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Political-Economic Aspects of Renewable Energy: Voting on the Level of Renewable Energy Support

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Summary: This paper investigates an intergenerational conflict arising from renewable energy support (RES). Using a simple polito-economic overlapping generations (OLG) model, it can be shown that old individuals unambiguously lose from renewable energy support and therefore vote for its minimum level. In contrast, young individuals benefit from positive environmental and consumption effects and, therefore, vote for a higher level of renewable energy support. The voting outcome is determined through a political process, whereby political parties converge to platforms that maximize the aggregate welfare of the electorate. Depending on the size of the exogenous parameters, the level of RES varies between the voting preferences of younger and older individuals. As a result, this model offers a good starting point for possible medium to long-term policy recommendations in order to increase the accepted level of RES.

Zusammenfassung: Dieses Papier untersucht einen Generationenkonflikt, der aufgrund der Förderung erneuerbarer Energien entsteht. Unter Verwendung eines einfachen polito-ökonomischen Modells sich überlappender Generationen kann gezeigt werden, dass die älteren Individuen durch die Förderung erneuerbarer Energien eindeutig schlechter gestellt werden und deshalb für ein minimales Niveau der Förderung stimmen. Im Gegensatz dazu profitieren die jungen Individuen von den positiven Umwelt- und Konsumeffekten und wählen deshalb ein höheres Niveau der Förderung. Das Abstimmungsergebnis wird im Rahmen eines politischen Prozesses bestimmt, wobei die politischen Parteien zu einer Plattform konvergieren, die aggregierte Wohlfahrt der Wählerschaft maximiert. Je nach der Größe der exogenen Parameter variiert das Niveau der Förderung erneuerbarer Energien zwischen den Präferenzen der jungen und alten Individuen. Als Ergebnis liefert dieses Modell einen guten Ansatzpunkt für mögliche mittel- bis langfristige Politikempfehlungen zur Erhöhung des von der jeweiligen Bevölkerungsgruppen akzeptierten Niveaus der Förderung erneuerbarer Energien.

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1. Introduction

The significant and continuous increase in CO2 emissions causes global warming which poses the risk of rapid, drastic changes in human and natural systems. In recognition of these issues, governments across the globe have set targets for carbon reduction.

Renewable energy provides one of the leading solutions to the climate change issue. However, renewable energy technologies are not cost-competitive with conventional technologies which have benefited for some considerable time from mass production and learning effects. In order to displace the use of fossil fuels, renewable energy technology needs to be promoted with supportive policies, leading to a rapid scale-up of these technologies. As a result, governments have set up a multitude of financial support schemes for renewable energy.

Although many people recognize climate change as a serious problem that warrants action, its public awareness and concerns can change rapidly due to effects caused by the renewable energy support.

According to Sundt et al (2014), renewable energy support is financed by the consumers either directly through a higher prices for renewable energy or indirectly through taxes, causing a negative effect in a short run.

However, renewable energy support either improves the environmental quality or decreases electricity market prices in a long run. These effects impact on population groups to different degrees, especially regarding age structure. Whereas younger individuals benefit from the long run effect, the group of older individuals faces only the negative short run effect.

In order to analyse these different effects, an overlapping generation model (OLG) can be applied. In each period t the population consists of young and old individuals. Facing the above described effects, each group has to vote on the level of renewable energy support in the period t. Older individuals lose unambiguously from renewable energy support and therefore favour a minimum level of support. As for younger agents, similar to the older individuals, on one hand they suffer from decreasing consumption due to this support. On the other hand they will benefit from a better quality of environment and increasing consumption in the period t+1 due to renewable energy support. Therefore they will vote for a higher level of renewable energy support.

Thus, there is an intergenerational conflict due to these contradictory interests. Since the policy preferences of the two politically active population groups diverge, voting outcome is determined through a political process, whereby political parties converge to platforms that maximize the aggregate welfare of the electorate.

The paper is organized as follows: Section 2 presents the literature review. The theoretical model is presented in Section 3. The first four subsections of the third section provide crucial assumptions of the model regarding the individuals, production, electricity market and environmental quality. Subsection 5 presents the voting outcome, while Subsections 6 and 7 present comparative statistics and policy recommendations, respectively, according to the theoretical model. Section 4 concludes.

2. Literature Review

Specifically concerning the environmental policy, a broad range of studies apply the OLG framework. Based on the degree of responsibility of the agents for the environment, two different kinds of models are distinguished.

On the one hand there are models without environmental maintenance where agents do not care about pollution and externalities are internalized by a social planner by means of taxes and transfers. Howarth and Norgaard (1992) presents a model where the externality, caused by pollution, does not affect agents' utility. Pollution is the by-product of firms' activity. There is no voluntary investment in environmental maintenance. This model suggests a social planner who maximizes the discounted sum of lifetime utility of all generations and sets a tax on energy consumption, in order to internalize the environmental externality. This emission tax has to be set equal to the marginal present-value cost that current energy use imposes on the future economy.

On the other hand, OLG models where agents' utility is affected by the environmental quality, and there is an environmental maintenance, are quite recent.

John and Pecchenino (1994) assumes that agents live two periods, working while young and consuming while old. The young allocate their wages between investment in capital and environmental quality. Investment in capital corresponds to consumption in the next period and degrades the environment bequeathed to future generations. Their investment in environmental quality improves the environment, but decreases the consumption in the next period. There is a potential conflict between economic growth and the environmental quality. John et al (1995) extends the model of John and Pecchenino (1994) and assumes that environmental maintenance is chosen by the government. They show that tax must be set by a long-lived planner who maximizes the utility of a representative generation, because policies pursued by short-lived governments fail to address the effects of today's choices on future generations.

Jouvet (1998) presents an OLG model of environmental externalities with "depollution technology" and uncertainty, where each agent can voluntarily contribute in order to reduce pollution by financing depollution activities. If an agent is sufficiently risk averse, voluntary contribution is a decreasing function of average efficiency of depollution technology.

Based on the models with environmental maintenance, there is a third block of models, which additionally analyse the impact of environmental quality on the longevity of individuals and vice versa.

Ono and Maeda (2001) refers to the models of John and Pecchenino (1994) and John et al (1995) and analyses, using an overlapping generations model with uncertain lifetimes, how aging affects the environment. They show that aging has two effects on the environment. Depending on the relative risk aversion with respect to consumption in old age, aging is either beneficial or harmful to the environment. If an agent is sufficiently risk averse, greater longevity results in the improvement of environmental quality. This means that under certain circumstances aging is not necessarily harmful to the environmental quality. Ono (2004) extends the model of Ono and Maeda (2001) by considering how the increasing power of the older individuals affects politically determined environmental quality. Focusing on greater longevity and a lower rate of population growth as sources of population aging, Ono (2004) shows that greater longevity leads to a reduction in environmental quality, whereas a lower rate of population growth leads to an increase in environmental quality.

Following John and Pecchenino (1994) and Ono and Maeda (2001), Mariani et al (2009) presents an OLG model, where the two-way causality between the environment and longevity is analysed. The key ingredient of the analysis is the fact that the survival of individuals until the last period is probabilistic and depends on the environmental quality. Anticipating this fact, agents invest in environmental care. It can be shown that a higher probability to be alive in the third period increases investment in the environment and reduces consumption. This implies that environmental conditions affect life expectancy and produce a positive correlation between longevity and environmental quality.

Jouvet et al (2007) investigates the impact of environmental quality on mortality by using a two-period OLG model, where longevity is influenced positively by health expenditure but negatively by pollution due to production. Under this setting, individuals choose how much to spend on health and do not internalize the impact of their decision on environmental quality. This model highlights that public intervention should take into account the multiple relationships between production, longevity and the environment, because these determine the corrections to be made by governments.

Tubb (2011) refers to Ono and Maeda (2001) and Ono (2004) by analyzing the relationship between population aging and environmental quality. Tubb (2011) assumes that individuals are taxed and that taxation revenue can be spent on either environmental investment or on transfers to the elderly. Aging increases the proportion of elderly individuals and therefore increases political pressure for the public planner to tilt the composition of public spending in favour of a transfer payment to the elderly. Since young individuals anticipate that greater longevity implies an increased return from such investment, ageing may simultaneously increase the young generation’s demand for environmental investments. There is a tension between the young and the older generation regarding their preferences for government expenditure.

3. Model

Though there are numerous theoretical contributions which analyse the environmental policy using the OLG framework, to the author's best knowledge, the existing literature has not paid sufficient attention to investigating the polito-economic voting outcome regarding the level of renewable energy support taking account of the short and long run effects.

To fill this research gap, a simple two-period polito-economic OLG model is introduced, which is based on the model by John and Pecchenino (1994).

3.1 Individuals

The population structure is based on that developed by John and Pecchenino (1994). The population consists of two groups, workers and retirees. At each time period t, a new generation appears. Each generation lives for two periods and is composed of L identical individuals. Workers are born in the period t and are denoted as L_t. Retirees are born in the period t-1 and denoted as L_{t-1}. There are two generations alive in any one period, the period in which they overlap.

According to John and Pecchenino (1994) young individuals are endowed with one unit of labour which they supply to firms inelastically. Each agent obtains wages. Working individuals allocate their income between current consumption , current savings and renewable energy support m_t.

Thus the budget constraint for a young agent in generation t is

$$w_t = c_t + s_t + m_t \tag{1}$$

Agents face tension between consumption and renewable energy support.

When old, individuals consume the return and support the renewable energy. The budget constraint for an old individual born in the period t is

$$c_{t+1} = (1 + r_{t+1}) s_t - m_{t+1} \tag{2}$$

Individuals born at date t have preferences defined over consumption and environmental quality in old and young age. Benefits, which occur in the period t+1, have to be discounted at the discount rate δ.

These preferences are represented by the following utility function:

$$U_t = U(c_t, Env_t) + \frac{1}{(1+\delta)} U(c_{t+1}, Env_{t+1}) \tag{3}$$

where Env_t describes the environmental quality in the period t and Env_{t+1} defines the environmental quality in the period t+1.

It is further assumed that either $U(c_t, Env_t)$ or $U(c_{t+1}, Env_{t+1})$ are twice continuously differentiable with

$$\begin{aligned} &\partial U/\partial c_t > 0,\ \partial U/\partial Env_t > 0, \partial^2 U/\partial c_t^2 < 0,\ \partial^2 U/\partial Env_t^2 < 0; \\ &\partial U/\partial c_{t+1} > 0,\ \partial U/\partial Env_{t+1} > 0, \partial^2 U/\partial c_{t+1}^2 < 0,\ \partial^2 U/\partial Env_{t+1}^2 < 0. \end{aligned} \tag{4}$$

3.2 Firm

The firm produces a homogeneous good, using capital *K*, labour *L* and energy *E* in each period. The neoclassical production technology is given by:

$$Y_t = F\left(K_t, L_t, E_t\right). \tag{5}$$

The production function has the usual neoclassical properties:

$$\frac{\partial Y_t}{\partial K_t} > 0,\ \frac{\partial Y_t}{\partial L_t} > 0,\ \frac{\partial Y_t}{\partial E_t} > 0, \frac{\partial^2 Y_t}{\partial K_t^2} < 0, \frac{\partial^2 Y_t}{\partial L_t^2} < 0, \frac{\partial^2 Y_t}{\partial E_t^2} < 0. \tag{6}$$

The profit of the firm in the period *t* is

$$\pi_t = p_t F\left(K_t, L_t, E_t\right) - w_t L_t - r_t K_t - p_t^E E_t. \tag{7}$$

Where p_t stands for the product price, w_t denotes wage, r_t stands for the interest rate and electricity prices are denoted as p_t^E .

The first-order conditions for profit maximization are

$$r_t = p_t \frac{\partial F\left(K_t, L_t, E_t\right)}{\partial K_t}, w_t = p_t \frac{\partial F\left(K_t, L_t, E_t\right)}{\partial L_t}, p_t^E = p_t \frac{\partial F\left(K_t, L_t, E_t\right)}{\partial E_t}. \tag{8}$$

The total consumption at time *t* is denoted as $C(t)$ and is given by

$$C(t) = \sum_{i=1}^{L_t} c_t^{young} + \sum_{i=1}^{L_{t-1}} c_t^{old}. \tag{9}$$

If the equality of the consumption ($c_t^{young} = c_t^{old} = c_t$) is assumed and perfect competition and market clearing are implied, it can concluded that

$$Y_t = (L_t + L_{t-1}) c_t \tag{10}$$

From this, it can be derived that

$$c_t = \frac{Y_t}{(L_t + L_{t-1})} = \frac{F\left(K_t, L_t, E_t\right)}{(L_t + L_{t-1})}. \tag{11}$$

3.3 Electricity Market

In each period *t* power generating plants are divided into two categories: those that use non-renewable fuels E_t^{NR} and those that use renewable fuels E_t^{RE} . It means that the electricity supply can be defined as following:

$$E_t = E_t^{NR} + \left(1 + \phi \frac{m_{t-1}}{w_{t-1}}\right) E_t^{RE}, \tag{12}$$

where the electricity from renewable energy sources can be enlarged due to the increase in the share of the renewable energy support m_{t-1} in the total wage w_{t-1} in the previous period *t-1*. The degree of renewable energy penetration on the electricity market is represented by ϕ, which is situated between 0 and 1.

It is further assumed that the electricity market is in equilibrium and the firm's electricity demand corresponds to the electricity supply.

If a Cobb-Douglas production function is assumed, the firm's electricity demand as an input factor can be derived from the profit function (7) and is given by

$$E_t = \left(\frac{p_t \left(1-\alpha-\beta\right) K_t^\alpha L_t^\beta}{p_t^E} \right)^{\alpha+\beta} . \tag{13}$$

The electricity market equilibrium corresponds to

$$E_t^{NR} + \left(1+\phi \frac{m_{t-1}}{w_{t-1}}\right) E_t^{RE} = \left(\frac{p_t \left(1-\alpha-\beta\right) K_t^\alpha L_t^\beta}{p_t^E} \right)^{\alpha+\beta} . \tag{14}$$

From this, it is possible to define the equilibrium electricity price:

$$p_t^E = \frac{p_t \left(1-\alpha-\beta\right) K_t^\alpha L_t^\beta}{\left(E_t^{NR} + \left(1+\phi \frac{m_{t-1}}{w_{t-1}}\right) E_t^{RE} \right)^{\frac{1}{\alpha+\beta}}} , \tag{15}$$

which corresponds in the next period to

$$p_{t+1}^E = \frac{p_{t+1} \left(1-\alpha-\beta\right) K_{t+1}^\alpha L_{t+1}^\beta}{\left(E_{t+1}^{NR} + \left(1+\phi \frac{m_t}{w_t}\right) E_{t+1}^{RE} \right)^{\frac{1}{\alpha+\beta}}} . \tag{16}$$

Considering this, it can be concluded that, due to an increasing supply of renewable energy as a result of renewable energy support, the electricity price in the period *t+1* will fall.

This result corresponds to *Fürsch et al (2012)* and *Ciarreta et al (2012),* stating that large scale deployment of renewable energy technologies may reduce wholesale prices, as the variable cost of some renewable generation technologies is low. This may lead to high cost plant being displaced in the merit order.

3.4 Environmental Quality

According to *John and Pecchenino (1994)* and *Ono and Maeda (2001)*, consumption results in environmental pollution which reduces the environmental quality. The term $\left(L_{t-2}+L_{t-1}\right)c_{t-1}$ is the aggregated consumption in the period *t-1*. The environmental quality is improved by an increase in the share of renewables in the energy mix. The share of renewable energy in the period *t* depends on the renewable energy support in the period *t-1* and is defined as $\left(1+\phi \frac{m_{t-1}}{w_{t-1}}\right)\frac{E_t^{RE}}{E_t}$.

Consequently, the environmental quality in the period *t* is defined as following:

$$Env_t = Env_{t-1} - \mu\left(L_{t-1} + L_{t-2}\right)c_{t-1} + \left(1 + \phi\frac{m_{t-1}}{w_{t-1}}\right)\frac{E_t^{RE}}{E_t};\ \mu > 0, \phi > 0 \quad (17)$$

However, individuals who live in the period *t* consider Env_t as exogenous, as they cannot influence it in the period *t*.

In analogy to Env_t, Env_{t+1} represents the environmental quality in the period *t+1* and is defined as following:

$$Env_{t+1} = Env_t - \mu\left(L_t + L_{t-1}\right)c_t + \left(1 + \phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}};\ \mu > 0,\ 0 > \phi > 1 \quad . \quad (18)$$

3.5 Voting

The two groups of individuals vote on the level of renewable energy support m_t by solving the respective maximisation problem. Due to the fact that the impact of renewable energy support on the electricity market is considered, an alternative approach is used. Contributing to the analysis by *John and Pecchenino (1994)*, which assumes that future consumption will be reduced due to an investment in environmental maintenance, the positive effect of renewable energy support on the production is considered.

Thus, the maximization problem faced by young individuals corresponds to

$$\max U^{young} = U\left(c_t, Env_t\right) + \frac{1}{\left(1+\delta\right)}U\left(c_{t+1}, Env_{t+1}\right) \quad (19)$$

subject to

$$w_t = c_t + s_t + m_t$$

$$c_{t+1} = \frac{Y_{t+1}}{(L_t + L_{t+1})} = \frac{F\left(K_{t+1}, L_{t+1}, E_{t+1}\right)}{(L_t + L_{t+1})}$$

$$E_{t+1} = E_{t+1}^{NR} + \left(1 + \phi\frac{m_t}{w_t}\right)E_{t+1}^{RE}$$

$$Env_{t+1} = Env_t - \mu\left(L_t + L_{t-1}\right)c_t + \left(1 + \phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}} .$$

Inserting the above constraints into (19), the corresponding utility function of young individuals is derived:

$$U^{young} = U\left(\left(w_t - s_t - m_t\right), Env_t\right)$$
$$+\frac{1}{\left(1+\delta\right)}U\left(\frac{F\left(K_{t+1}, L_{t+1}, E_{t+1}^{NR} + \left(1+\phi\frac{m_t}{w_t}\right)E_{t+1}^{RE}\right)}{\left(L_t + L_{t+1}\right)}, Env_t - \mu\left(L_t + L_{t-1}\right)c_t + \left(1+\phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}}\right). \tag{20}$$

The corresponding first-order condition is

$$\frac{\partial U^{young}}{\partial m_t} = -\frac{\partial U\left(\left(w_t - s_t - m_t\right), Env_t\right)}{\partial\left(w_t - s_t - m_t\right)} +$$
$$+\frac{1}{\left(1+\delta\right)}\cdot\left\{\phi\frac{1}{w_t}E_{t+1}^{RE}\frac{\partial U\left(\frac{Y_{t+1}}{\left(L_t + L_{t+1}\right)}, Env_t - \mu\left(L_t + L_{t-1}\right)c_t + \left(1+\phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}}\right)}{\partial\left(\frac{Y_{t+1}}{\left(L_t + L_{t+1}\right)}\right)}\frac{\partial\left(\frac{Y_{t+1}}{\left(L_t + L_{t+1}\right)}\right)}{\partial Y_{t+1}}\frac{\partial Y_{t+1}}{\partial\left(E_{t+1}^{NR} + \left(1+\phi\frac{m_t}{w_t}\right)E_{t+1}^{RE}\right)}\right.$$
$$\left.+\phi\frac{1}{w_t}\frac{E_{t+1}^{RE}}{E_{t+1}}\frac{\partial U\left(\frac{Y_{t+1}}{\left(L_t + L_{t+1}\right)}, Env_t - \mu\left(L_t + L_{t-1}\right)c_t + \left(1+\phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}}\right)}{\partial\left(Env_t - \mu\left(L_t + L_{t-1}\right)c_t + \left(1+\phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}}\right)}\right\} = 0. \tag{21}$$

Renewable energy support affects the utility function of young individuals through three channels.

On the one hand there is one negative effect, which arises due to a negative impact of m_t on the consumption in the period *t*.

On the other hand, young individuals face two positive effects. Due to the renewable energy support in the period *t*, there is an increase in renewable energy supply in the period *t+1*. According to (6), this will lead to an increase in production. Based on (10), an increase in production leads to a growing consumption in the period *t+1*. Thus, it can be concluded that renewable energy support leads to a positive consumption effect. Another possible explanation of the positive consumption effect in the period *t+1* might be a negative impact on the electricity prices due to renewable energy enlargement according to (16).

The second positive effect of renewable energy support is the improvement of the environmental quality in the period *t+1* according to (18). An increase in renewable energy support leads to a growing share of renewables in the energy mix and reduces CO_2 emissions.

Young individuals will vote for a level of m_t which balances out negative and positive effects so that $\partial U^{young} / \partial m_t = 0$.

Because the elderly cannot enjoy improvements in the quality of future environment and the benefits from the positive consumption effect in the period *t+1*, their maximization problem in period *t* is given by

$$\max U^{old} = U\left(c_t, Env_t\right) \tag{22}$$

subject to

$$c_t = \left(1+r_t\right)s_{t-1} - m_t .$$

Inserting the above constraint into the objective function, the utility function of older individuals is given by:

$$U^{old} = U\left(\left(\left(1+r_t\right)s_{t-1} - m_t\right), Env_t\right) . \tag{23}$$

In order to estimate the optimal level of m_t, retirees differentiate the above function in regard to renewable energy support:

$$\frac{\partial U^{old}}{\partial m_t} = -\frac{\partial U\left(\left(\left(1+r_t\right)s_t - m_t\right), Env_t\right)}{\partial\left(\left(1+r_t\right)s_t - m_t\right)} < 0 . \tag{24}$$

Since renewable energy support negatively affects consumption and utility of the retirees in the period *t*, they will unambiguously lose from renewable energy support and vote for a zero level of m_t .

Based on the derived results, there is an intergenerational conflict between generations alive in the period *t* arising from different attitude towards the renewable energy support. The corresponding effects which influence the preferences of population groups are summarized in the table below:

Table 1: Summary of effects and preferred level of renewable energy support

	Old individuals	Young individuals
Consumption effect (period *t*)	**<0**	**<0**
Environmental effect (period *t+1*)	-	**>0**
Consumption effect (period *t+1*)	-	**>0**
Voting preferences regarding m_t	$m_t^{old} = 0$	$m_t^{young} \geq m_t^{old}$

Because of the divergent preferences of the two politically active population groups, the workers and the retirees, policy choices are determined through a political process. Using a majority voting mechanism, the political voting outcome depends on the assumed size of the corresponding groups. *Gradstein and Kaganovich (2004)* states that since the old are always the minority, the policy preferences of the older generation will have no impact on political outcomes, if age is the only determinant of policy choices. The interests of older individuals will have no impact on political outcomes and the voting outcome will correspond to m_t^{young} . This is why using a majority voting mechanism in an OLG framework is problematic. Facing this problem, *Gradstein and Kaganovich (2004)* supposes that political parties converge to platforms that maximize the aggregate welfare of the electorate.

Given the sizes of the two constituent age groups, the aggregate welfare in the period *t* is defined by

$$U_t^* = \frac{L_{t-1}}{L_t + L_{t-1}} U^{old} + \frac{L_t}{L_t + L_{t-1}} U^{young}, \tag{25}$$

where $L_{t-1}/(L_t + L_{t-1})$ represents the share of old individuals in the total population and $L_t/(L_t + L_{t-1})$ denotes the share of young individuals in the total population.

The maximization problem corresponds to

$$\max U_t^* = \frac{L_{t-1}}{L_t + L_{t-1}} U^{old} + \frac{L_t}{L_t + L_{t-1}} U^{young} \tag{26}$$

subject to

$$w_t = c_t + s_t + m_t$$

$$c_t = (1 + r_t) s_{t-1} - m_t$$

$$c_{t+1} = \frac{Y_{t+1}}{(L_t + L_{t+1})} = \frac{F(K_{t+1}, L_{t+1}, E_{t+1})}{(L_t + L_{t+1})}$$

$$E_{t+1} = E_{t+1}^{NR} + \left(1 + \phi \frac{m_t}{w_t}\right) E_{t+1}^{RE}$$

$$Env_{t+1} = Env_t - \mu(L_t + L_{t-1}) c_t + \left(1 + \phi \frac{m_t}{w_t}\right) \frac{E_{t+1}^{RE}}{E_{t+1}}.$$

Substituting the above constraints into (26) and building the first derivative of U_t^* with respect to m_t, the following first-order condition is obtained:

$$\begin{aligned}
\frac{\partial U_t^*}{\partial m_t} = &-\frac{L_{t-1}}{L_t + L_{t-1}} \frac{\partial U\left(((1+r_t)s_t - m_t), Env_t\right)}{\partial\left((1+r_t)s_t - m_t\right)} + \frac{L_t}{L_t + L_{t-1}} \left(-\frac{\partial U\left((w_t - s_t - m_t), Env_t\right)}{\partial(w_t - s_t - m_t)} \right. \\
&+ \frac{1}{(1+\delta)} \cdot \left\{ \phi \frac{1}{w_t} E_{t+1}^{RE} \frac{\partial U\left(\frac{Y_{t+1}}{(L_t + L_{t+1})}, Env_t - \mu(L_t + L_{t-1})c_t + \left(1 + \phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}}\right)}{\partial\left(\frac{Y_{t+1}}{(L_t + L_{t+1})}\right)} \frac{\partial\left(\frac{Y_{t+1}}{(L_t + L_{t+1})}\right)}{\partial Y_{t+1}} \frac{\partial Y_{t+1}}{\partial\left(E_{t+1}^{NR} + \left(1 + \phi\frac{m_t}{w_t}\right)E_{t+1}^{RE}\right)} \right. \\
&\left.\left. + \phi \frac{1}{w_t} \frac{E_{t+1}^{RE}}{E_{t+1}} \frac{\partial U\left(\frac{Y_{t+1}}{(L_t + L_{t+1})}, Env_t - \mu(L_t + L_{t-1})c_t + \left(1 + \phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}}\right)}{\partial\left(Env_t - \mu(L_t + L_{t-1})c_t + \left(1 + \phi\frac{m_t}{w_t}\right)\frac{E_{t+1}^{RE}}{E_{t+1}}\right)} \right\} \right) = 0.
\end{aligned} \tag{27}$$

The aggregate welfare is affected by an increase in m_t through four channels. On the one hand, an increase in m_t decreases the consumption of old and young agents in the period *t* due to the tension between renewable energy support and consumption, which is described by the first two parts of the above term. On the other hand, a change in m_t improves environmental quality and increases consumption in the period *t+1*. These effects are expressed through the terms in curly brackets. Young individuals, who live in the period *t+1*, will benefit from these effects.

In order to choose an optimal level of m_t, negative and positive effects have to be balanced out so that $\partial U_t^* / \partial m_t = 0$. Under a certain constellation of exogenous parameters, the actual voting outcome is situated between the voting preferences of young and old individuals, concluding that $m_t^{young} \geq m_t^* \geq m_t^{old}$, because government takes into account the interests of both groups.

3.6 Comparative Statistics

The optimum level of renewable energy support depends on the size of exogenous parameter ϕ, discount rate δ and proportion of old $L_{t-1} / (L_t + L_{t-1})$ as well as young individuals $L_t / (L_t + L_{t-1})$.

Parameter ϕ describes the degree of renewable energy penetration on the electricity market and increases the level of renewable energy level.

A growth in $L_{t-1} / (L_t + L_{t-1})$ increases the proportion of elderly individuals in the population and thereby increases political pressure for the representatives to choose a lower level of renewable energy support, as older individuals unambiguously lose from an increase in renewable energy support. An increase in the proportion of older individuals can be explained by population aging. An opposite effect can be seen when $L_t / (L_t + L_{t-1})$ grows and increases the political power of young individuals, forcing the representative government to choose a higher level of renewable energy support.

The discount rate, δ, represents the time preference. An increase in δ means a higher preference for the present and therefore reduces the level of renewable energy support. Comparative statics can be summarized in the table below:

Table 2: Comparative statistics

Degree of renewable energy penetration on the electricity market	$\phi \uparrow \rightarrow m_t^* \uparrow$
Proportion of old individuals	$L_{t-1}/(L_t + L_{t-1}) \uparrow \rightarrow m_t^* \downarrow$
Proportion of young individuals	$L_t/(L_t + L_{t-1}) \uparrow \rightarrow m_t^* \uparrow$
Discount rate	$\delta \uparrow \rightarrow m_t^* \downarrow$

To summarize the above results, it can be shown that population aging and a higher preference for the present reduce the level of renewable energy support and therefore are harmful for the environmental quality, while a higher effectiveness of renewable energy support regarding the degree of renewable energy penetration leads to an increase in the level of support and is beneficial for the environment.

3.7 Policy Recommendations

Based on the comparative statistics presented in the table above, it is possible to sketch basic policy recommendations.

Considering the time preference and the population structure, they are country-specific and can be influenced only in the long run. The share of elderly in the overall population is typically determined by natural reproduction rates and immigration, whereby only the immigration rate is a variable that policy makers could influence. The political time preference δ could be affected by a change of government, particularly in the case of coalition governments.

Concerning the parameter ϕ, which measures the degree of renewable energy penetration on the electricity market, *UNEP (2013)* measures it by considering the share of the potential that is achieved for a given technology in a given year. According to *Painuly (2002)*, the potential of renewable energy technology refers to its technological, techno-economic and economic potential. Technological potential assumes that a technically feasible technology is used. The techno-economic potential implies that a technically feasible and economically viable technology is used in a competitive market. Economic potential is achieved when a technically feasible and economically viable technology is used in an environment free from market failures and distortions. The technological potential refers to the highest order of theoretically possible usage level, followed by techno-economic and economic potential. In order to increase the degree of penetration, it is necessary to move the current usage of renewable energy towards the technological potential or reduce the gap between technological and techno-economic potential. However, there are different obstacles that need to be overcome to achieve the technological potential. The major obstacles are market barriers, economic and financial barriers, institutional barriers, social barriers and technical barriers. Due to the fact that these barriers consist of several elements which vary across renewable energy technologies and countries, *Painuly (2002)* states that measures to overcome these barriers are specific to a country and a technology.

4. Conclusion

This paper investigated the voting behaviour of different population groups regarding the renewable energy support. It can be concluded that old individuals will vote for a minimum level of renewable energy support due to a negative consumption effect. Young individuals also face the negative consumption effect in the period t. However, they will choose a higher level of renewable energy support because they benefit from positive effects in the following period. Due to an increase in renewable energy support, they benefit from a better environmental quality and a higher consumption. Instead of using a majority voting mechanism, it is assumed that political parties converge to platforms that maximize the aggregate welfare of the electorate by choosing an optimal level of renewable energy support. Thus, the actual voting outcome is situated between the contradictory preferences of the older and younger individuals.

Extending the analysis by John and Pecchenino (1994), which states that there is a potential conflict between economic growth and the environmental quality, on the basis of this paper it can be shown that renewable energy support may create a positive impact on the future consumption.

Depending on the size of the exogenous parameters, the level of renewable energy support varies between the voting preferences of young and old individuals.

Based on the results of the model, it can be shown that population aging and a higher preference for the present reduce the level of renewable energy support and therefore are harmful for the environmental quality, whereas a higher effectiveness of renewable energy support regarding the degree of renewable energy penetration leads to an increase in the level of support and is beneficial for the environment.

This model offers a suitable starting point for possible medium to long-term policy recommendations in order to increase the public acceptance of renewable energy support.

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