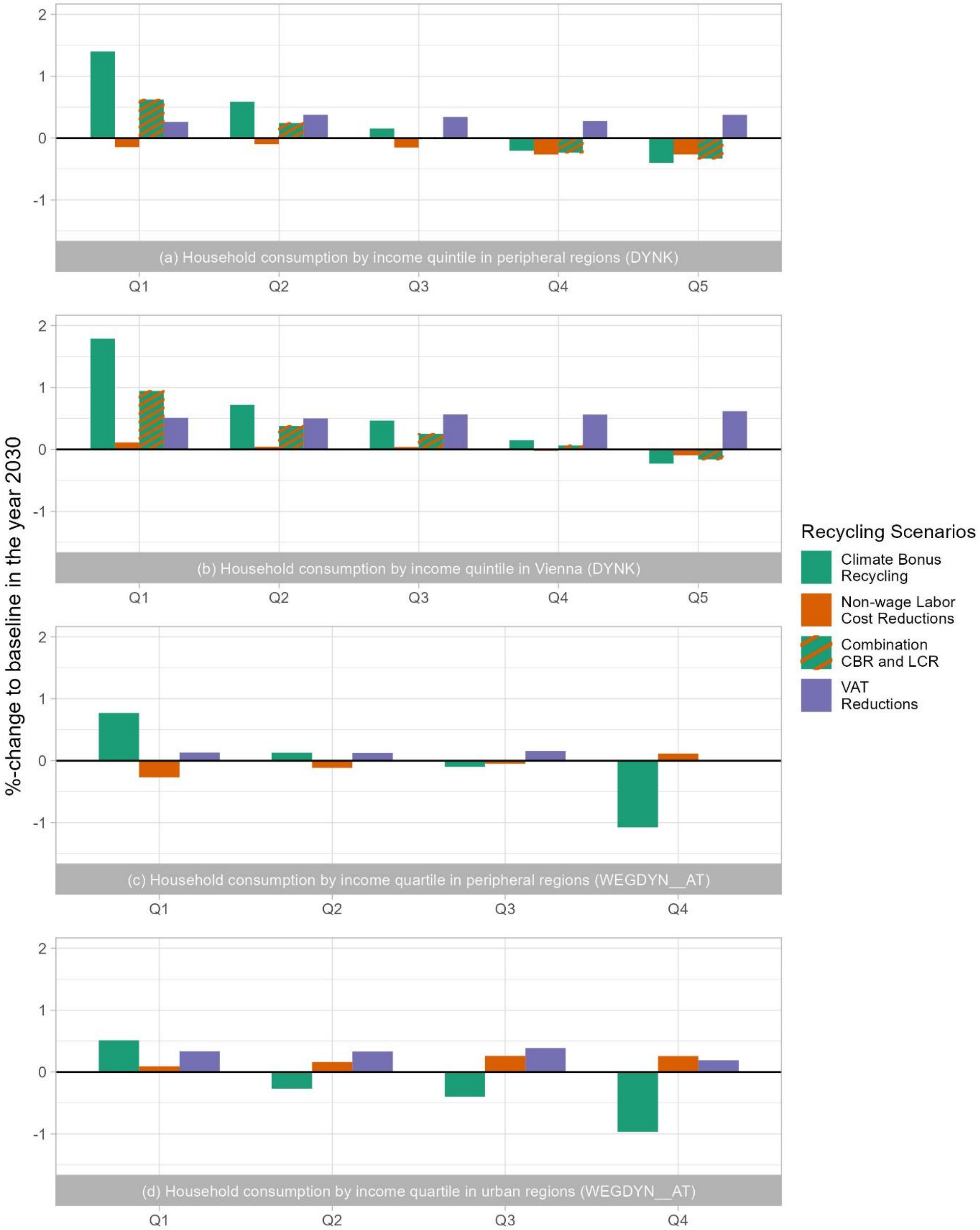

Figure 4. Effects of the policy scenarios (carbon price scenario A + recycling options) on real consumption by household income class and area of residence (quintiles in DYNK, quartiles in WEGDYN_AT)

To sum up, we find that all revenue recycling options lead to sizeable reductions in CO_2 emissions in non-ETS sectors and that, for each model, the differences in emissions between scenarios are negligible. The reduction of non-wage labor costs is associated with the clearest positive macroeconomic outcomes in terms of GDP and unemployment. This can be explained by the fact that employment is stimulated and that taxes on labor are more distortionary than carbon pricing, thus a recycling of revenues through this channel more than compensates for the negative effects of carbon pricing on competitiveness and employment. Including distributional concerns in the assessment makes it considerably more difficult to identify desirable recycling options. Only the climate bonus payments scenario consistently produces a progressive distributional outcome in both models. This recycling option, however, leads to negative economic effects for households in the upper segments of the income distribution. The VAT reduction scenario achieves positive impacts, without large variation between different groups. The scenario with a reduction in non-wage labor costs has to be assessed differently, depending on the model chosen: In WEGDYN_AT, the consumption possibilities of higher income quartiles increase, while those of lower income quartiles are reduced. In DYNK, the effect is progressive but neutral to negative.

In isolation, neither of the revenue recycling options can achieve a triple dividend. Only the reduction in non-wage labor costs leads to clear positive macroeconomic effects in both models and only the climate bonus leads consistently to desirable distributional outcomes. A combination of revenue recycling via lump-sum transfer together with a reduction in non-wage labor costs therefore offers the most promising path to a triple dividend. In light of the results for the pure revenue recycling options, we would, however, not expect to achieve a triple dividend from the WEGDYN_AT model. The impact on GDP would likely be negative (as we can expect that the strong negative effect in the case of climate bonus payments cannot be fully compensated by the moderate positive effect due to labor cost reductions); the relatively strong progressive effect of climate bonus payments would be mitigated somewhat by non-wage labor cost reductions, the effect on unemployment could be either negative or positive, depending on the changes in the consumer price index. Simulations with DYNK, by contrast, suggest that combining climate bonus payments and reductions in non-wage labor costs results in positive impacts on GDP growth and employment (see Table A. 1 in Appendix A). The results based on DYNK indicate that combining a climate bonus with a reduction in non-wage labor costs (MIX) does indeed result in a slight reduction in unemployment (-0.2%), leaves GDP unchanged and boosts the consumption possibilities of low- to medium-income households (between 0.8% in the first and 0.1% in the third quintile).

4. Discussion

4.1 Policy relevance of results

Our results, which are in line with previous findings (see Table 1 above), are specific to Austria, but they provide valuable insights for other high-income countries. With respect to the climate targets, our simulations confirm that carbon pricing can contribute to achieving the required emission reductions. The estimated emission reductions are in the broad range of the literature, and naturally depend on the assumptions regarding the carbon price itself, as also illustrated by the results from the sensitivity analysis in Appendix B. The introduction of the carbon price increases the costs of emission intensive fuels, resulting in a decreased demand for these products. One key determinant for the resulting demand reductions are the assumptions on the underlying price elasticities. In both models, these are empirically estimated energy price elasticities or elasticities of substitution. The recent literature, however, suggests that consumers tend to respond more strongly to changes in tax rates as compared to pure changes in prices (Rivers and Schaufele, 2015; Andersson, 2019). Due to this tax salience effect, emission reduction effects might effectively be higher than suggested by the model simulations.

Our results underscore that reductions in non-wage labor costs are most suitable in terms of compensating for negative impacts in competitiveness[25], however, they are not able to change the regressive nature of carbon pricing. The opposite is confirmed with respect to lump-sum climate bonus payments. The literature indicates that reductions in non-wage labor costs that are targeted at vulnerable groups in the labor market (such as the long-term unemployed, young workers or older workers) can be particularly effective in generating employment (OECD, 2011; Saez et al., 2019). We can thus expect that the distributional impact of recycling via a targeted reduction in non-wage labor costs, which we cannot investigate with our macro-models, may be somewhat more progressive than shown in our estimates, as the groups that could benefit from the measure, especially unemployed and low-skilled workers, are located in the lower segments of the income distribution. Notwithstanding, our results corroborate the view that including lump-sum payments to households in a revenue recycling package is the safest option for enhancing social fairness. Microsimulation studies for Austria as well as for other countries have highlighted how adjusting the design of cash transfers to household income but also other criteria can improve their vertical as well as horizontal distributional effects (i.e. redistribution between richer and poorer households as well as between households with similar income but different consumption needs). This is important because distributional concerns are an obstacle for the acceptance of carbon pricing measures in the population (Drews and Bergh, 2016; Carattini et al., 2017). Evidence indicates that the acceptability of carbon pricing increases if the policy is perceived to have a neutral or progressive distributional impact. However, it must be emphasized that a successful implementation of the policy depends not only on policy-makers setting the right technical parameters, but also on the provision of sufficient information and adequate communication (Köppl and Schratzenstaller, 2023).

With respect to the reduction of the reduced VAT rate, both models generate results that are consistent with expectations based on previous research. The stronger overall boost to consumption according to DYNK is consistent with the short-term focus of the model, while we can expect WEGDYN_AT to give a more realistic assessment with respect to the medium- to long-term effects of this recycling option. Arguably, this is also true of the distributional impact, because only WEGDYN_AT shows weaker consumption effects for the richer than for the poorer households, as we would expect from the literature. Bach and Isaak (2017) estimate that a reduction by 2pp in the reduced VAT rate, which is comparable to the VAT reduction generated through revenue recycling in our scenario, will lessen the tax burden in households belonging to the bottom deciles about twice as strongly as in households belonging to the top deciles. According to previous research, a reduction targeting the standard VAT rate or one targeting durable goods would result in a higher pass-through and therefore

[25] Reductions in VAT are found to have positive effects in WEGDYN_AT, but only neutral effects in DYNK.

in somewhat stronger positive consumptions effects (Benedek et al., 2015). In Austria, which already has two different reduced tax rates, such a scenario would contravene the EU directive on the common system of VAT, but this measure could be an option for other countries.

In an overall assessment, our results show that pursuing multiple objectives with carbon pricing requires very careful policy design, which in turn underlines the importance of a detailed analysis that takes the specific context into account.

4.2 Limitations and further research avenues

Our study contributes to a thorough understanding of the policy options associated with carbon pricing while shedding light on the nuanced differences that emerge when we evaluate this type of policy using different macroeconomic models. Nonetheless, it is subject to several limitations that need to be addressed in future research. Although we were able to simulate a wide range of recycling options, our models lack the ability to assess the role of green spending, which should also be considered to provide policy makers with a complete picture of recycling options. In this regard, there is a large research gap in the literature, which is particularly relevant because studies indicate that a significant share of people have a preference for recycling carbon tax revenues by investing in green spending (Maestre-Andrés et al., 2019; Dütschke et al., 2023). A further limitation concerns the fact that we model carbon pricing as a unilateral measure implemented by Austria, thus disregarding developments in CO_2 prices in other countries. Arguably, this leads us to overstate the negative impact of carbon pricing on Austria's competitiveness vis-à-vis its trading partners.

Finally, a general critique that may apply to our study, is that both macroeconomic models used are firmly rooted in the economic tradition, assuming optimizing agents and convergence towards a (long-term) equilibrium, while there have been calls from some researchers and institutions to pursue new economic modelling approaches that consider features such as agents' heterogeneity, behavioral elements and the role of institutions (Hafner et al., 2020). In addition to new approaches in macroeconomic modelling, recent studies (Chepeliev et al., 2021; Antosiewicz et al., 2022) show that a promising avenue for further research consists in the combination of macro- and microeconomic modelling. This can be of particular value when it comes to assessing in greater detail distributional effects, such as the impact of carbon pricing and revenue recycling on households with different socio-demographics or labor market effects on different groups within the working population.

5. Conclusions

With this paper we have investigated the potential for robust policy options for carbon pricing and revenue recycling for Austria, by comparing the findings of two different types of macroeconomic models. Our results confirm the tradeoff between equity and efficiency identified in previous analyses. The implications of reducing value-added taxes are less clear across models in terms of macroeconomic impact, with neutral effects on household income distribution. As highlighted by previous research, the impact of a specific VAT reduction will be subject to uncertainty because of the broad range of factors that influence the extent of the pass-through to consumer prices. An indication for a triple dividend, i.e. a reduction in CO_2 emissions, positive macroeconomic effects, and improvements in distributional outcomes, emerges only for a combination of the options for labor cost reduction and climate bonus payments in the New Keynesian model DYNK and cannot be expected for the CGE model WEGDYN_AT.

Macroeconomic models might not be sufficiently detailed for identifying a triple dividend and address distributional issues, which could be avoided by linking top-down macroeconomic models with microsimulation models. Moreover, carbon pricing just constitutes one element in the policy mix needed for achieving the emission reduction targets. Other instruments, such as bans of fossil heating systems or of cars with combustion engines but also subsidies, might entail different effects regarding a potential triple dividend and should also be addressed by respective policy assessments.

Acknowledgements

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Appendix A: Detailed macro results for carbon price scenario A

Table A. 1: Change in non-ETS emissions, GDP and the unemployment rate compared to Baseline in 2030 in Carbon Price Scenario A

	Unemployment Rate (in pp)		*GDP (in %)*		*Non-ETS Emissions (in %)*	
	DYNK	WEGDYN_AT	DYNK	WEGDYN_AT	DYNK	WEGDYN_AT
CBR	*0.08*	*0.98*	*-0.09*	*-0.61*	*-5.39*	*-7.21*
LCR	*-0.52*	*-0.41*	*0.09*	*0.07*	*-5.34*	*-6.74*
VTR	*-0.06*	*-0.12*	*0.00*	*0.14*	*-5.47*	*-6.87*
MIX	*-0.23*		*0.00*		*-5.37*	

CBR… Climate Bonus Recycling, LCR… Non-wage Labor Cost Reduction, VTR… VAT reduction, MIX… Mix of CBR and LCR

Table A. 2: Percentage change in household consumption per income quintile and region, DYNK, in Carbon Price Scenario A

Scenario[1]	*Region*	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*
	peripheral	1.40	0.59	0.15	-0.21	-0.40
	suburban	1.73	0.62	0.31	0.02	-0.28
CBR	*other urban*	1.56	0.79	0.63	0.29	-0.11
	Vienna	1.79	0.72	0.47	0.15	-0.23
	total	1.65	0.65	0.31	-0.02	-0.29
	peripheral	-0.15	-0.10	-0.15	-0.27	-0.26
	suburban	-0.03	-0.09	-0.11	-0.11	-0.16
LCR	*other urban*	0.03	0.05	0.11	0.04	-0.05
	Vienna	0.11	0.04	0.04	-0.02	-0.09
	total	-0.01	-0.05	-0.08	-0.14	-0.17
	peripheral	0.26	0.38	0.34	0.27	0.38
	suburban	0.43	0.38	0.33	0.43	0.49
VTR	*other urban*	0.55	0.65	0.57	0.62	0.59
	Vienna	0.51	0.50	0.57	0.56	0.62
	total	0.43	0.43	0.40	0.41	0.49
	peripheral	0.62	0.24	0.00	-0.24	-0.33
	suburban	0.84	0.26	0.10	-0.05	-0.22
MIX	*other urban*	0.79	0.42	0.37	0.17	-0.08
	Vienna	0.94	0.38	0.25	0.06	-0.16
	total	0.81	0.30	0.11	-0.08	-0.23

[1]CBR… Climate Bonus Recycling, LCR… Non-wage Labor Cost Reduction, VTR… VAT reduction, MIX… Mix of CBR and LCR

Table A. 3: Percentage change in household consumption per income quartile and region, WEGDYN_AT, in Carbon Price Scenario A

Scenario	*Region*	*Q1*	*Q2*	*Q3*	*Q4*
CBR	*peripheral*	0.77	0.13	-0.10	-1.08
	suburban	0.73	0.05	-0.09	-1.04
	urban	0.51	-0.27	-0.40	-0.97
	total	0.68	0.02	-0.17	-1.04
LCR	*peripheral*	-0.27	-0.12	-0.05	0.12
	suburban	-0.15	0.01	0.07	0.24
	urban	0.09	0.16	0.26	0.26
	total	-0.13	-0.03	0.05	0.17
VTR	*peripheral*	0.13	0.12	0.16	0.00
	suburban	0.17	0.21	0.23	0.10
	urban	0.33	0.33	0.39	0.19
	total	0.21	0.19	0.23	0.07

CBR… Climate Bonus Recycling, LCR… Non-wage Labor Cost Reduction, VTR… VAT reduction

Appendix B: Detailed macro results for carbon price scenario B

Table A. 4: Change in non-ETS emissions, GDP and the unemployment rate compared to Baseline in 2030 in Carbon Price Scenario B

	Unemployment Rate (in pp)		*GDP (in %)*		*Non-ETS Emissions (in %)*	
	DYNK	WEGDYN_AT	DYNK	WEGDYN_AT	DYNK	WEGDYN_AT
CBR	0.14	1.66	-0.16	-1.07	-8.23	-11.03
LCR	-0.87	-0.65	0.13	007	-8.15	-10.28
VTR	-0.11	-0.16	0.01	-1.02	-8.36	-10.50
MIX	-0.37		-0.01		-8.19	

CBR… Climate Bonus Recycling, LCR… Non-wage Labor Cost Reduction, VTR… VAT reduction, MIX… Mix of CBR and LCR

Table A. 5: Percentage change in household consumption per income quintile and region, DYNK, in Carbon Price Scenario B

Scenario[1]	*Region*	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*
CBR	*peripheral*	2.30	0.94	0.21	-0.40	-0.73
	suburban	2.87	0.99	0.47	-0.02	-0.51
	other urban	2.59	1.29	1.03	0.45	-0.22
	Vienna	2.98	1.17	0.75	0.21	-0.43
	total	2.72	1.04	0.47	-0.08	-0.54
LCR	*peripheral*	-0.30	-0.22	-0.31	-0.50	-0.50
	suburban	-0.10	-0.21	-0.23	-0.24	-0.31
	other urban	0.00	0.05	0.15	0.03	-0.11
	Vienna	0.15	0.03	0.03	-0.08	-0.20
	total	-0.06	-0.13	-0.18	-0.29	-0.33
VTR	*peripheral*	0.40	0.61	0.54	0.42	0.60
	suburban	0.71	0.60	0.53	0.70	0.81
	other urban	0.92	1.09	0.96	1.05	0.99
	Vienna	0.85	0.83	0.94	0.94	1.02
	total	0.70	0.71	0.65	0.66	0.80
MIX	*peripheral*	1.01	0.37	-0.05	-0.45	-0.61
	suburban	1.40	0.40	0.13	-0.12	-0.41
	other urban	1.31	0.68	0.59	0.25	-0.17
	Vienna	1.58	0.61	0.39	0.07	-0.31
	total	1.34	0.46	0.15	-0.18	-0.44

[1]CBR… Climate Bonus Recycling, LCR… Non-wage Labor Cost Reduction, VTR… VAT reduction, MIX… Mix of CBR and LCR

Table A. 6: Percentage change in household consumption per income quartile and region, WEGDYN_AT, in Carbon Price Scenario B

Scenario	*Region*	*Q1*	*Q2*	*Q3*	*Q4*
CBR	*peripheral*	1.26	0.19	-0.19	-1.85
	suburban	1.19	0.05	-0.17	-1.79
	urban	0.82	-0.45	-0.70	-1.66
	total	1.10	0.00	-0.32	-1.79
LCR	*peripheral*	-0.47	-0.22	-0.11	0.13
	suburban	-0.27	-0.01	0.08	0.34
	urban	0.12	0.27	0.40	0.38
	total	-0.24	-0.07	0.05	0.23
VTR	*peripheral*	0.19	0.17	0.23	-0.06
	suburban	0.26	0.32	0.35	0.10
	urban	0.52	0.55	0.6	0.26
	total	0.31	0.29	0.34	0.05

CBR… Climate Bonus Recycling, LCR… Non-wage Labor Cost Reduction, VTR… VAT reduction