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Title:

Green Fiscal Reforms and the Demographic Squeeze: Lessons from Japan*

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ABSTRACT

How does carbon pricing perform in an economy with a declining population growth? We develop an overlapping generations model calibrated to Japan. Using this model, we examine how demographic change interacts with green fiscal reforms, in which revenues from carbon pricing are used to improve the efficiency of the tax system. Our results show that demographic change erodes the tax base, so the fiscal response has a larger impact on welfare than the carbon policy itself. Relative to a constant population growth benchmark, ignoring demographic change can overestimate the welfare costs of carbon pricing by 11 percent when pension benefits are reduced and carbon revenues are used to cut capital taxes. Microsimulation analysis indicates that low-income households face higher short-run welfare losses under policies that are most efficient in the long-run, highlighting a trade-off between efficiency and progressivity in the design of carbon pricing in aging economies.

JEL **classifications: H22, H23, Q52**
Keywords: green fiscal reforms, carbon pricing, demographic change

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1. Introduction

Demographic change is a global concern of the twenty-first century.[1] In many countries, the increasing share of retirees relative to working populations threatens the sustainability of social security systems and public finances. At the same time, governments face increasing pressure to implement ambitious climate policies. One potential tool to address both challenges is a "green fiscal reform." Such reforms raise additional revenues from a carbon pricing policy and redistribute them through the reduction of other existing tax rates, such as personal and corporate income taxes. This paper investigates how green fiscal reforms interact with demographic changes to better understand the efficiency and equity of carbon pricing policy. We explore this space through ex-ante numerical simulation analysis with an applied general equilibrium model of the Japanese economy.

Balancing pension budgets is of particular urgency in Japan, where the speed of population aging is among the fastest in the world. This urgency reflects three factors. First, Japan has the highest proportion of elderly citizens in the world.[2] Second, its birth rate is well below the replacement level of 2.1. Third, its life expectancy is one of the highest in the world. Although the rate of population aging in other countries may not be as rapid as in Japan, many are expected to follow similar population growth trajectories. Parallel to these trends, Japan has ambitions to implement a national carbon pricing policy, which raises the question of how it might interact with demographic change driven by low fertility, population aging, and overall population decline.[3]

We build on Williams et al. (2015), employing an overlapping-generations (OLG) computable general equilibrium model in which cohorts are born at five-year intervals and live for 55 years. The model is calibrated to Japan using the GTAP 11 Data Base (Aguiar et al., 2023). Demographic change follows UN population projections, shown in Figure 1. The resulting erosion of the tax base requires the government to balance its budget either by uniformly increasing capital, labor, and value-added taxes (VAT) rates or by proportionally reducing pension transfers. Carbon pricing policy is introduced as a tradable permits system that reduces emissions by 15%, which roughly corresponds to a carbon price of \$100/ton. In our main policy experiments, revenues from the carbon pricing are recycled back to the economy through reductions in capital, labor, or VAT rates, or through lump-sum transfers to households. As a neutral benchmark, we also consider a wasted revenue scenario in which revenues from the carbon policy are collected and discarded rather than recycled. This allows

[1] See https://www.un.org/en/global-issues/ageing.

[2] https://www.nippon.com/en/japan-data/h01446/

[3] In 2023, Japan introduced a voluntary emission trading system known as GX-ETS, which is expected to be mandatory by 2026. See https://gx-league.go.jp/en/ for more details.

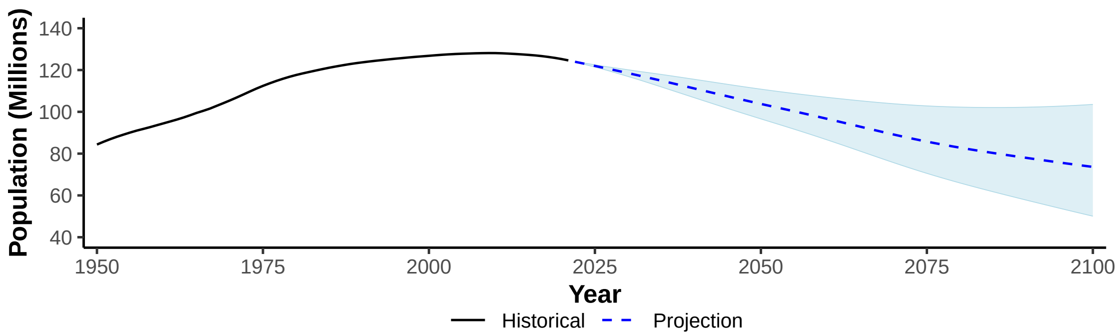

Figure 1: Population trajectory for Japan.

Source: United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects: The 2022 Revision. https://population.un.org/wpp/

us to isolate changes in relative efficiency for each recycling instrument.

To assess the tax incidence within generation, we implemented a microsimulation of household finance. The microsimulation combines model-implied after-tax price and factor-return changes with income and expenditure shares by quintile. Income shares are constructed from household survey data and administrative tax records. Expenditure shares are drawn from national consumption data. Under linear demand and supply approximations, we compute changes in consumer and producer surplus for each quintile and sum them to obtain quintile-level welfare changes. Transfers and revenues from the carbon policy enter as income changes without associated price wedges.

Our quantitative analysis yields several key findings. We begin by quantifying the fiscal reforms required to sustain Japan's public pension system in response to demographic change, both with and without carbon pricing. Our simulations show that demographic change alone necessitates substantial increases in distortionary tax (capital, labor, and VAT) rates or deep cuts in pension benefits. When the government balances the pension budget by uniformly raising the distortionary tax rates, the resulting tax hikes are sizeable and persistent, and they remain largely in place even after carbon revenues are recycled back to the economy. Alternatively, cutting pension benefits while maintaining tax rates requires sizable and proportional reductions in transfers. These findings indicate that in an aging and shrinking economy, the fiscal response to demographic change is of first order importance for welfare and sets the fiscal context within which carbon pricing must be evaluated.

We next examine how demographic change and carbon pricing jointly affect labor and capital supply. Population aging and decline reduce aggregate labor and capital endowments, raise their marginal products, and induce households to supply more work effort and savings on a per capita basis. The way in which the pension budget is balanced plays a central role in shaping these responses: financing demographic pressures through higher distortionary tax rates dampens incentives to work and accumulate assets, whereas financing them through lower pension benefits strengthens incentives to self insure for retirement by increasing labor supply and private saving. The use of carbon revenues further affects these factor supply responses. Recycling revenues via cuts in capital income taxation encourages capital accumulation in an environment where capital is already scarce and, over time, generates larger increases in the capital stock and labor supply than recycling through labor or consumption tax cuts, which yield smaller and more short lived effects.

We also show that the welfare effects of carbon pricing differ sharply across policy regimes. Relative to an otherwise identical economy with constant population growth rate, implementing carbon pricing along Japan's projected demographic transition reduces the welfare cost of a given emissions reduction by up to about 11 percent when demographic pressures are accommodated by cutting pension benefits and recycling carbon revenues through lower capital income taxes. By contrast, when demographic change is financed through higher capital, labor, and consumption tax rates and carbon revenues are recycled via consumption tax cuts, the welfare cost of carbon pricing can be up to 9 percent higher than in the constant population growth benchmark. These differences imply that analyses that abstract from demographic change can understate or overstate the welfare cost of carbon pricing by nearly ten percent, depending on how pension finances and carbon revenues are handled.

The distribution of these welfare effects across cohorts is also highly uneven. In all regimes, cohorts that are already alive when the policy is introduced bear the largest welfare losses because they live through the transition but do not fully benefit from the new steady state, whereas cohorts born later gain more from the higher capital intensity and lower capital taxation that emerge under the more efficient policy combinations. This intergenerational gradient is particularly pronounced when demographic pressures are met through pension cuts and carbon revenues are used to reduce capital income taxes, which shifts a larger share of the adjustment burden onto current generations in exchange for larger efficiency gains for future ones.

Finally, we examine within generation equity using a microsimulation of household finance. The data show that low income households derive most of their income from wages and public transfers and hold little wealth, whereas high income households rely heavily on capital income. This composition implies that the fiscal mix that minimizes the aggregate welfare cost of carbon pricing, which combines cuts in pension benefits with recycling of carbon revenues through lower capital income taxes, disproportionately burdens low income households in the short-run while conferring larger gains on higher income households. More progressive recycling options, such as labor tax cuts or lump sum transfers, mitigate welfare losses for the poorest quintiles but deliver smaller efficiency gains in the aggregate. Taken together with the intergenerational results, these findings highlight that policy regimes that are most efficient and most favorable to future cohorts tend to be regressive within current cohorts, underscoring a sharp trade off between aggregate efficiency and short-run progressivity in the design of green fiscal reforms in aging economies.

This paper makes three main contributions to the literature on carbon pricing, demographic change, and fiscal policy. First, we extend the tax interaction and "double dividend" literature by embedding demographic change into an OLG framework (Goulder, 1995; Bovenberg and Goulder, 1996; Williams et al., 2014, 2015; Barrage, 2020).[4] Earlier work shows that recycling carbon tax revenues into reductions in distortionary taxes can raise efficiency, with capital-tax recycling generally yielding the largest gains. We confirm this ranking and demonstrate that demographic change magnifies efficiency differences by altering savings and labor supply responses. We also show that the welfare cost of implementing a carbon tax after demographic change is higher under less efficient policy scenarios, which implies that governments delaying carbon pricing until after pension reforms may encounter greater challenges. More broadly, we find that demographic change exerts a much larger influence on welfare outcomes than the carbon pricing itself, underscoring the need to analyze carbon pricing in the fiscal context shaped by demographic transitions.

Second, our paper is most closely related to Gonand and Jouvet (2015) and Gonand (2016), who examine how carbon tax revenues can be used to alleviate the fiscal pressures of aging populations in OECD countries. These papers show that recycling revenues to reduce pension contributions can generate a weak form of the double dividend, since pension financing is itself distortionary. Our contribution is to move beyond their setting in several respects. We focus on Japan, where the demographic transition is both sharper and more advanced, and therefore more consequential for long-run fiscal sustainability. We also broaden the set of fiscal instruments considered, analyzing not only pension contributions but also capital, labor, and VAT taxation as budget balancing tools. Finally, we evaluate welfare effects against the waste-revenue benchmark introduced above rather than lump-sum transfers. This approach provides a more neutral and objective basis for comparing the efficiency of recycling instruments.

Third, we contribute to the literature on the intergenerational distribution of carbon pricing. Several recent studies examine how carbon taxes shift welfare across cohorts. Fried, Novan and Peterman (2018) analyze the U.S. using an OLG model and show that carbon taxes impose disproportionate burdens on current generations while benefiting future ones, with the direction and size of these tradeoffs depending on revenue use. Rausch and

[4]Double dividend is a concept where carbon tax revenues may be used to offset pre-existing distortionary tax rates in the economy to achieve an increase in welfare (Goulder, 1995; Bovenberg and Goulder, 1996).

Yonezawa (2018) focus on the U.S. as well, highlighting how lifetime incidence varies with pre-existing distortions and the design of the tax-and-transfer system. Kotlikoff et al. (2021) emphasize intergenerational equity in climate policy design and argue for policies that balance efficiency with fairness across cohorts. Our contribution is to extend this line of research by embedding demographic change directly into the analysis. We show that aging and population decline intensify intergenerational tradeoffs and fundamentally reshape the welfare profile across cohorts. In addition, our microsimulation reveals that intergenerational dynamics interact strongly with within-generation inequality. Policies that maximize aggregate efficiency disproportionately benefit high-income households, whereas lower-income groups are better protected under recycling instruments that deliver smaller efficiency gains in the aggregate.

Taken together, our analysis shows that demographic change is not a secondary consideration. It is instead a determinant of both the efficiency and the distributional incidence of carbon pricing. Studies that abstract from demographic dynamics risk mismeasuring the welfare costs of carbon taxes and overlooking central policy tradeoffs.

The remainder of the paper is structured as follows. Section 2 explains the OLG model in detail and summarizes the various policy scenarios we model. Results are presented in Section 3. The methods and results from the microsimulation of household finance are presented in Section 4. Lastly, Section 5 provides concluding remarks.

2. Model

Our model follows the design of Williams et al. (2015) with modifications to accommodate changes in population growth rates, carbon pricing, and calibration to GTAP 11.[5] The OLG structure is as follows: each generation g is born in year $t = g$ and lives for $N = 55$ years. They are endowed with $\omega_{g,t}$ of time which can be converted into leisure ℓ_t or labor. Wages $\pi_{g,t}$ are converted into consumption $c_{g,t}$ which is combined with leisure into final consumption $z_{g,t}$ in a constant elasticity of substitution function. Final consumption then enters the constant relative risk aversion utility function:

[5] The model was originally developed in Carbone, Morgenstern and Williams (2012).

$$
\begin{aligned}
\max_{c_{g,t},\ell_{g,t},a_{g,t}} \quad & u_{g,t}(z_{g,t}^{1-\theta}) = \sum_{t=g}^{g+N} \left(\frac{1}{1+\rho}\right)^{t-g} \frac{z_{g,t}^{1-\theta}}{1-\theta} \\
\text{s.t.} \quad & z_{g,t} = (\alpha c_{g,t}^{\sigma} + (1-\alpha)\ell_{g,t}^{\sigma})^{1/\sigma}, \\
& \sum_{t=g}^{g+N} \beta_t[p_t^c c_{g,t} + a_{g,t+1}] \leq \sum_{t=g}^{g+N} \beta_t[(1+r_t)a_{g,t} + p_t^l \pi_{g,t}(\omega_{g,t} - \ell_{g,t}) + p_t^l \gamma_{g,t}], \\
& \ell_{g,t} \leq \omega_{g,t}, \\
& c_{g,t}, \ell_{g,t} \geq 0
\end{aligned}
\tag{2.1}
$$

where σ is the substitution parameter between consumption and leisure, ρ is the utility discount rate, $1/\theta$ is the intertemporal elasticity of substitution, β_t is the discount factor, p_t^c is the price of consumption, p_t^l is the wage rate, $a_{g,t}$ are total assets held by generation g in period t and p_t^f is the price of foreign exchange which is the currency used for pensions $\gamma_{g,t}$.

Generations supply labor and accumulate capital investments at different rates over their lifespans, which scale between generations following total factor productivity (TFP) change and population growth (see Figure 2). This reflects that younger households derive more of their consumption from labor wages and accumulate investments over the course of their lifespan which they eventually draw down in retirement. They also receive a pension from the government.[6] The steady-state baseline is modeled with a population growth rate of -0.67% per year, as projected for 2025 by United Nations (2022), and a TFP growth rate of 1.5%. The index for these growth rates combined is shown in Figure 3. We calibrate production and trade to the GTAP 11 Data Base, modeling Japan as a small open economy that trades with rest of world. The overlapping generations structure is particularly useful for identifying outcomes of long-run changes such as population growth, because generations only take into account events that happen in their lifetime. In models with a single representative agent, the agent optimizes over the entire time horizon, which in this case would result in behavior taking into account effects of population levels that would not be realized for several more generations. In the OLG model, each generation has no preference for events that occur outside their own lifespan.

[6] See the pension schedule in Japan Pension Service. https://www.nenkin.go.jp/international/japanese-system/nationalpension/nationalpension.html

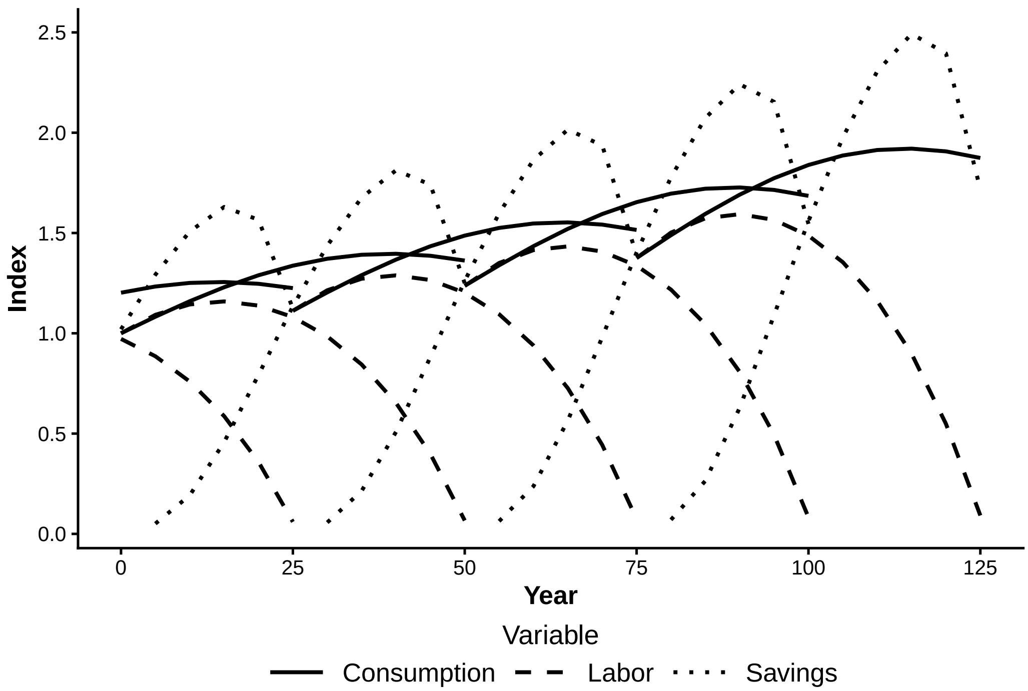

Figure 2: Lifecycle labor supply, capital accumulation and consumption for a subset of generations in the steady-state scenario.

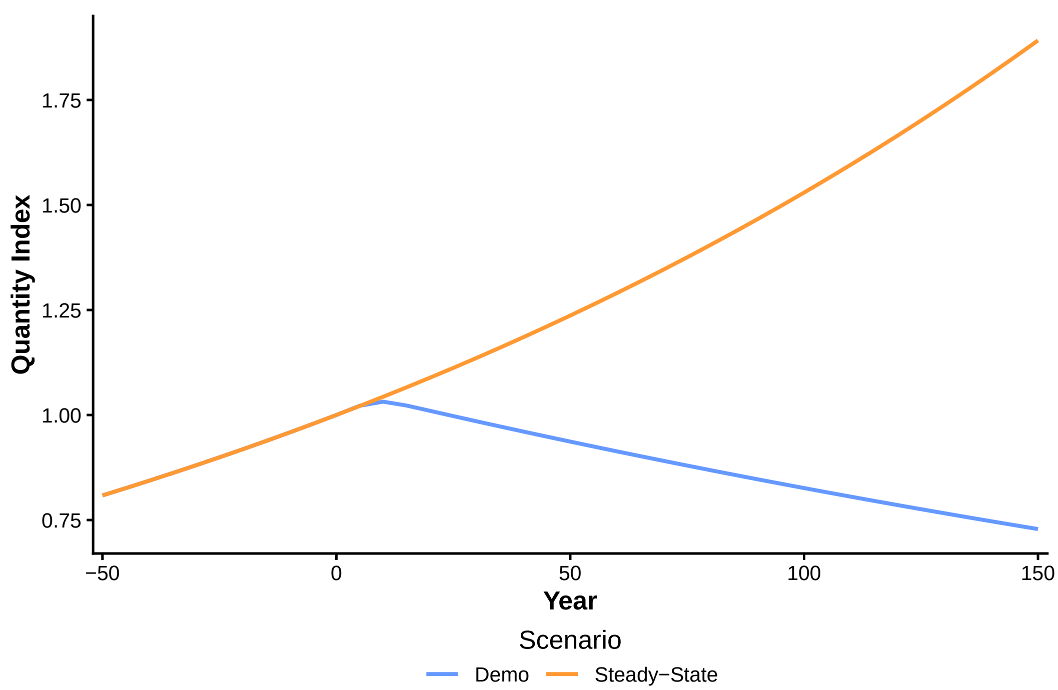

Figure 3: Steady-state and demographics counterfactual growth rates for population and TFP combined.

Counterfactual Scenarios

Figure 4 illustrates the baseline and counterfactual experiments we run. Scenario A is the baseline steady-state growth scenario with no carbon pricing. Scenario B incorporates the cap-and-trade permit system with an endogenous price to restrict emissions below a ceiling of 85% of the level in scenario A. The government receives all cap-and-trade revenues which are used to lower pre-existing tax rates on capital, labor, VAT, or can be redistributed to households via lump-sum transfers. Scenario C replaces the steady-state population growth rate with a smoothed version of the low variant population projection for Japan from United Nations (2022).[7] The reduced population growth causes tax revenues to decline, which can be offset with one of two endogenous sources of additional revenue: (1) the government can uniformly raise capital, VAT and labor tax rates to maintain constant pension levels, or (2) reduce pension spending for all generations to balance the budget.[8] Scenario D caps emissions at 85% of the level in scenario C, includes each of the four revenue recycling options described above and the demographics profile with each of the two budget balancing options. Scenarios B′ and D′ introduce the cap-and-trade system; however, revenues are wasted,[9] which provides a neutral point from which to compare outcomes excluding the direct effects of demographic change.

Comparing scenario A and D combines all effects: demographic change, cap-and-trade, and the revenue recycling instrument. Comparing scenarios A and C isolates the effect of demographic change and the relevant instrument chosen to balance government budgets. Next, there are several comparisons we can make to identify the marginal cost of implementing cap-and-trade with revenue recycling instruments to households, which allow us to compare models with and without demographic change in an apples-to-apples manner. Comparing C and D isolates the effect of cap-and-trade: the revenue recycling instrument and related interaction effects. Comparing scenarios D and D′ isolates the effect of the revenue recycling instrument and related interaction effects. To identify how the efficiency of the revenue recycling options interacts with the demographic profile, we can compare changes in welfare between scenarios D and D′ with those between B and B′. In both of these comparisons, the base is the scenario where carbon revenues are wasted, and the change in welfare is solely due to the efficiency of the revenue recycling instrument and related interaction effects.

Figure 5 shows emissions levels with and without cap-and-trade in the steady-state and

[7] We estimate an s-curve fit to the low variant projection (United Nations, 2022) to help the solver converge to a solution.

[8] Implementation of these policies in the model is analogous to other proposed policies such as reducing the replacement ratio, raising the retirement age, etc.

[9] We model this as a revenue adjustment that does not enter the utility function or other government spending.

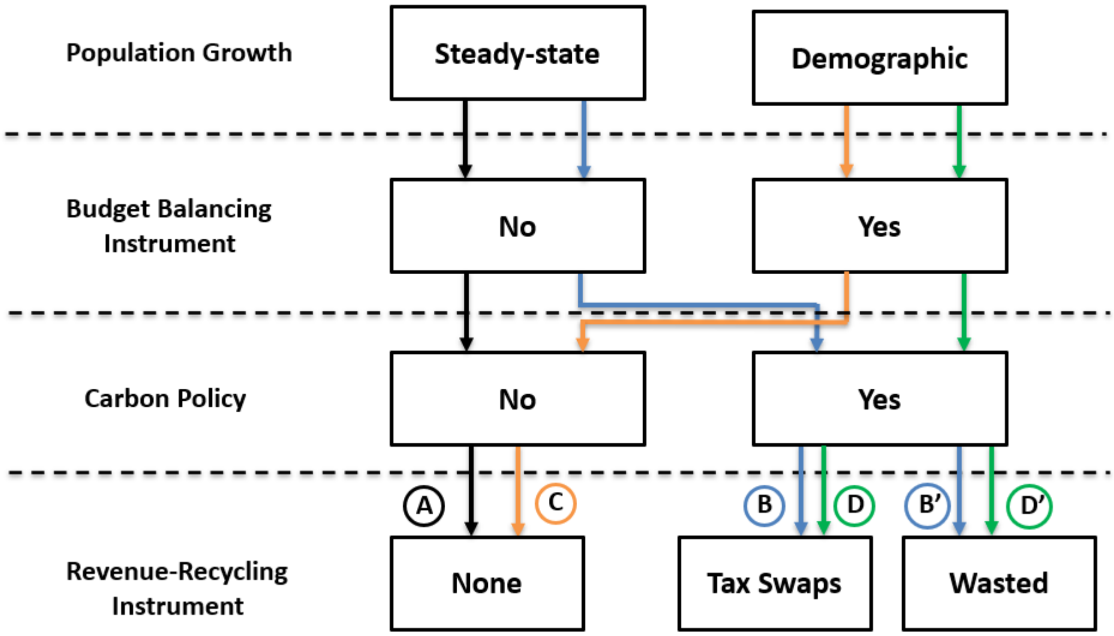

Figure 4: Counterfactual Model Scenarios

Note: Decision tree of policy scenarios illustrating the sequence of assumptions that generate alternative welfare outcomes. The first branch distinguishes between a steady-state economy and a demographic scenario with declining population growth. The second branch introduces the choice of a budget balancing instrument. Yes indicates the government either increases tax rates or reduces transfers to compensate for the erosion of the tax base due to the population decline. The third decision node introduces a carbon price, while the last decision node is the revenue-recycling instruments. Tax swap indicates that the revenues from the carbon pricing are used to either reduce the existing tax rate (capital, labor, or value-added tax) or provide a lump-sum transfer. Wasted indicates that the revenues from the carbon pricing are wasted. Scenario A (black path) is the baseline steady-state growth scenario with no carbon pricing. Scenario B (blue path) incorporates cap-and-trade and revenue recycling. Scenario C (orange) incorporates the demographic change and budget balancing. Scenario D (green) incorporates all (demographic change, budget balancing, carbon poilicy, and revenue recycling). Scenarios B′ and D′ are varients of Scenarios B and D where the revenues from carbon pricing is wasted.

the demographic change scenarios. In the demographics scenarios without carbon policy, emissions diverge from the steady state for two reasons. First, emissions scale with population. The smaller counterfactual population in scenario C has a similar emissions intensity per person to scenario A, but reduced population levels cause emissions to decline. Second, the two budget balancing instruments in the two dotted lines for scenario C have different levels of distortions baked into them. The tax rates scenario increases distortions which reduce emissions by more than the transfers scenario. To identify apples-to-apples comparisons for welfare outcomes between these different scenarios, we model the cap-and-trade system as reducing emissions by 15% between scenarios A and C to B and D, respectively.

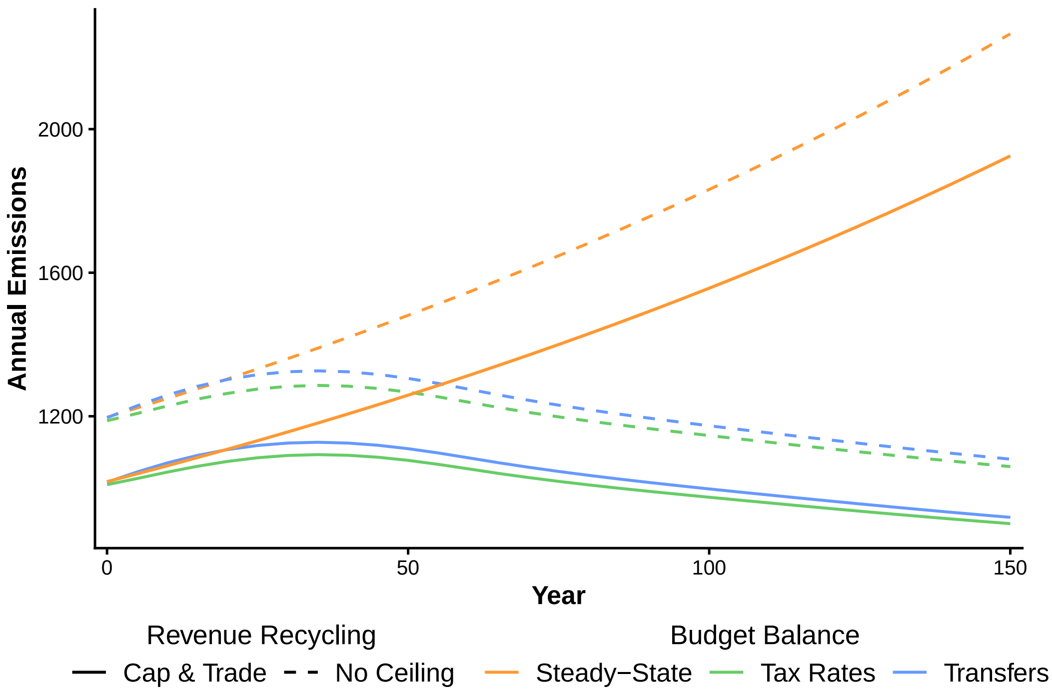

Figure 5: Emissions with and without cap and trade under alternative population paths.

Note: The dotted lines show emissions without carbon pricing under a steady state population path and under the demographic change path, with differences between the blue and green lines reflecting alternative instruments used to balance the pension budget (higher tax rates versus lower pension benefits). The solid lines show emissions when a cap and trade policy is introduced that reduces emissions by 15 percent relative to each corresponding baseline path, with carbon revenues wasted rather than recycled. In the model notation, the dotted series correspond to scenarios A (steady state without carbon pricing) and C (demographic change without carbon pricing), and the solid series correspond to scenarios B′ and D′ (steady state and demographic change with cap and trade and wasted revenues).

3. Results

Table 1 presents the change in tax rates and transfers for each revenue recycling and budget balancing scenario. The transfers column are changes in the sum of transfers for all generations who receive them in year zero, adjusted to constant real value and net of any lump-sum transfers from the carbon policy. Scenario B shows that without demographic change, recycling carbon revenues through capital taxes allows for a 2.24% decrease in capital tax rates for all periods in the model. Recycling through labor and VAT reduces those rates by 1.61% and 0.71%, respectively. Directly transferring the carbon revenues to households increases transfers in period zero by 2.23%. Total real pensions over all time periods are held constant in the model, which results in some variation in response to the revenue recycling and budget balancing instrument adjustments even when carbon revenues are not directly transferred to households.

Table 1: Percentage changes in tax rates and pension transfers by scenario

Budget Balancing Instrument	Scenario	Recycling Instrument	Tax Rates (% Change)			Transfers (% Change)
			Capital	Labor	VAT	
None	B	Capital	-2.24	–	–	-0.21
		Labor	–	-1.61	–	0.31
		VAT	–	–	-0.71	0.29
		LumpSum	–	–	–	2.23
Tax Rates	C	-	1.74	1.74	1.74	-4.64
	D	Capital	-0.58	1.74	1.74	-5.02
		Labor	1.74	0.16	1.74	-4.48
		VAT	1.74	1.74	1.11	-4.44
		LumpSum	1.74	1.74	1.74	-2.76
Transfers	C	-	–	–	–	-12.35
	D	Capital	-2.48	–	–	-12.74
		Labor	–	-1.78	–	-12.21
		VAT	–	–	-0.76	-12.18
		LumpSum	–	–	–	-10.16

Note: Entries report percentage changes in statutory capital, labor, and value added tax (VAT) rates and in pension transfers relative to the steady state economy without carbon pricing and demographic change (scenario A). The Budget Balancing Instrument indicates how the pension system is kept solvent: None denotes the steady state population path in which only carbon revenues are recycled (scenario B); Tax Rates denotes balancing through proportional changes in capital, labor, and VAT rates; Transfers denotes balancing through proportional changes in pension benefits (scenarios C and D in both cases). Scenario B introduces cap and trade with revenue recycling under the steady state population path, while scenarios C and D add demographic change with, respectively, no carbon pricing and cap and trade with revenue recycling. The Recycling Instrument shows how carbon revenues are used in scenarios B and D (reductions in capital, labor, or VAT rates or lump sum transfers).

Scenario C for the tax rates balancing instrument shows that tax rates must increase by 1.74% in all periods to offset the erosion of the tax base caused by the new demographics profile. Alternatively, scenario C with the transfers balancing instrument shows that pensions for all claimants must be cut by 12.35% to bring government spending in line with reduced tax revenues. While this does not translate directly into a numerical increase in the retirement age, such a policy could aim to increase the age to a level that would reduce pension expenditures by 12.35%.

With both budget balancing instruments, carbon revenue recycling is not enough to fully offset all the required changes in tax rates or transfers, indicating that the magnitude of the fiscal impact from demographic change overshadows that of carbon pricing.

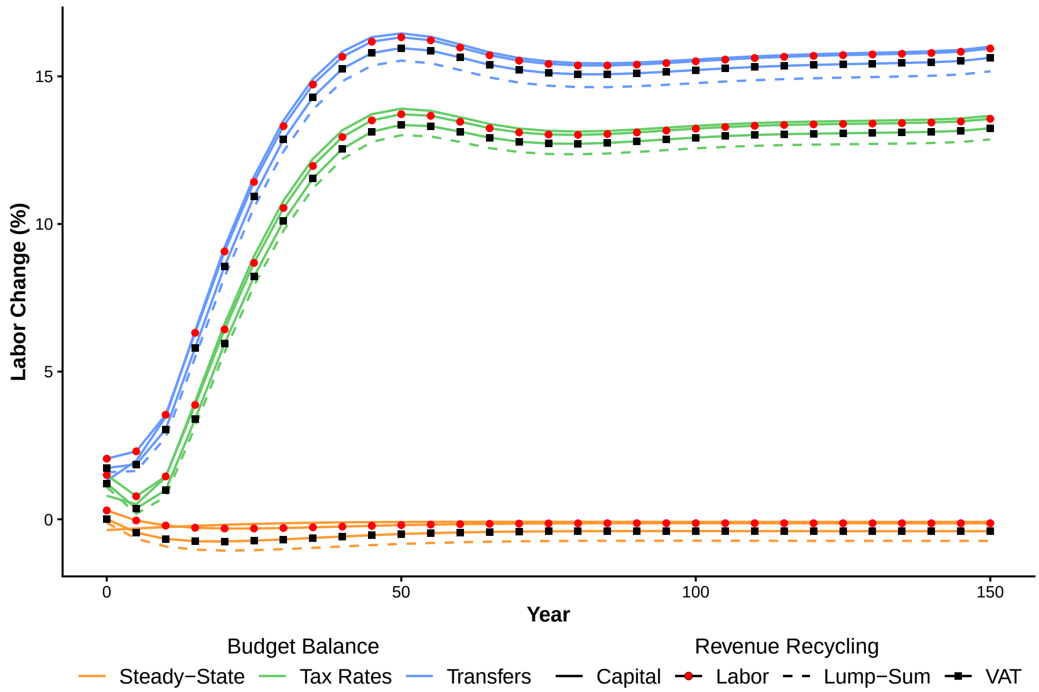

Figure 6: Labor supply responses to demographic change and cap and trade

Note: Each line shows the percent change in per capita labor supply by year relative to the steady state economy without carbon pricing (scenario A). The yellow series reports the change when a cap and trade policy with revenue recycling is introduced in an economy with constant population growth (scenario A to B). The blue and green series report the change when demographic change, pension budget balancing, and the same cap and trade policy with revenue recycling are introduced relative to the steady state baseline (scenario A to D). The two colors indicate whether the pension budget is balanced through higher tax rates (tax rates case) or lower pension benefits (transfers case). Within each color, different symbols distinguish the four revenue recycling options, where carbon revenues are used to reduce capital, labor, or consumption tax rates or are returned as lump sum transfers.

I. Factor supply changes

The overall effect of the decline in population growth on the system is to reduce total factor supplies. There are fewer households to supply labor and capital investment. With this change, the marginal product of labor and capital increases, which prompt the wage and rental rate to increase accordingly. Households respond by increasing factor supplies. This per-capita increase, and how it interacts with the budget balancing response and carbon policy, is the primary mechanism for efficiency and welfare impacts.

Figure 6 illustrates the percent change in labor supply from scenario A to B and D. The yellow series are the percent change in labor supply for scenario B, and the blue and green series are for scenario D, where the two colors indicate if increased tax rates or reduced transfers are used to balance budgets. Each revenue recycling option has a distinct symbol within scenarios B and D.

The large differences between labor supply levels in scenarios B and D indicate that the effects of demographic change on household factor supply decisions are large. The choice between transfers and tax rates for the budget balancing instrument does have a material impact on wages and labor supply choices, as does the choice of revenue recycling instruments, but the effects of these policies are small relative to the decline in growth rates. In the tax rates case, households respond to elevated wages from the new demographics profile, but also face elevated tax rates which suppress the marginal income from labor supply, counteracting some of the increase from the demographics profile. In the transfers scenarios, wages are elevated from the demographics profile, but households are also compensating for the 12% reduction in pensions by increasing labor supplies and do not have elevated tax rates reducing wages as in the tax rates scenario.

The pattern of labor supply responses to each revenue recycling instrument corresponds to the relative level of distortions present in each policy. In the short-run, recycling revenues to reduce labor taxes stimulates the highest labor supply relative to the other recycling options. Over time, capital tax recycling yields a slightly higher labor response. There are capital stocks carried over from before the onset of population decline and before the budget balancing response in year zero. While the legacy capital investments remain, marginal productivity of labor is higher than that for capital, and labor tax recycling is more valuable. Over time, legacy capital stocks depreciate, and marginal productivity of capital exceeds that of labor. Once this transition occurs, capital tax recycling yields a slightly higher labor supply level than labor recycling, as higher capital stocks increase the marginal product of labor more than reduced labor taxes.

Figure 7 presents the per-capita change in savings between scenarios A to B and D. The percent change in capital supplies for each scenario are broadly similar to those for labor supplies, with a slightly larger difference between the budget balancing policies, and a slightly larger response to capital tax recycling relative to the other recycling instruments. The immediate response in all scenarios is slightly muted compared to the immediate positive labor response, as legacy capital stocks from before the decline in growth rates cushion the decline in total capital stocks. Legacy capital in combination with increased distortions in the tax rates budget balancing instrument causes an immediate temporary decrease in savings per capita. In the labor supply plot, this dip was still present but did not go below zero. After the initial dip, increased rental rates dominate the inefficiency introduced by the budget balancing response, and per capita savings increase. Again, the ordering of the revenue recycling instruments within each budget balancing option depends on the levels of distortions present in each option.

Calculating percent change between scenarios A and D as in Figure 7 combines the

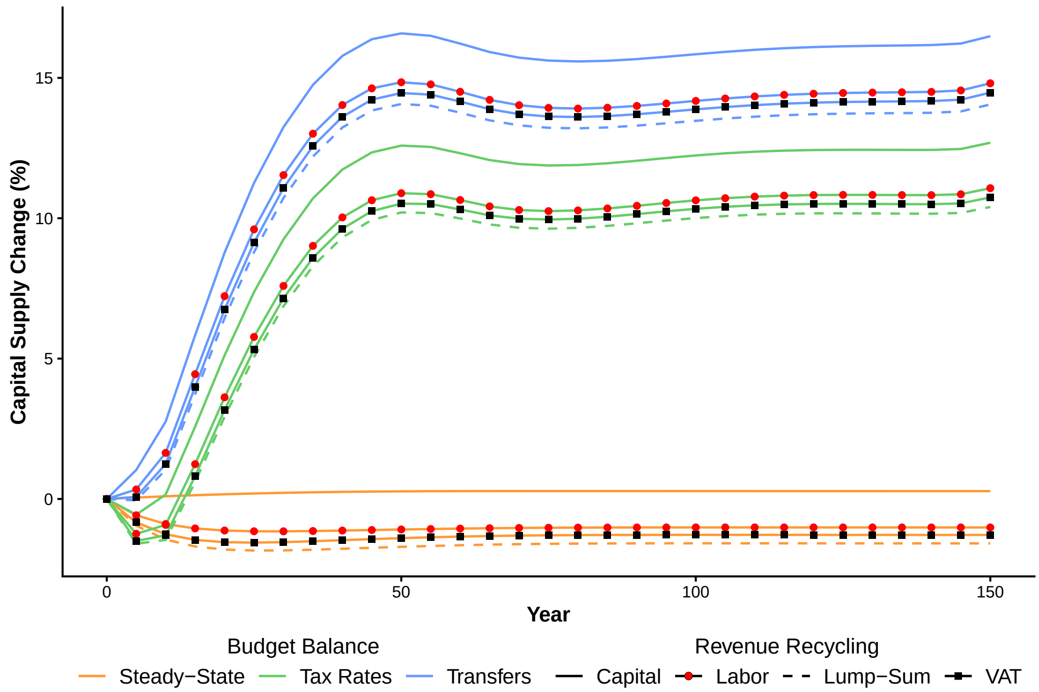

Figure 7: Capital supply responses to demographic change and cap and trade

Note: Each line shows the percent change in per capita capital supply by year relative to the steady state economy without carbon pricing (scenario A). The yellow series reports the change when a cap and trade policy with revenue recycling is introduced in an economy with constant population growth (scenario A to B). The blue and green series report the change when demographic change, pension budget balancing, and the same cap and trade policy with revenue recycling are introduced relative to the steady state baseline (scenario A to D). The two colors indicate whether the pension budget is balanced through higher tax rates (tax rates case) or lower pension benefits (transfers case). Within each color, different symbols distinguish the four revenue recycling options, where carbon revenues are used to reduce capital, labor, or consumption tax rates or are returned as lump sum transfers.

direct and interaction effects of demographic change, fiscal adaptation, carbon taxation, and revenue recycling. The differences between revenue recycling options appear small relative to the changes from demographic change. Figure 8 changes the base of the percent change calculation to scenario C for the blue and green series. This removes the direct effects of demographic change from the results, and isolates per capita welfare outcomes for adding the carbon tax and revenue recycling instruments. Any interaction effects between the carbon tax and revenue recycling instrument and the demographics profile are still present.

Figure 8 shows that the carbon tax in scenario D reduces labor supply below the levels in scenario C regardless of recycling instrument for all periods with the exception of labor and VAT recycling in the earliest years. Relative to Figure 6, this plot shows that interactions with demographic change and the budget balancing response can make the suppressing effect of the carbon policy on labor markets either more or less pronounced than in the steady-

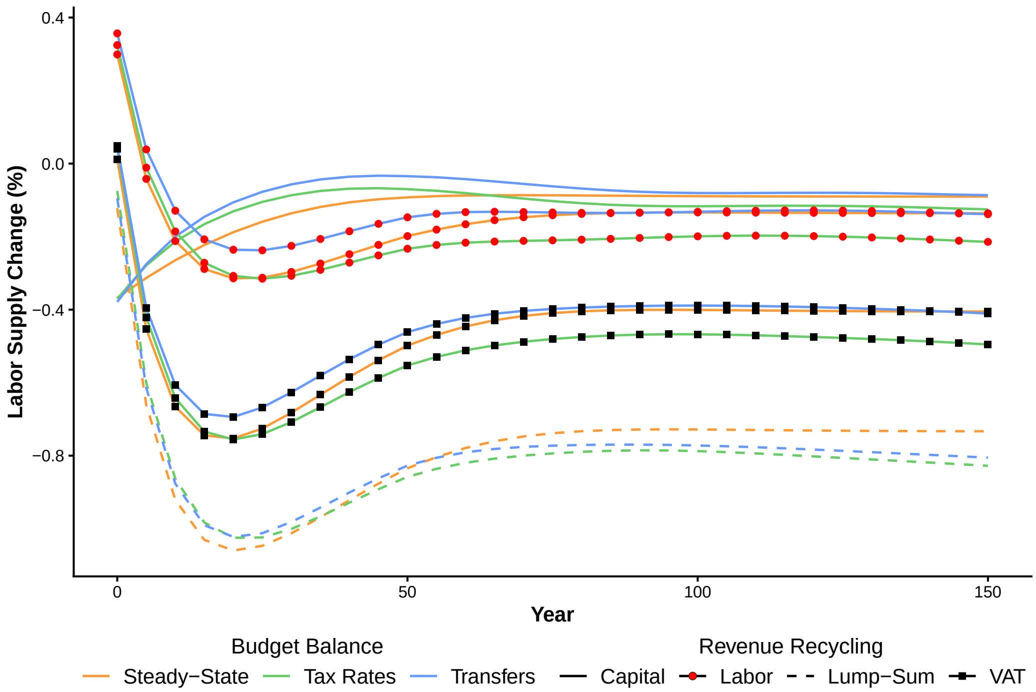

Figure 8: Isolating labor supply responses to cap and trade under alternative population paths

Note: Each line shows the percent change in per capita labor supply by year relative to a scenario without carbon pricing. The yellow series reports the change when a cap and trade policy with revenue recycling is introduced in an economy with constant population growth, measured relative to the steady state baseline without carbon pricing (scenario A to B). The blue and green series report the change when the same cap and trade policy with revenue recycling is introduced along the demographic path, measured relative to the demographic baseline without carbon pricing (scenario C to D). Using the demographic baseline removes the direct effect of population aging and pension budget balancing and isolates the additional impact of the carbon tax and revenue recycling instruments under demographic change. The two colors again indicate whether the pension budget is balanced through higher tax rates (tax rates case) or lower pension benefits (transfers case), and different symbols within each color distinguish the four revenue recycling options.

state model, depending on the recycling instrument chosen. Reducing transfers and recycling through capital taxes results in higher labor supply levels than in the steady-state for all periods, while the effect is more mixed for other policy combinations. This highlights again the trend where labor supply recycling increases labor levels in the earliest periods when legacy capital stocks are still available, but increasing capital investments soon overtakes the value of reducing labor taxes to raise the marginal product of labor.

Figure 9 illustrates percent changes in capital supplies from scenario A to B and C to D. This plot shows that recycling carbon revenues to reduce capital taxes has the effect of increasing capital stocks. This is the only case of a sustained increase for either factor types in any of our scenarios. It is more pronounced for all periods in the transfers scenario, and earlier periods for the tax rates scenario. The increase in savings per capita is why labor

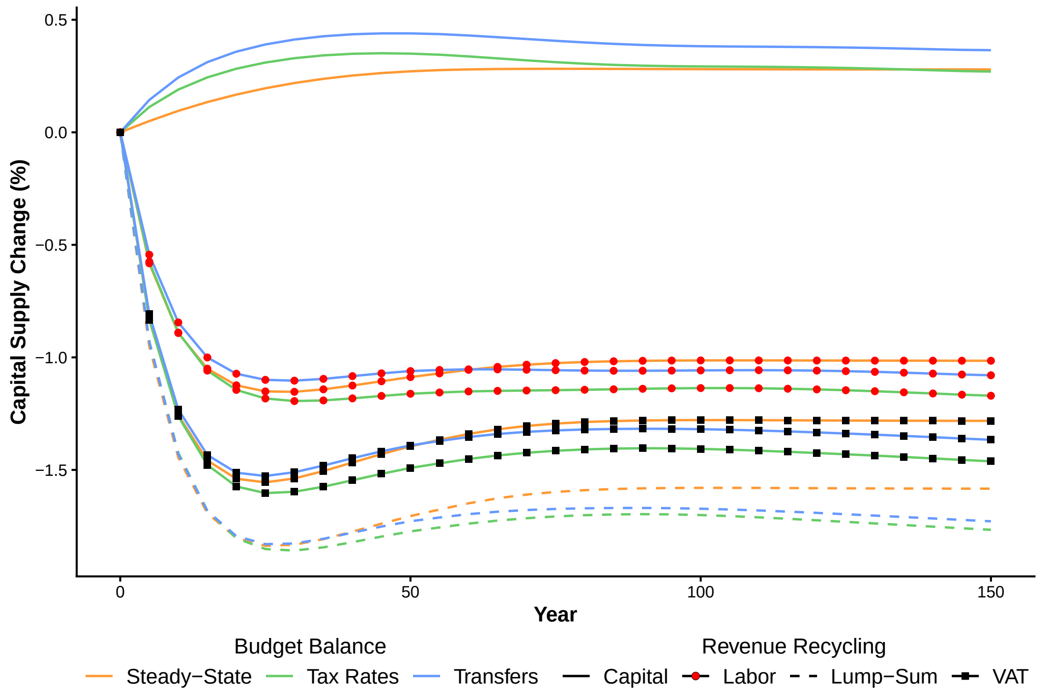

Figure 9: Isolating capital supply responses to cap and trade under alternative population paths

Note: Each line shows the percent change in per capita capital supply by year relative to a scenario without carbon pricing. The yellow series reports the change when a cap and trade policy with revenue recycling is introduced in an economy with constant population growth, measured relative to the steady state baseline without carbon pricing (scenario A to B). The blue and green series report the change when the same cap and trade policy with revenue recycling is introduced along the demographic path, measured relative to the demographic baseline without carbon pricing (scenario C to D). Using the demographic baseline removes the direct effect of population aging and pension budget balancing and isolates the additional impact of the carbon tax and revenue recycling instruments under demographic change. The two colors again indicate whether the pension budget is balanced through higher tax rates (tax rates case) or lower pension benefits (transfers case), and different symbols within each color distinguish the four revenue recycling options.

supplies increase by more with capital tax recycling than labor tax recycling. The other instruments result in a reduction in savings as the cap-and-trade system causes distortions in capital markets that are not compensated by the other revenue recycling options. In a world with declining populations, where all factor supplies are becoming more scarce, the revenue recycling option that drives any factor supply up becomes more valuable than in a world with steady-state growth rates.

II. Welfare Changes

Our overlapping generations structure models welfare outcomes for each generation individually. Figure 10 presents the changes in lifetime welfare of each generation for the

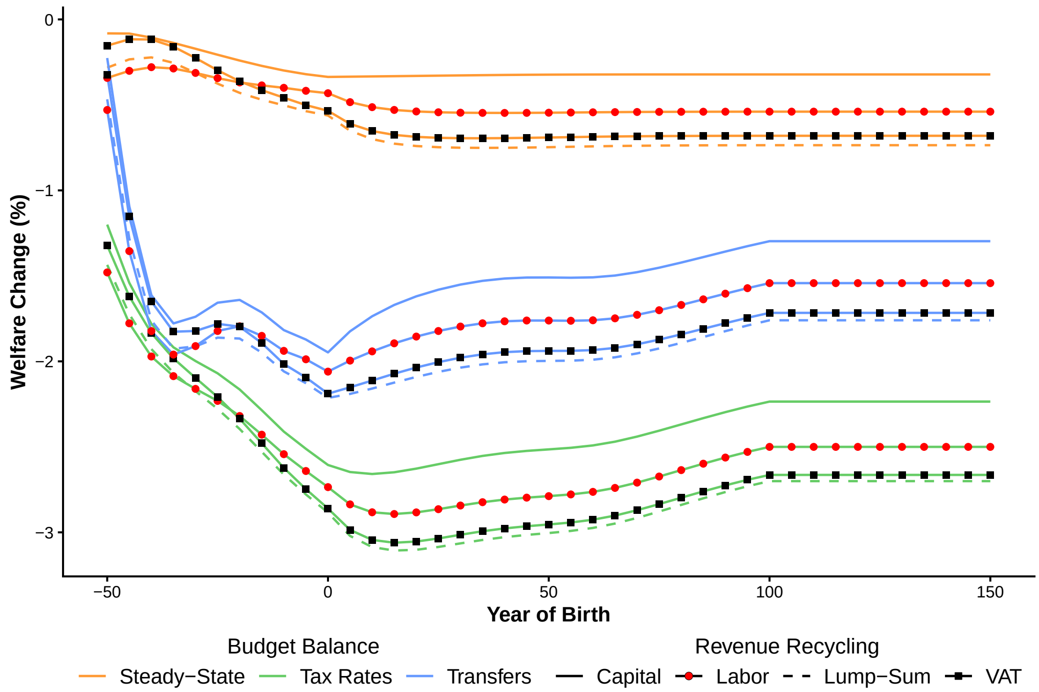

Figure 10: Lifetime welfare by generation under demographic change and cap and trade

Note: Each line shows the percent change in lifetime welfare per capita by generation relative to the steady state without carbon pricing (scenario A). The yellow series compares the steady state with and without cap and trade (scenario A to B). The blue and green series compare the steady state without carbon pricing to economies with demographic change, pension budget balancing, and cap and trade (scenario A to D), where blue denotes balancing through higher tax rates and green denotes balancing through lower pension benefits. Different symbols indicate the four revenue recycling options.

different combinations of budget balancing and carbon tax revenue recycling. Generations born in or near year zero, the year the budget balancing policy is implemented in the two demographics scenarios, experience the lowest welfare outcomes. These generations have not had the chance to accumulate assets in the pre-shock world, and live to enjoy relatively few of their years after the model has returned to equilibrium. The figure also shows that older generations benefit less from labor tax recycling relative to the other revenue recycling instruments as they depend primarily on savings and transfers for income. Generations are born in negative time periods so the model has one generation to represent each age group for a complete population in year zero. Overall, adapting to demographic change by reducing transfers and recycling carbon revenues through capital taxes yields the highest welfare outcome. This follows the factor supply changes discussed in the previous section. Households are spurred to compensate for the reduction in transfers, and face the least distortions in wage and rental rates in the transfers/capital scenario.

We can modify the base from scenario A to scenario C for the percent change calculation

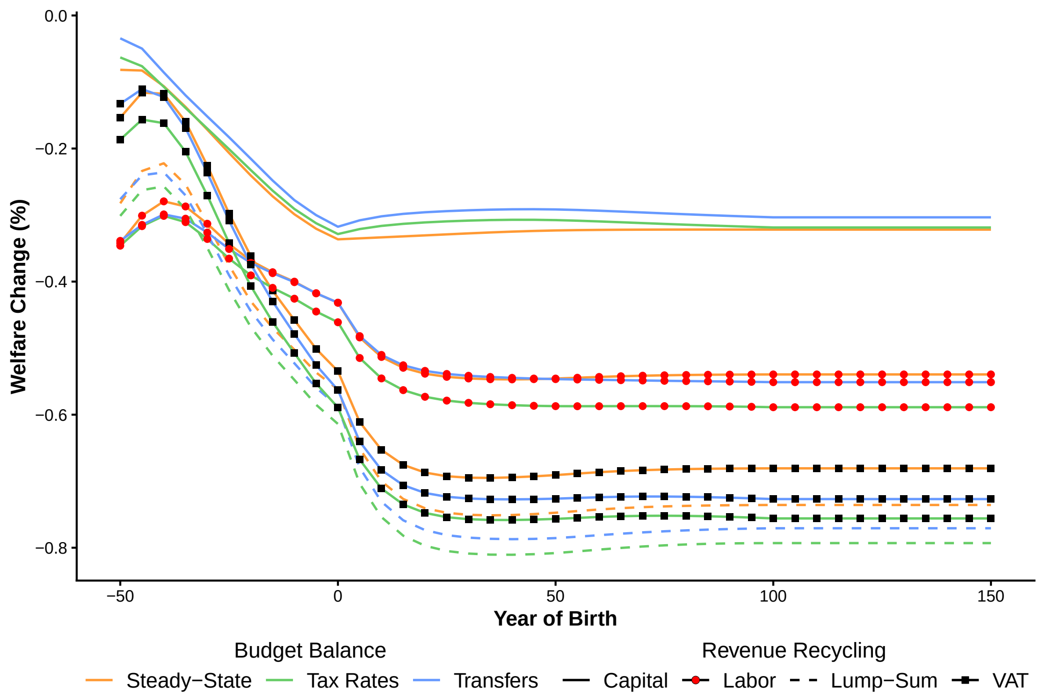

Figure 11: Isolating lifetime welfare responses to cap and trade under alternative population paths

Note: Each line shows the percent change in lifetime welfare per capita by generation, relative to a scenario without carbon pricing. The yellow series compares the steady state with and without cap and trade (scenario A to B), while the blue and green series compare the demographic economy with and without cap and trade (scenario C to D), so that demographic change and pension financing are held fixed. For the generation born in year 25, welfare costs are about 11 percent lower in the transfers with capital tax recycling case and about 9 percent higher in the tax rates with value added tax recycling case than in the corresponding steady state cases.

in the blue and green series for scenario D, as previously detailed for figure 8. This isolates per capita welfare changes due to direct effects of the carbon tax and revenue recycling options, and interaction effects with the new demographics profile and budget balancing option. Figure 11 identifies the welfare cost of implementing the carbon tax and recycling instrument in whatever world future decision makers inhabit; if they live in the steady-state or post-demographics worlds with a balanced budget, they will only be concerned with how the carbon tax interacts with their existing fiscal structure. This plot uncovers how welfare costs from models of carbon taxes accounting for demographic change compare to those that ignore it.

Figure 11 shows a similar ordering of welfare preferences for revenue recycling options in the steady-state and demographics scenarios. This is the classic result in the taxation literature, where reducing capital taxes reduces distortions by the most, and lump-sum transfers by the least. However, the welfare outcomes for capital tax recycling in the demographics

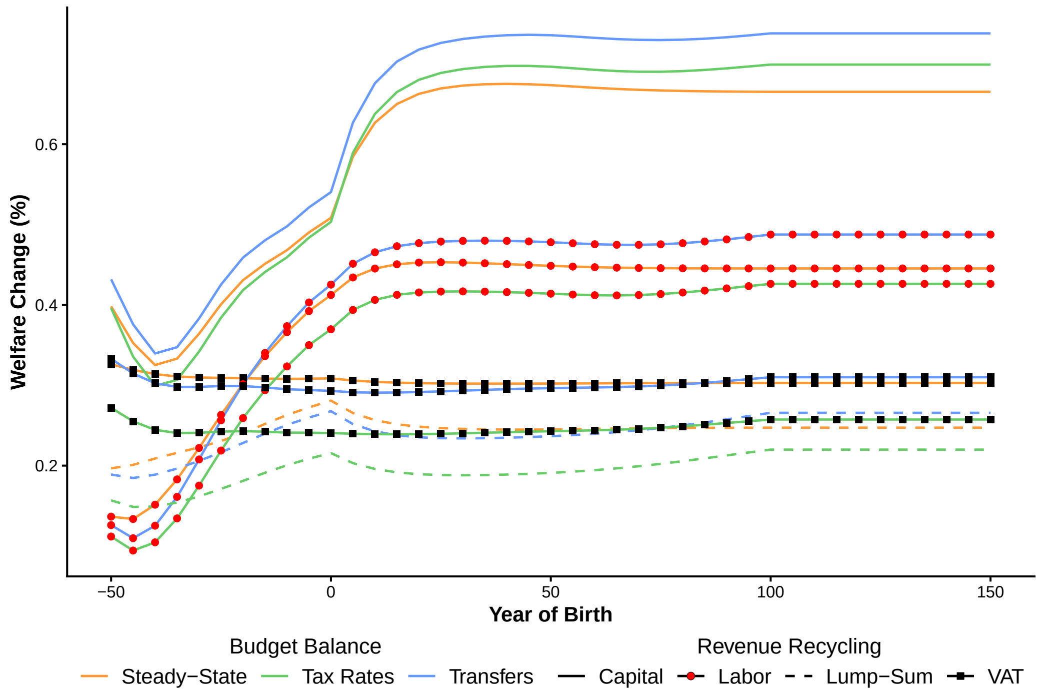

Figure 12: Lifetime welfare gains from recycling carbon revenues under alternative population paths

Note: Each line shows the percent change in lifetime welfare per capita by generation from a scenario with cap and trade and wasted revenues to a scenario with cap and trade and recycled revenues. The yellow series compares the steady state with wasted revenues to the steady state with revenue recycling (scenario B′ to B). The blue and green series compare the demographic economies with wasted revenues to the corresponding economies with revenue recycling (scenario D′ to D), where blue denotes pension budget balance through higher tax rates and green denotes balance through lower pension benefits. Different symbols indicate the four revenue recycling options.

scenarios are slightly higher than in the steady-state scenario. The percent difference between welfare outcomes for transfers/capital and steady-state capital is greatest for the generation born in year 25, where welfare costs are roughly 11% lower than those for the steady-state. The largest increase in costs is for tax rates/VAT which have roughly 9% higher welfare costs than the steady-state/VAT scenario. These differences follow the relative changes in factor supplies, and emphasize that demographic change and the budget balancing instruments magnify both positive and negative welfare changes. In a world where labor and capital markets are depressed by a declining population, and the marginal factor productivity is higher, capital tax recycling has larger benefits than in the steady-state world.

We can further isolate carbon pricing effects with another scenario where the carbon tax is implemented and revenues are wasted, B′ and D′. Now we are taking population growth rates *and* the existence of a carbon tax as given, and weighing the costs of different choices for how to use the revenue. Figure 12 presents the welfare changes from D′ to D and B′ to

B, which has several differences from Figure 11. First, the difference between the capital tax recycling scenarios are larger, particularly for later generations. This means that the higher welfare outcomes associated with the transfers option for scenario D in Figure 11 are primarily due to revenue recycling benefits, not lower welfare costs of the carbon tax. There is also a different ordering for later generations in the labor scenario, where welfare outcomes are higher in Figure 12 than Figure 11. This means that the welfare benefits of revenue recycling are higher for those generations relative to the steady state, but the cost of the carbon tax itself is also higher. There is a similar effect for VAT and labor. Overall, Figure 12 shows that revenue recycling is quite a bit more valuable for many instruments in the transfers scenario than the tax rates scenario.

4. Within-Generation Equity

How might households with different levels of income have different experiences of the cap-and-trade and budget balancing policies? Figure 13 illustrates income sources as a percent of total household income by income quintile in Japan. The larger share of wages and government transfers for lower-income households suggests they are affected differently by cuts in pensions and benefit less from capital tax recycling than higher-income households, who have a larger share of income coming from capital. We created a microsimulation of household finance following Williams et al. (2014) to understand how the policies we are modeling affect income groups differently. We take the after-tax price and quantity changes as outputs from the OLG model, and multiply those changes by the shares of income and expenditures for the different groups. This allows us to approximate disaggregated welfare results for each quintile.

We constructed our income share profiles for each quintile using survey data collected by Keio University and tax records from the National Tax Agency of Japan.[10] Using a mix of sources helps correct for under-reporting of capital income in survey data, and under-representation of low-income households in tax data. We weighted the survey data more heavily for low-income households, and the tax records more heavily for high-income households. The output of this process is the income shares shown in Figure 13. We conduct the same exercise of constructing expenditure share profiles using data from the Statistics Bureau of Japan.[11]

[10]We are using the Keio Household Panel Survey (KHPS), which can be accessed at the Panel Data Research Center at Keio University (https://www.pdrc.keio.ac.jp/en/paneldata/datasets/jhpskhps/) and the 148th National Tax Agency Annual Statistics Report: FY2022 for the tax data (https://www.nta.go.jp/publication/statistics/kokuzeicho/r04/R04.pdf). Both last accessed on September 10, 2025

[11]We use the 2019 version of the National Survey of Family Income, Consumption, and Wealth (https:

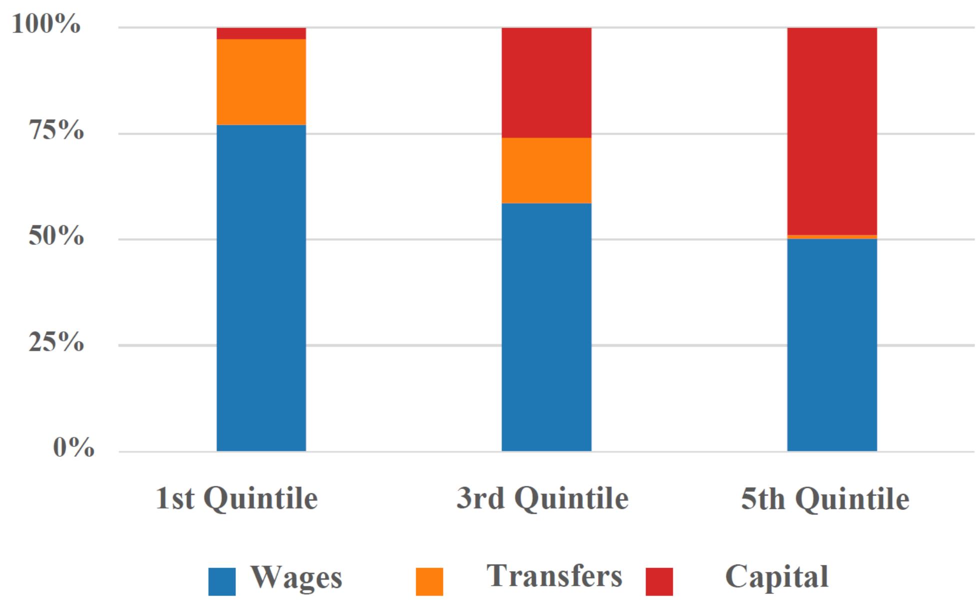

Figure 13: Share of income by source for each quintile

Note: Each bar shows the share of total income coming from wages, capital income, and public transfers for each income quintile. Higher income quintiles obtain a larger share of income from capital, while lower income households rely mainly on wages and public transfers.
Source: Keio Household Panel Survey and National Tax Agency Annual Statistics Report

By assuming linear supply and demand for the set of observed price and quantity changes, we can calculate the change in producer and consumer surplus for quintile k as

$$\Delta cs_i^k = \left[-\left(1+\frac{1}{2}\frac{\Delta q_i}{q_i}\right)\frac{\Delta p_i}{p_i}\right]\times\frac{x_i^k}{x^k} \qquad \Delta ps_j^k = \left[\left(1+\frac{1}{2}\frac{\Delta q_j}{q_j}\right)\frac{\Delta p_j}{p_j}\right]\times\frac{y_j^k}{y^k}$$

where the terms in brackets are the price and quantity changes for good i or income source j from the OLG model, and the fractions outside the brackets are the income and expenditure shares from survey and tax data. Income from the carbon tax and government transfers has no marginal cost changes or changes in price, so the producer surplus calculation for that income is exclusively the change in income. The total incidence for each quintile follows as:

$$\Delta W^k = \sum_i \Delta cs_i^k + \sum_j ps_j^k.$$

The change in welfare between scenarios A and D for each quintile in year zero of the model is shown in Figure 14. Lower income quintiles prefer labor recycling and lump-sum

//www.stat.go.jp/english/data/zenkokukakei/index.html). Last accessed on September 10, 2025

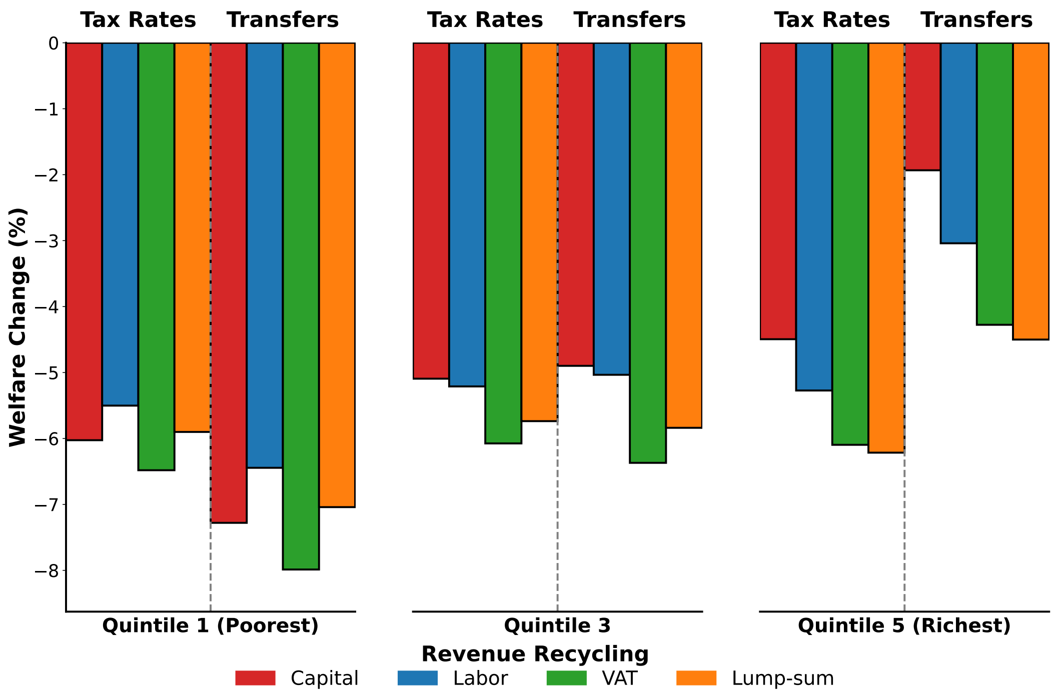

Figure 14: Change in welfare across income quintiles

Note: Each bar shows the change in welfare for the generation alive in year zero of the model, by income quintile, when moving from the steady state without carbon pricing to the economy with demographic change, pension budget balancing, and cap and trade with revenue recycling (scenario A to D). The figure compares welfare outcomes across income quintiles under alternative combinations of pension budget balancing instruments and carbon revenue recycling options.

transfers to capital tax recycling regardless of whether tax rates or transfers are used to adapt to demographic change. This follows from the large share of household income they receive from wages, which dominates the short-run efficiency gains they see in expenditures from capital tax recycling. At the same time, they are better off with most revenue recycling instruments under the tax rates response than the transfers response. Although the transfers regime represents a way to adapt to demographic changes that reduces distortions, the efficiency improvement is not enough to offset the outsized share of income that poor quintiles receive from government transfers relative to the other quintiles.

Looking further up the income spectrum, middle-income households have a slight welfare improvement with capital over labor tax recycling, and similarly, slightly better outcomes in the transfers scenario. They are comparatively less dependent than low-income quintiles on government transfers, and have larger capital stocks and expenditures to benefit from efficiency gains. Quintile 5 shows that the comparative advantage of the transfers scenario in the aggregated results in Figure 10 flows primarily to the richest households. This highlights a dynamic where the efficiency gains of reducing distortions on capital supply may have positive effects for society overall in the future, barring distributional issues. In the short-run, however, these gains accrue primarily to the wealthiest households. These results are only for the time period immediately following the implementation of the carbon pricing, so the long-run redistributive effects of the revenue recycling and budget balancing scenarios may change over time. It is possible that future low-income quintiles would prefer that the carbon tax had initially been used to lower capital taxes, and that demographic change had been addressed with pension cuts, as the compound growth of larger capital stocks can lead to substantially higher levels of welfare in the long-run. However, in the short-run, the welfare of low-income quintiles is clearly in tension with that of future generations.

5. Conclusion

This paper has examined how green fiscal reforms interact with demographic change in shaping the efficiency of carbon pricing, using Japan as a case study. We developed an overlapping generations computable general equilibrium model calibrated to Japan and combined it with a microsimulation of household finance. Together, these tools quantify aggregate and distributional consequences of carbon pricing in an economy where population aging and decline erode the tax base and strain the pension system.

Our results show that demographic change fundamentally alters the fiscal environment in which carbon pricing operates. The erosion of the tax base requires substantial fiscal reforms, either by raising existing tax rates or by reducing pension benefits. These adjustments have first-order effects on factor supplies and welfare. They largely determine how households respond to carbon pricing. In an aging and shrinking economy, the choice of pension budget balancing instrument and the recycling of carbon revenues can make the welfare cost of a given emissions reduction notably lower or higher than in an otherwise identical model with a constant population growth. In particular, combining pension benefit cuts with recycling of carbon revenues through lower capital taxes yields the largest efficiency gains, while financing demographic pressures through higher distortionary tax rates and recycling via value-added tax cuts produces higher welfare costs.

The analysis also highlights sharp distributional trade-offs across both generations and income groups. Across policy scenarios, cohorts that are alive when reform is implemented bear the largest welfare losses because they experience the transition but do not fully benefit from the new steady state. By contrast, later cohorts gain more from higher capital intensity and lower capital taxation under the more efficient policy combinations. The microsimulation of household finance further shows that these efficiency-enhancing policies are regressive within current cohorts: low-income households, who rely mainly on wages and public transfers and hold little wealth, face larger welfare losses than high-income households when pensions are cut, and carbon revenues are used to reduce capital taxes. In this sense, the policy combinations that are most efficient in the long-run and most favorable to future cohorts impose the largest short-run losses on low-income households in current generations. More progressive recycling options, such as labor tax cuts or lump sum transfers, better protect low-income households but deliver smaller aggregate efficiency gains, underscoring a trade-off between aggregate efficiency and short-run progressivity in the design of green fiscal reforms in aging economies.

Taken together, our findings imply that demographic change is not a secondary consideration in the design of carbon pricing. It is a key determinant of both the aggregate efficiency and the distributional incidence of green fiscal reforms. Analyses that abstract from demographic dynamics risk mismeasuring the welfare costs of carbon pricing and overlooking central trade-offs between efficiency, intergenerational equity, and within-generation progressivity. For aging economies contemplating carbon pricing, our results suggest that decisions about pension reform and revenue recycling must be made jointly with climate policy, rather than in isolation, if policymakers are to manage these trade-offs transparently and coherently.

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