Efficiency and distributional impacts of EU carbon and labor market integration

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Abstract

This paper examines the efficiency and distributional impacts of harmonizing carbon permit prices across the EU, the UK, Norway, and Switzerland (EU+) under alternative assumptions about labor market structure. We employ the ELBE-JRC model, a multi-region, multi-sector computable general equilibrium model with a fully integrated household microsimulation module covering 30 countries. The model is applied to 18 illustrative scenarios that incorporate three CO_2 cooperation regimes (EU ETS with national pricing, with non-ETS trading, and full ETS), three labor mobility scopes (national, sectoral, EU-wide) and two labor market assumptions (full employment versus allowing for unemployment). Our main findings are as follows. First, harmonizing carbon prices yields large efficiency gains, cutting aggregate welfare losses by up to 80% relative to fragmented carbon markets, driven primarily through the uses-side channel. Second, allowing for involuntary unemployment amplifies welfare losses by a factor of 3 to 10, due to higher consumer prices depressing real wages that trigger the wage-curve mechanism. Third, broader labor market integration generally worsens aggregate welfare, particularly under fragmented carbon markets, because cross-sectoral and cross-border reallocation raises consumption prices more than it increases nominal incomes. [TBC]

1. Introduction

The EU's climate policy architecture rests on two pillars: the EU Emissions Trading System (EU ETS), covering electricity, energy-intensive industry, and aviation, and national policies for non-ETS sectors (such as transport, buildings and agriculture) under the Effort Sharing Regulation. From a cost-effectiveness perspective, economists have long argued for expanding the scope of carbon pricing across sectors and countries (Böhringer et al., 2006; Metcalf, 2009). The planned launch of a second ETS (ETS2) in 2027, covering fuels used in road transport and buildings, represents a further step toward comprehensive carbon pricing across the EU.

The efficiency rationale for expanding carbon pricing is well established: equalizing marginal abatement costs across sectors and countries reduces the total cost of achieving a given emissions reduction target. However, the political feasibility of further carbon price harmonization depends critically on its distributional consequences, both between and within EU countries, and on how these consequences interact with the design of labor markets and revenue recycling mechanisms. The way in which the burdens and benefits of harmonized carbon pricing in the EU are effectively distributed depends not only on direct policy choices regarding the redistribution of carbon pricing revenues to countries and households, but also on how a carbon price, or multiple carbon prices in segmented markets, affects the decisions of firms and households in decentralized and interconnected energy, emissions, product, and factor markets.

This paper contributes by systematically studying the interplay of CO_2 market integration and labor market integration using the ELBE-JRC model (Landis, Fredriksson, and Rausch, 2021), a multi-country, multi-sector general equilibrium model of the EU economy with household heterogeneity based on micro-survey data. We introduce a labor market scope dimension that varies from sectoral (labor immobile across sectors within a country), to national (mobile across sectors within a country, the standard assumption in most CGE models), to EU+-wide (mobile across the EU, the UK, Norway, and Switzerland). In addition, we add involuntary unemployment through a wage-curve specification (Blanchflower and Oswald, 1994), which introduces a negative relationship between the real wage and the unemployment rate.

Our analysis builds on two predecessor studies. Landis, Fredriksson, and Rausch (2021) used the same model family to show that harmonizing CO_2 prices yields efficiency gains at the EU level, that these gains flow disproportionately to low-income countries under Phase IV redistribution rules, and that within-country incidence is progressive and driven by sources-side effects of income. However, their model assumed full employment and a single national labor market. More recently, Antosiewicz et al. (2025) developed a dynamic version with directed technical change, endogenous innovation, and unemployment (also via a wage curve), and applied it to analyze the distributional effects of EU ETS, both ETS1 and ETS2. They found that endogenous innovation dramatically reduces welfare costs (to −0.5% of EU welfare by 2050), that unemployment increases from 5.9% to 7.0%, and that within-income-group variation in utility impacts exceeds between-group variation. Neither study, however, examines the role of labor market scope, i.e. the degree of labor market integration, and its interaction with carbon market integration and unemployment.

We analyze 18 scenarios, characterized by three CO_2 cooperation regimes, three labor market scopes, and two unemployment assumptions. Our main findings are as follows. [TBC]

The remainder of this paper is organized as follows. Section 2 describes the model and the scenario design. Section 3 presents the main results on efficiency, distributional, and labor market effects, by country, sector, and households. Section 4 concludes.

2. Model and scenarios

2.1 The ELBE-JRC Model

We use "The Energy and Labor model for the EU" or ELBE-JRC model (Landis, Fredriksson, and Rausch, 2021), which is a multi-region, multi-sector static general equilibrium model of the world economy with regional focus on Europe, formulated as a mixed complementarity problem in GAMS/MPSGE (Rutherford, 1999). The model builds on the GTAPinGAMS model type (Lanz and Rutherford, 2016) and extends it with physical energy data, climate policy mechanisms, and labor market features to represent climate policies and their effects on the economy. It resolves EU Member States as individual regions, alongside other 17 individual or aggregated regions, for a total of 44 regions. The model is detailed on energy use and carbon emissions related to the combustion of fossil fuels. Energy goods identified in the model include coal, gas, crude oil, refined oil products, and electricity. In addition, the model features energy-intensive sectors that are potentially most affected by changes in the price of carbon.

The production side covers 10 commodity groups including five energy goods, one aggregate sector of energy-intensive industries, transport, agriculture, manufacturing, and services. All industries are characterized by constant-returns-to-scale production functions and operate in perfectly competitive markets. Consumer preferences and production technologies use nested CES functions. Within each EU country, households are represented by a single representative agent in the CGE model, which is coupled in a micro-consistent manner to a microsimulation model of household demand. The coupling follows the sequential recalibration (decomposition) algorithm of Rutherford and Tarr (2008), which iterates between the macro CGE and the household-level microsimulation until convergence.

Production of non-resource sectors follows a KLEM structure (Figure X). At the top level, a KLE (capital-labor-energy) composite trades off against a materials composite (with the elasticity of substation $\sigma_{\mathrm{MAT-KLE}}$= 0.2). Within the KLE bundle, value-added (KL) substitutes against energy (σ_{KLE}= 0.25). The KL nest combines capital, sector-specific natural resources, and a labor bundle (σ_{KL} from GTAP, 0.2–1.7). The labor bundle aggregates different skill types at σ_{LAB}= 1. The energy nest distinguishes electricity from a fossil fuel composite (σ_{ENE}= 0.3), within which oil, coal, and gas substitute (σ_{FOS} = 0.8). These elasticities are doubled in the forward calibration of the baseline to match the evolution of carbon emissions and GDP growth rates in the Global Energy and Climate Outlook (Section 2.3). Fossil fuel extraction is modeled with a sector-specific resource factor using a calibrated supply elasticity. International trade follows the Armington approach with bilateral, commodity-specific elasticities.

Overall, ELBE-JRC model has two main distinct features. First, it is coupled in a fully integrated manner to a microsimulation module [to be explained further], which is based on statistically matched microdata from the Eurostat Household Budget Survey (HBS) and the European Union Statistics on Income and Living Conditions (EU-SILC) for 2015 (Temursho et al., 2026). This enables a detailed assessment of within-country household-level distributional impacts along both the uses side (expenditure patterns) and the sources side (factor income composition) of household budgets. Second, ELBE-JRC allows for a detailed analysis of the impact of labor market frictions on the cost of climate policy in that it incorporates labor market frictions in various forms: (i) restricted labor market segmentation (or scope) by labor skill type; (ii) involuntary unemployment motivated through minimum wage constraints or wage curves; and (iii) endogenous labor-leisure choice.

2.2 Labor market structure

Two dimensions of labor market in the ELBE-JRC model are central to our analysis: the scope of labor mobility and the presence of involuntary unemployment. In addition, the treatment of labor supply and its interaction with the government budget closure shape the welfare results in important ways.

Labor mobility scope. We consider three levels of labor market integration. Under *national* scope, labor is perfectly mobile across sectors within a country but immobile across national borders, implying one single labor market per country with a uniform wage rate. This is the standard assumption in most CGE models (see e.g. Landis et al. 2021; Antosiewicz et al. 2025). Under *sectoral* scope, each sector within each country constitutes a separate labor market with its own wage rate. Workers cannot move between sectors at all, as the transformation elasticity governing cross-sectoral reallocation is set to zero. This means that if carbon pricing contracts a sector's output and therefore also its labor demand, workers in that sector experience lower wages but do not move to expanding sectors. This is a deliberately strong assumption that captures, in the extreme, the short-run friction that workers cannot costlessly switch industries when carbon pricing triggers structural change. Under *EU+* scope, all EU+ countries share a single labor market, so labor is perfectly mobile across both sectors and national borders within the EU+, implying a uniform wage response to shocks. This represents a fully integrated European labor market.

The choice of labor scope has consequences beyond the direct effect on wages. Under national scope, cross-sectoral labor reallocation changes the composition of output, which in turn affects the carbon tax base, carbon revenues, consumption prices, and the government's need for compensating fiscal adjustments. Under sectoral scope, the sectoral composition of output is largely frozen, preserving the tax base but preventing cross-sectoral reallocation. Under EU+ scope, labor markets are pooled across countries, compressing cross-country wage differentials and reshaping the distribution of output across countries with different carbon prices, consumption baskets, and fiscal positions. These indirect general equilibrium effects, operating through carbon markets, international trade, consumption prices, and the government budget, may be quantitatively as important as the direct wage and income effects of labor reallocation.

Involuntary unemployment. Under the full employment closure, all labor markets clear and there is no unemployment, i.e. wages adjust to equilibrate supply and demand. Under the unemployment closure, involuntary unemployment arises from a wage -- an empirically well-documented negative relationship between the real wage and the unemployment rate (Blanchflower and Oswald, 1994). We implement it as a constant-elasticity function: the real wage (nominal wage divided by the consumer price index) equals a constant times the unemployment rate raised to the power of the wage curve elasticity, set to −0.1, the standard value in the literature (see de Galdeano and Turunen, 2005, for European estimates). The constant is calibrated to reproduce observed country-level unemployment rates from ILO data.

When carbon pricing raises consumer prices, the real wage falls for any given nominal wage. The wage curve then requires a higher unemployment rate to restore equilibrium, reducing effective labor supply (see e.g. Weitzel et al., 2023). This generates an additional welfare cost channel that is absent from full employment models.[1]

The unemployment mechanism also interacts with the labor scope dimension. The wage curve operates at the regional level, but the relevant wage depends on which labor markets exist. Under sectoral scope, each sector has its own wage, so the wage curve responds to sector-specific price and output conditions. Under national scope, a single country-wide wage drives the unemployment rate, so all sectors within a country experience the same unemployment response regardless of their individual exposure to carbon pricing. Under EU+ scope, the wage curve responds to EU+-wide labor market conditions, so unemployment in one country is affected by wage and price developments across all EU+ countries.

Labor supply. In the specifications used in this paper, total labor supply is exogenous, i.e. the representative agent's time endowment is entirely allocated to work, with no labor-leisure substitution margin. This means that the welfare measure (equivalent variation) captures changes in consumption utility only, not changes in the value of leisure time. The model does allow for endogenous labor-leisure choice as a feature, but we do not activate it in the current simulations in order to isolate the effects of labor scope and unemployment without the additional confounding margin of voluntary labor supply adjustment.

2.3 Emission baseline and targets

To carry out our counterfactual experiments, we utilize carbon emission projections from the 2021 Global Energy and Climate Outlook (GECO, Keramidas et al. 2021). For the EU, this time series baseline is fully compatible with the economic, energy and emission trends of the EU Reference scenario 2020 (European Commission, 2021) that was used to assess e.g., the "Fit for 55″ policy package. This implies that the current 55% emission reduction target with respect to 1990 emissions is not met in this baseline, but that other policies in the EU (e.g., to foster renewables

[1] In the current study, we do not activate the labor-leisure choice feature of the ELBE-JRC model, thus the time lost to unemployment produces neither income nor leisure utility. Unlike a model with endogenous labor-leisure choice, where reduced work could be partially offset by increased leisure valued by the consumer, our specification treats all unemployment as an uncompensated income loss.

and energy efficiency) would lead to exceeding the 40% emission reduction target in place at that time.

ELBE-JRC is calibrated to the data from version 10 of the Global Trade Analysis Project (GTAP), describing the base year 2014. When applying the changes in GECO 2021 baseline projections to GTAP emissions for 2014, we get the corresponding baseline projection for 2030. We then impose the updated National Determined Contributions (NDCs) climate targets as of COP26 in Glasgow as quantified in GECO 2021 (see also Garaffa et al., 2023) to arrive at emissions targets for all regions. For the EU, this includes the 55% emission reduction target. The baseline emissions for 2014 and 2030, and the corresponding 2030 targets, as imposed in the model, are reported in **Table 1**.

Table 1: 2030 baseline and target CO2 emissions (bln tonnes, GECO 2021)

Region, country	2014 benchmark	2030 baseline	2030 -to-2014 change (%)	2030 target emissions	2030 target-to-baseline change (%)
EU	2,869	1,451	-49.4	1,212	-16.5
EU+	3,402	1,730	-49.2	1,447	-16.3
CHN	7,788	10,832	39.1	10,012	-7.6
JPN	1,014	622	-38.7	450	-27.7
KOR	499	298	-40.2	241	-19.2
IND	1,912	2,854	49.3	2,453	-14.0
CAN	574	347	-39.5	292	-15.9
USA	5,155	3,911	-24.1	2,768	-29.2
BRA	451	365	-18.9	338	-7.4
RUS	1,409	1,714	21.6	1,693	-1.2
ANZ	406	416	2.4	284	-31.7
EUR	359	346	-3.5	330	-4.5
MEA	1,921	2,104	9.5	2,070	-1.6
AFR	1,091	1,742	59.7	1,677	-3.7
OAM	1,211	1,025	-15.4	971	-5.3
OAS	2,342	3,920	67.4	3,302	-15.8
World	29,533	32,224	9.1	28,328	-12.1

Note: EU+ includes EU countries, the UK, Norway, and Switzerland.

We see that the GECO 2021 baseline implies a 49% EU-wide decrease in carbon emissions in 2030 compared to 2014. Globally, however, emissions are projected to increase by 9%, largely driven by the 39% increase in carbon emissions in China. Imposing carbon limits on the 2030 baseline implies a 12% decrease in global emissions, and about a 16% decrease in EU emissions. The 2030 projected and targeted reductions of 24% (with respect to 2014) and 29% (with respect to 2030 baseline) for the US seem largely unrealistic, given the current administration's stance on climate change; however, in our simulations, we retain these trends, adhering to the emission pathways of GECO 2021.

2.4 Policy scenarios

We examine three stages of CO_2 market integration across the EU, the UK, Norway, and Switzerland (referred to as the EU+ in what follows).

1. *EU+ ETS without trading among non-ETS sectors ("no-trade")*: Energy-intensive sectors are covered by a single ETS with fully auctioned permits. Non-ETS emission targets are met at the national level through endogenous CO_2 prices that equalize marginal abatement costs across domestic non-ETS sectors. This reflects largely the legislative framework prior to the introduction of ETS2.
2. *EU+ ETS with trading among non-ETS ("trade")*: In addition to ETS coverage of energy-intensive sectors, abatement obligations for non-ETS emissions are tradable across participating countries, equalizing non-ETS CO_2 prices while maintaining the same aggregate non-ETS emissions as in scenario 1. This is the scenario that relates closest to the current policy architecture with ETS1 and ETS2 as two separate emission trading systems.
3. *Full ETS*: All emissions in countries participating in the EU+ ETS are covered by a single, unified European emissions trading system. Hence, all sectors and countries face a single carbon price.

In our analysis, we assume that emission permits are fully auctioned, reflecting a future European ETS design that no longer relies on partial grandfathering of allowances. Carbon pricing revenue is recycled among countries participating in the EU+ ETS according to the rules for allocating auctioned allowances in Phase IV of the EU ETS, as outlined in Regulation (EU) 2018/842. The rules are largely based on countries' benchmark ETS sector emissions in 2005, but they generally allocate additional allowances and revenue to lower-income Member States, providing them with a larger share than their benchmark emissions alone would justify. Within regions, revenue is redistributed among heterogeneous households on a per-capita lump-sum basis. **Table 2** presents the resulting shares used to allocate ETS revenue among the participating countries. For comparison, it also shows alternative distribution schemes based on the projected 2030 population sizes and 2014 benchmark emissions. These alternative schemes, however, are not applied in the current analysis.

Table 2 Carbon revenue shares by country (%)

Country	EU ETS Phase IV rules		Population share in 2030	Benchmark emissions share in 2030
	Segmented carbon markets	Full ETS		
AUT	0.92	1.44	1.75	1.62
BEL	1.73	2.59	2.22	2.92
CYP	0.22	0.37	0.18	0.35
CZE	5.08	3.48	2.00	2.52
DNK	0.98	1.35	1.15	1.52
EST	0.22	0.40	0.25	0.24
FIN	1.49	1.27	1.04	1.43

FRA	3.44	8.29	12.90	9.33
DEU	21.76	17.70	15.65	19.94
GRC	2.96	4.68	1.94	4.51
HUN	1.40	1.57	1.78	1.16
IRL	0.84	1.15	0.99	1.30
ITA	7.68	8.31	11.00	9.36
LVA	0.25	0.41	0.33	0.26
LTU	0.43	0.50	0.46	0.32
LUX	0.08	0.39	0.14	0.44
MLT	0.11	0.12	0.11	0.11
NLD	4.51	4.40	3.32	4.96
POL	15.52	11.10	6.98	7.76
PRT	1.44	1.51	1.87	1.47
SVK	1.17	1.07	1.01	0.68
SVN	0.39	0.41	0.39	0.38
ESP	7.38	7.00	8.97	6.97
SWE	0.55	1.03	2.15	1.16
GBR	10.57	11.15	13.34	12.56
CHE	0.22	1.05	1.72	1.18
NOR	1.29	1.71	1.07	1.93
BGR	2.99	1.84	1.20	1.21
HRV	0.59	0.67	0.72	0.50
ROU	3.78	3.02	3.37	1.91

Note: Segmented carbon markets refer to the other two scenarios of EU+UK ETS with and without trading among non-ETS sectors.

For the targeted CO_2 emission reductions, we assume that non-EU regions meet their NDCs from the Paris Agreement, in line with the GECO 2021 projections reported in **Table 1**. Regions that do not participate in the EU+ ETS regulate their emissions through regionally uniform CO2 prices. Total EU+ ETS emissions are reduced by 62% relative to 2005 levels, which is implemented as a 50% reduction in 2014 benchmark emissions for ETS sectors. In the no-trade scenario, non-ETS reduction targets are also imposed at the level of individual countries in EU+, which are defined as their 2030 baseline emissions minus 50% reductions in their benchmark ETS emissions [redo these targets?]. These are given in **Table A1** in the Appendix.

Throughout the analysis, we impose an equal-yield constraint whereby governments adjust final consumption taxes to keep real public expenditure constant relative to the benchmark without climate policy. This ensures that all components of final demand other than household consumption remain unchanged, allowing household consumption to serve as a meaningful welfare measure. This assumption is necessary since the model does not account for the utility generated by investments or government spending. Balancing the government budget, through adjustments in final consumption taxation, guarantees that the full value of carbon pricing revenue is available for redistribution, despite the erosion of non-carbon related tax bases by climate policy.

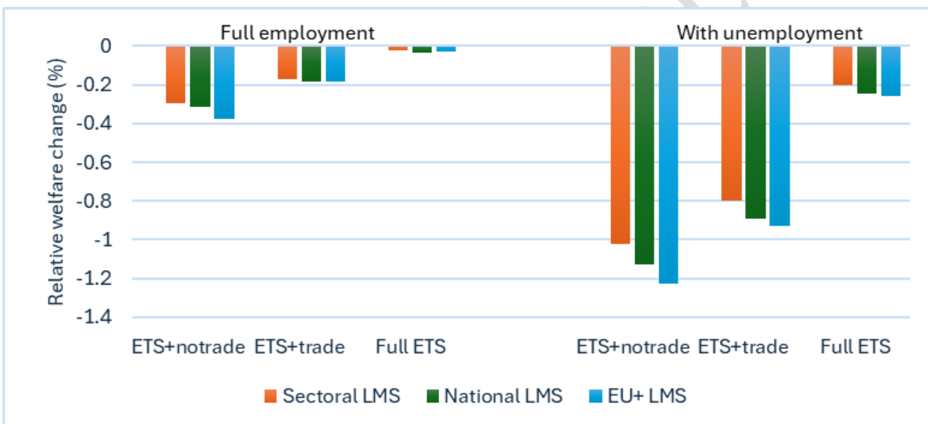
The combination of three CO_2 cooperation scenarios, three labor scope assumptions, and two unemployment closures yields 18 distinct model runs, enabling a systematic assessment of how labor market structure interacts with carbon market integration to shape the efficiency and distributional outcomes of EU climate policy.

3. Results

3.1 Aggregate welfare impacts

Figure 1 reports the aggregate EU+ welfare effects, measured as equivalent variation (EV) relative to baseline consumption expenditure, indicating changes in money-metric utility. It shows by what percentage the baseline expenditure budget would need to change to achieve the counterfactual consumption utility at baseline prices. The absolute welfare impacts, along with the summary of carbon prices are presented in **Table 3**.

Figure 1: Aggregate EU+ relative welfare impacts (%) of alternative designs of carbon and labor markets integration



Source: Own calculations. Labor market scope is abbreviated as LMS, while `notrade' and `trade' refer to, respectively, no trading and trading among non-ETS sectors.

Three key patterns emerge. First, CO_2 market integration generates large efficiency gains. For example, under the full employment and EU+ labor market scope, moving from the first segmented markets case without non-ETS trading (−0.37%) to the second segmented markets case with non-ETS trading (−0.18%) reduces welfare losses by 51%, and further moving to full ETS (−0.03%) additionally reduces them by 83%. The gains arise because carbon price harmonization eliminates the large dispersion in marginal abatement costs across countries and sectors. For example, under national pricing, with full employment and EU+ labor scope, non-ETS CO_2 prices range from \$27/tCO_2 in Poland to \$1,115/tCO_2 in Finland (**Figure XXX**), while the ETS permit price is only \$7/tCO_2. Full ETS collapses all prices to a single \$45/tCO_2, shifting abatement from high-cost sources (where countries and sectors were over-abating under fragmented national prices) to low-cost sources (where they were under-abating).

Second, unemployment amplifies welfare losses by a factor ranging between 3.3 (notrade/EU+ scope) to 10.5 (full ETS/sectoral scope). The mechanism operates through the wage curve: carbon pricing raises the consumer price index, reducing the real wage for a given nominal wage. The wage curve then requires a higher unemployment rate to restore equilibrium, effectively rationing labor supply. This reduces effective factor inputs, GDP, and household income. Crucially, the amplification factor is largest under the most integrated carbon market (full ETS), where the uniform carbon price creates concentrated adjustments in carbon-intensive regions that are magnified by labor market frictions.

Table 3: Welfare impacts and carbon prices

	Full employment			With unemployment		
	ETS+notrade	ETS+trade	Full ETS	ETS+notrade	ETS+trade	Full ETS
	Relative welfare change (in %)					
Sectoral LMS	-0.29	-0.17	-0.02	-1.03	-0.80	-0.20
National LMS	-0.31	-0.19	-0.04	-1.13	-0.89	-0.25
EU+ LMS	-0.37	-0.18	-0.03	-1.23	-0.93	-0.26
	Absolute welfare change (in bn $2014)					
Sectoral LMS	-40.6	-23.7	-2.6	-141	-110	-28
National LMS	-43.5	-25.8	-5.1	-156	-123	-34
EU+ LMS	-52.0	-25.4	-4.3	-169	-129	-36
	ETS carbon permit prices					
Sectoral LMS	7.85	8.04	40.3	7.64	7.85	39.9
National LMS	6.96	7.20	45.1	6.56	6.81	44.6
EU+ LMS	6.96	7.16	45.2	6.52	6.77	44.8
	Non-ETS carbon prices					
Sectoral LMS	259.2*	227.3	--	253.2*	222.6	--
National LMS	281.6*	247.9	--	274.4*	242.4	--
EU+ LMS	280.3*	248.4	--	273.8*	242.9	--

Note: (*) Non-ETS carbon prices in the ETS+notrade scenario are averages of the corresponding country-specific carbon prices.

Third, higher level of labor market integration leads to a greater welfare losses in all cases, except under the full employment case when moving from national to EU+ labor scope in the ETS+trade and full ETS scenarios. The step from sectoral to national scope is always welfare-reducing: cross-sectoral labor reallocation accelerates the contraction of carbon-intensive sectors, depresses factor prices and incomes economy-wide, and erodes the tax base, requiring a larger distortionary VAT adjustment. The step from national to EU+ scope depends on whether carbon prices are harmonised. Under no-trade fragmented prices, EU+-wide labor pooling compresses wages across countries facing very different carbon costs, amplifying the underlying price distortion and worsening welfare by −0.06 pp. Under harmonised prices (ETS+trade and full ETS), the same pooling operates on a level playing field, producing a small net welfare improvement (+0.003 pp and +0.006 pp respectively). When unemployment is activated, the wage-curve mechanism converts the wage compression from labor pooling into higher unemployment, overturning the small gains observed under full employment.

EU+ aggregate welfare decomposition. Before examining detailed distributional effects, it is important to clarify how welfare changes decompose. The welfare measure (EV as a percentage of baseline consumption expenditure) reflects both income changes and consumption price changes (see also Landis et al., 2021a, fn. 22). Specifically,

$$\text{Welfare} \approx \text{Sources-side effect} + \text{Uses-side effect.}$$

The *sources-side* (or income) effect captures changes in the nominal expenditure budget available for consumption. It reflects changes in factor incomes (labor, capital, resource rents), carbon revenue recycling, fiscal closure adjustments, and transfers. The *uses-side* (or expenditure) effect captures changes in what a given budget can purchase, i.e., the change in the consumer price index relative to baseline. A positive uses-side effect means the consumption basket has become relatively cheaper, increasing purchasing power.

These two sides can move in opposite directions: a country can gain welfare despite losing income (if prices fall enough) or lose welfare despite gaining income (if prices rise enough). Our results show that both sides are quantitatively important and that ignoring either would lead to incorrect conclusions about the distributional effects of carbon pricing.

Table 4 EU+ aggregate welfare decomposition

Scenario	Welfare (%)	Sources-side (%)	Uses-side (%)
	ETS+notrade, full employment		
— sectoral scope	-0.293	0.221	-0.514
— national scope	-0.314	0.263	-0.577
— EU+ scope	-0.373	0.244	-0.617
	ETS+trade, full employment		
— sectoral scope	-0.171	0.228	-0.399
— national scope	-0.186	0.270	-0.456
— EU+ scope	-0.183	0.284	-0.467
	Full ETS, full employment		
— sectoral scope	-0.019	-0.060	0.041
— national scope	-0.037	-0.065	0.029
— EU+ scope	-0.031	-0.076	0.045
	ETS+notrade, unemployment		
— sectoral scope	-1.025	-0.397	-0.629
— national scope	-1.131	-0.413	-0.718
— EU+ scope	-1.225	-0.494	-0.732
	ETS+trade, unemployment		
— sectoral scope	-0.798	-0.301	-0.497
— national scope	-0.893	-0.316	-0.577
— EU+ scope	-0.932	-0.348	-0.585
	Full ETS, unemployment		
— sectoral scope	-0.200	-0.296	0.096
— national scope	-0.247	-0.320	0.073
— EU+ scope	-0.261	-0.346	0.086

Note: Sources-side (or income) effect captures changes in nominal consumption spending, while the uses-side (or expenditure) effect refer to purchasing power effect of consumption price changes..

Table 4 shows the EU+ aggregate welfare decomposition into sources-side (change in nominal consumption spending) and uses-side (purchasing power effect of consumption price changes) reveals how the effects of carbon pricing and labor market integration operate through distinct channels.

Carbon market integration (reading down the three cooperation regimes for a given labor scope) reduces welfare losses through both channels, but predominantly through the uses-side. Under full employment with national scope, the sources-side moves from +0.263 (notrade) to +0.270 (trade) to −0.065 (fullets). The sources-side is positive under notrade and trade because the high carbon revenues generated by fragmented, high non-ETS prices are recycled to households, raising their nominal consumption budgets. Under full ETS, the uniform €45/tCO_2 generates less revenue, so the sources-side turns slightly negative. The uses-side, however, improves dramatically: from −0.577 (notrade) to −0.456 (trade) to +0.029 (full ETS). Under fragmented markets, the wide dispersion of carbon prices creates large and uneven commodity price increases that raise the CPI substantially. Under full ETS, the uniform price causes more moderate and uniform price adjustments, and the CPI falls slightly, turning the uses-side positive. The efficiency gain from carbon market integration thus operates primarily through the uses-side, by reducing consumption price distortions, rather than through higher nominal income.

Labor market integration (reading across the three labor scopes for a given cooperation regime) shows a more nuanced pattern, with the two sides often moving in opposite directions.

- Under ETS+notrade with full employment, moving from sectoral to national to EU+ scope worsens welfare despite a slightly improving sources-side (+0.221 → +0.263 → +0.244), because the uses-side deteriorates by more (−0.514 → −0.577 → −0.617). Broader labor mobility enables the economy to generate slightly more nominal consumption spending from reallocation and the associated fiscal adjustments, but this same reallocation reshapes the composition of output, causing consumption prices to rise -- a uses-side loss that more than offsets the sources-side gain. The welfare cost of broader labor scope under fragmented carbon pricing is thus a price effect, not an income effect.
- Under ETS+trade with full employment, the sectoral-to-national step follows the same pattern: the sources-side improves (+0.228 → +0.270) but the uses-side deteriorates more (−0.399 → −0.456). The national-to-EU+ step, however, shows a near-cancellation: the sources-side improves further (+0.270 → +0.284) while the uses-side worsens only slightly (−0.456 → −0.467), leaving welfare nearly unchanged (−0.186 → −0.183, a gain of +0.003 pp). With harmonised non-ETS prices, EU-wide labor pooling generates a small additional nominal income gain without triggering the large consumption price increases seen under fragmented markets.

- Under full ETS with full employment, the national-to-EU+ step reveals the opposite pattern from notrade: the sources-side worsens (−0.065 → −0.076), meaning nominal consumption spending falls further, but the uses-side improves (+0.029 → +0.045), meaning the CPI falls. The uses-side improvement dominates, yielding a net welfare gain of +0.006 pp. With fully harmonised carbon prices, EU-wide labor pooling compresses cross-country wage differentials in a way that slightly reduces the EU-wide consumption price level.
- Comparing across all three cooperation regimes with full employment, a clear pattern emerges: the sources-side effect of broader labor scope is positive under notrade and trade (where high carbon revenues provide a cushion), but negative under full ETS (where the lower carbon price generates less revenue to redistribute). The uses-side effect of broader labor scope is consistently negative under notrade (fragmented prices amplify consumption price increases), modestly negative under trade, and slightly positive under full ETS (harmonised prices allow favorable price adjustments). The net welfare effect of labor scope integration therefore depends on which side dominates, and this, in turn, depends on the degree of carbon market integration.
- *With unemployment*, the sources-side is negative across all scenarios because reduced employment directly cuts nominal consumption spending. Broader labor scope worsens the sources-side monotonically under all cooperation regimes (e.g., under notrade: −0.397 → −0.413 → −0.494), as the wage-curve mechanism converts the wage changes from labor reallocation into employment losses that reduce nominal income. The uses-side also deteriorates with broader scope (−0.629 → −0.718 → −0.732 under notrade), because the output composition effects that raise consumption prices under full employment are amplified when unemployment further distorts the production structure. The small uses-side gains from EU+ scope observed under full employment (full ETS: +0.029 → +0.045) do not disappear with unemployment, they actually increase (+0.073 → +0.086), but are overwhelmed by the much larger sources-side deterioration (−0.320 → −0.346).

The detailed mechanisms and country-level evidence underlying these aggregate results are discussed next.

3.2 Distributional effects by country

Carbon market integration generates large efficiency gains at the EU aggregate level, but these gains are distributed very unevenly across countries. **Error! Reference source not found.** displays country-level welfare effects (EV relative to baseline consumption expenditure) for all 30 EU+ countries across the three carbon cooperation regimes, for both full employment and unemployment. We first discuss the results under the standard national labor market scope assumption.

TBA.

3.3 Distributional effects by sector

TBA.

3.4 Distributional effects by households

TBA.

4. Conclusions

This paper provides the first systematic analysis of the joint interaction between CO_2 market integration, labor market scope, and involuntary unemployment in the context of EU climate policy. Using 18 scenarios from the ELBE-JRC model -- a multi-country, multi-sector CGE model coupled to a household microsimulation -- we trace how the efficiency and distributional consequences of carbon price harmonization are shaped by the degree to which workers can reallocate across sectors and borders.

Three following conclusions emerge from the results.

Carbon market integration is the dominant source of efficiency gains, operating primarily through the uses side. Moving from fragmented national non-ETS carbon prices, which range from €28/tCO_2 in Poland to over €1,100/tCO_2 in Finland under the no-trade scenario, to a single EU+ permit price of approximately €45/tCO_2 under full ETS reduces aggregate EU+ welfare losses by more than 90% under full employment. The efficiency gain operates primarily by compressing the large and uneven consumption price increases that fragmented markets create, rather than by raising nominal household income.

Unemployment is the most consequential model assumption for welfare magnitudes. Introducing a wage-curve unemployment mechanism amplifies aggregate welfare losses by a factor of 3.5 to 10.5, depending on the scenario. The mechanism is straightforward: carbon pricing raises the consumer price index, reduces the real wage, and the wage curve requires a higher unemployment rate to restore equilibrium. This makes the choice of labor market closure -- full employment versus wage-curve unemployment -- far more consequential for estimated welfare costs than the choice of labor mobility scope.

Labor market scope matters, but its direction depends on the degree of carbon market integration. Broader labor mobility generally worsens welfare under fragmented carbon markets, because cross-sectoral and cross-border reallocation reshapes the output mix in ways that raise consumption prices beyond any income gains. Under harmonized carbon prices, this negative price effect weakens or reverses, and EU+-wide labor pooling produces small net welfare gains under full employment. With unemployment, the wage-curve mechanism converts the wage changes from labor reallocation into employment losses that dominate, making broader labor scope welfare-reducing in nearly all scenarios.

[TBC; distributional results by country, sector, and households]

Several important limitations should be noted. The model does not include an energy system module, so the role of capital investment in clean technologies, changes in capital intensity, and the distributional effects of capital income from green investment are not captured. Free allocation of allowances and other non-price EU climate policies are also abstracted from.

Taken together, the results underscore that the efficiency and equity consequences of EU climate policy cannot be assessed from the carbon market design alone. Labor market structure, through both the scope of worker mobility and the presence of unemployment, is a first-order determinant of welfare outcomes. Policies that deepen carbon market integration while retaining Phase IV-style redistribution toward lower-income Member States remain broadly welfare-improving and distributionally progressive, but their aggregate costs are larger when labor markets are rigid and unemployment is endogenous than standard full-employment models suggest.

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A. Supplementary Tables

Table A1: Projection of baseline CO2 emissions (bln tonnes) and non-ETS emission reduction targets

Country	2030 baseline from GECO 2021	Reduction targets for non-ETS emissions relative to 2030 baseline (%)
AUT	30.2	-32.3
BEL	60.1	-34.8
CYP	6.5	-36.1
CZE	42.8	-79.8
DNK	23.2	-42.2
EST	7.8	-39.7
FIN	17.5	-74.7
FRA	152.7	-30.2
DEU	344.0	-68.8
GRC	34.3	-63.2
HUN	16.8	-54.9
IRL	24.0	-41.5
ITA	140.8	-63.0
LVA	5.1	-30.4
LTU	3.4	-63.4
LUX	6.3	-21.5
MLT	4.4	-45.6
NLD	76.4	-59.8
POL	207.1	-65.3
PRT	21.2	-54.9
SVK	9.5	-68.3
SVN	10.1	-40.5
ESP	111.0	-58.4
SWE	18.7	-36.2
GBR	218.6	-56.6
CHE	22.8	-16.4
NOR	37.3	-36.3
BGR	19.2	-85.5
HRV	9.8	-42.8
ROU	48.5	-57.1