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Summary

This paper investigates an intergenerational conflict arising from renewable energy support. Using a politico-economic overlapping generations (OLG) model, it can be shown that older individuals unambiguously lose from renewable energy support and therefore vote to keep it at a minimum level. In contrast, younger individuals face ambiguous effects arising from renewable energy support. In the short run, they also lose from a negative consumption effect. In the long run, however, younger individuals benefit from a positive environmental effect. Renewable energy support also generates both positive and negative effects on consumption. The voting outcome is determined through a political process, whereby political parties converge to platforms that maximize the aggregate welfare of the electorate.

Zusammenfassung

Dieses Papier untersucht einen Generationenkonflikt, der aufgrund der Förderung erneuerbarer Energien entsteht. Unter Verwendung eines einfachen polit-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 sind die jungen Individuen mit einem nicht eindeutigen Effekt konfrontiert. In der kurzen Frist werden sie durch die Förderung erneuerbarer Energien genauso wie die älteren Individuen schlechter gestellt werden. Allerdings profitieren sie in der langen Frist von einem positiven Umwelteffekt und stehen unter bestimmten Bedingungen auch einem positiven Konsumeffekt gegenüber. Aus diesem Grund wählen sie 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.

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1. Introduction

In recognition of the challenges presented by climate change and global warming, governments across the globe have set targets for reducing carbon emissions, whereby renewable energy provides one of the leading solutions to the climate change issue (IPCC, 2011). However, a significant problem is that renewable energy technologies are not cost-competitive with conventional technologies, which have benefited for some considerable time from mass production and learning effects (Menanteau et al., 2003). In order to displace the use of fossil fuels, renewable energy technology needs to be promoted by means of supportive policies, leading to a rapid scale-up of these technologies (Gallagher, 2013). As a result, governments utilize a multitude of financial support schemes for renewable energy. However, renewable energy support depends on social acceptance, which is recognized as an important issue shaping the widespread implementation of renewable energy technologies (E. Moula et al., 2013). Although several empirical studies show high levels of public support for renewable energy technologies (AEE, 2016), this might change due to, amongst other things, economic and environmental effects (Akella et al., 2009). Since renewable energy support is financed by the consumers either directly through higher prices for renewable energy or indirectly through taxes, it causes a negative effect in the short run (Sundt et al., 2014). However, in the long run, on the one hand, renewable energy support might improve environmental quality and, on the other hand, decrease electricity market prices due to potential lower weighted average costs of electricity from renewable energy sources in comparison to estimated fossil fuel-fired electricity generation costs (Akella et al., 2009; IRENA, 2015). These effects influence population groups to different degrees, especially regarding age structure. Whereas younger individuals benefit from long-run effects, the group comprised of older individuals faces only a negative short-run effect. Indeed, Jäger and Schmidt (2015) deliver empirical evidence that older individuals tend to discount future payoffs more heavily than working-age individuals showing that there is a negative effect of population aging on public investment and renewable energy promotion, respectively.

In order to analyse the effects discussed above caused by renewable energy support on different population groups, an overlapping generations model (OLG) can be applied, which captures a potential interaction of different generations of individuals and might be used to identify their voting behaviour in regard to renewable energy support.

Since the main industrial countries are facing the challenge of demographic change, the aging of society might interact with public support for renewable energy, which makes the derived theoretical and empirical results also interesting from a policy perspective.

The paper is organized as follows: Section 2 is devoted to a review of the main literature in which OLG models are employed in the field of environmental economics. The theoretical model is presented in section 3. The first four subsections of the third section provide the crucial assumptions of the model regarding individuals, firms and environmental quality, while Subsection 4 presents the voting outcome. Section 4 delivers possible political implications and concludes.

2. A review of the theoretical literature

A broad range of studies specifically concerning environmental policy apply the OLG framework. Taking the degree of responsibility of the agents for the environment into account, two different kinds of models can be distinguished.

On the one hand, there are models without environmental maintenance where agents do not care about pollution and social planners internalize externalities by means of taxes and transfers. Howarth and Norgaard (1992), for example, present a model where the externality, caused by pollution, does not affect agents' utility. A social planner sets a tax on energy consumption in order to maximize the discounted sum of the lifetime utility of all generations. Analysing the nexus between resource exhaustion and pollution within an OLG framework, Babu et al. (1997) suggest introducing a specific tax in order to correct the inefficiency caused by environmental degradation due to excessive fossil fuel consumption. Assuming that policies pursued by short-lived governments fail to address the effects of today's choices on future generations, John et al. (1995) investigate the effect of an environmental tax chosen by the long-lived planner who maximizes the utility of representative generations.

On the other hand, OLG models where agents' utility is affected by the environmental quality, and there is an environmental maintenance, have been developed more recently. Under the assumption that individuals live for two periods, working while young and consuming while old, and allocate their wages between investment in capital and environmental quality, John and Pecchenino (1994), for instance, investigate a potential conflict between economic growth and the environmental quality.

Based on the models with environmental maintenance, there are models which additionally analyse the impact of environmental quality on the longevity of individuals and vice versa. Ono and Maeda (2001) refer to John and Pecchenino (1994) and John et al. (1995) by analysing how aging affects the environment. Depending on the relative risk aversion with respect to consumption in old age, aging might be both beneficial and harmful to the environment. Ono (2004) extends the model of Ono and Maeda (2001) and investigates the impact of the increasing power of older individuals on 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 environmental degradation, whereas a lower rate of population growth contributes to an increase in environmental quality. Following John and Pecchenino (1994) as well as Ono and Maeda (2001), Mariani et al. (2009) analyse causality between environmental quality and longevity. It can be shown that a higher probability to be alive in the latter period increases investment in the environment and reduces consumption. Referring to Ono and Maeda (2001) and Ono (2004), Tubb (2011) analyses the relationship between population aging and environmental quality. Under the assumption that individuals are taxed and that taxation revenue can be spent either on environmental investment or on transfers to the elderly, an aging population increases political pressure on the public planner to tilt the composition of public spending in favour of a transfer payment to the elderly. However, since young individuals anticipate that greater longevity implies an increased return from environmental investment, ageing increases the younger generation's demand for environmental investments. Thus, there is a tension between younger and older generations regarding their preferences for governmental expenditures.

3. Theoretical model

Although there are numerous theoretical contributions, which analyse environmental policy using the OLG framework, to the best knowledge of the author, the existing literature has not paid sufficient attention to investigating the politico-economic voting outcome regarding the level of renewable energy support. Extending Udalov (2014), this paper makes use of the overlapping generations framework suggested by John and Pecchenino (1994). However, in contrast to John and Pecchenino (1994), where individuals make investments in environmental maintenance, this paper investigates individuals' decisions regarding their contributions to renewable energy support. For this purpose a Cobb-Douglas production function with energy as an additional input is used, whereby the energy price level of the small open economy considered is assumed to be exogenous. Since old and young individuals live in the same time period, they simultaneously have to decide on their preferred level of renewable energy support. The main goal of this theoretical model is to identify possible effects of renewable energy support on different population groups.

3.1 Individuals

Following 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. Older individuals 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.

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 (c_t), current savings (s_t) and renewable energy support (m_t). Thus, the budget constraint for a young agent in the period t is

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

Agents face a trade-off between consumption and renewable energy support. When old, individuals consume the return from savings (s_t) and support 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 in the period 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. According to Ono (2009), these preferences are represented by the following utility function:

$$U_t = \ln c_t^1 + \ln Env_t + \frac{1}{(1+\delta)}\left(\ln c_{t+1}^2 + \ln Env_{t+1}\right), \quad (3)$$

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

Furthermore, individuals are assumed to be non-altruistic, which implies that the elderly do not care for the young and the young do not care for the elderly.

3.2 Firms

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

$$Y_t = K_t^{\alpha} L_t^{\beta} E_t^{1-\alpha-\beta}. \quad (4)$$

According to Bollino and Micheli (2011), energy (E) is produced, using two imperfect substitutes, namely fossil fuels (FE) and renewables (RE):

$$E_t = FE_t^{\gamma} \left(\sigma m_{t-1} RE_t\right)^{1-\gamma}, \quad (5)$$

whereby renewable energy support m_{t-1} from the previous period increases the amount of renewable energy as an input factor and σ denotes the effectiveness of renewable energy support.

The profit of the firm in the period t is

$$\pi_t = p_t K_t^{\alpha} L_t^{\beta} E_t^{1-\alpha-\beta} - w_t L_t - r_t K_t - p_t^E E_t. \quad (6)$$

Assuming a small open economy, which faces given wages (w_t), interest rate (r_t) and energy prices (p_t^E), each firm chooses labour (L_t), capital (K_t) and energy (E_t) to maximize its profits. Thus, the first-order conditions are

$$r_t = \alpha\, p_t K_t^{\alpha-1} L_t^{\beta} E_t^{1-\alpha-\beta}\,, \tag{7}$$

$$w_t = \beta\, p_t K_t^{\alpha} L_t^{\beta-1} E_t^{1-\alpha-\beta}\,, \tag{8}$$

$$p_t^E = (1-\alpha-\beta)\, p_t K_t^{\alpha} L_t^{\beta} E_t^{-\alpha-\beta}\,, \tag{9}$$

Where (7), (8) and (9) state that the firm hires labour, capital and energy until the marginal products equal the factor prices. Due to the assumed condition of perfect competition, these conditions imply factor markets clearing.

3.3 Environmental quality

According to John and Pecchenino (1994) and Ono and Maeda (2001), environmental quality is reduced by aggregate consumption but can be improved by renewable energy support. This mechanism is expressed as the formula:

$$Env_{t+1} = Env_t - \omega c_t + \pi m_t\,, \tag{10}$$

where Env_t is the quality of the environment in the period t. The term ωc_t, is the degradation of the environment as a result of the consumption in the period t, while πm_t measures environmental improvement as a result of renewable energy support.

3.4 Voting

The two groups of individuals vote on the level of contributions to the renewable energy support mt by maximizing the corresponding utility function with respect to mt. Thus, the maximization problem faced by young individuals corresponds to

$$\max U_t^{young} = \ln c_t^1 + \ln Env_t + \frac{1}{(1+\delta)}\left(\ln c_{t+1}^2 + \ln Env_{t+1}\right), \tag{11}$$

subject to

$$c_t = w_t - s_t - m_t\,,$$

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

$$r_{t+1} = \alpha\, p_{t+1} K_{t+1}^{\alpha-1} L_{t+1}^{\beta} E_{t+1}^{1-\alpha-\beta},$$

$$E_{t+1} = FE_{t+1}^{\gamma} \left(\sigma\, m_t RE_{t+1}\right)^{1-\gamma},$$

$$Env_{t+1} = Env_t - \omega c_t + \pi m_t.$$

Inserting the above constraints into (11), the corresponding utility function of young individuals can be derived as:

$$\begin{aligned} U_t^{young} &= \ln\left(w_t - s_t - m_t\right) + \ln Env_t \\ &+ \frac{1}{(1+\delta)} \ln\left(\left(1 + \alpha\, p_{t+1} K_{t+1}^{\alpha-1} L_{t+1}^{\beta} \left(FE_{t+1}^{\gamma}\left(\sigma\, m_t RE_{t+1}\right)^{1-\gamma}\right)^{1-\alpha-\beta}\right)\left(w_t - c_t - m_t\right) - m_{t+1}\right) \\ &+ \frac{1}{(1+\delta)} \ln\left(Env_t - \omega c_t + \pi m_{tt}\right). \end{aligned} \tag{12}$$

In order to determine the optimal level of m_t^{young}, the above function has to be differentiated with respect to renewable energy support:

$$\frac{\partial U_t^{young}}{\partial m_t} = -\frac{1}{c_t^1} + \frac{1}{(1+\delta)}\left(\frac{(1-\gamma)(1-\alpha-\beta)\frac{1}{m_t} r_{t+1} s_t - (1 + r_{t+1})}{c_{t+1}^2}\right) + \frac{1}{(1+\delta)}\frac{\pi}{Env_{t+1}} = 0 \tag{13}$$

Considering equation (13), renewable energy support affects the utility function of young individuals through four channels. In the period t, there is a negative effect $-1/c_t^1$ caused by the negative impact of m_t on consumption. In period t+1, young individuals face three effects. According to (10), there is an environmental improvement $\pi/(1+\delta)Env_{t+1}$ in period t+1 as a result of renewable energy support. However, renewable energy support has an ambiguous effect on consumption in period t+1:

$$\frac{1}{(1+\delta)}\left(\frac{(1-\gamma)(1-\alpha-\beta)\frac{s_t}{m_t} r_{t+1} - (1 + r_{t+1})}{c_{t+1}^2}\right) \tag{14}$$

On the one hand, according to (2), (5) and (7), renewable energy support increases an individual's consumption in the period t+1. On the other hand, since there is a trade-off between renewable energy support and savings in the period t, an increase in renewable energy support has a negative effect on consumption in the period t+1 due to (1) and (2). The overall effect of m_t on an individual's consumption in the period t+1 is positive if the following inequality condition is fulfilled:

$$(1-\gamma)(1-\alpha-\beta) > \frac{(1+r_{t+1})\,m_t}{r_{t+1}s_t}. \quad (15)$$

Thus, the effect of m_t on an individual's consumption in the period t+1 is positive if output elasticity of renewable energy is greater than the ratio of opportunity costs of renewable energy in the sense of lost consumption in the period t+1 to income on savings.

Younger individuals will vote for a level of m_t that balances out negative and positive effects so that $\partial U^{young} / \partial m_t = 0$. Since long-term effects, which occur in the future, are discounted to their present value, the voting outcome of young individuals is sensitive to changes in the discount rate δ, which represents the individual's time preference. A higher δ increases preferences for the present and has a negative effect on the level of renewable energy support.

As regards the elderly, they cannot enjoy future improvements in the quality of the environment and possible benefits from the positive consumption effect in the period t+1, since their maximization problem in period t is given by

$$\max U_t^{old} = \ln c_t^2 + \ln Env_t, \quad (16)$$

subject to

$$c_t^2 = (1+r_t)\,s_{t-1} - m_t.$$

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

$$U_t^{old} = \ln\left((1+r_t)\,s_{t-1} - m_t\right) + \ln Env_t. \quad (17)$$

In order to estimate the retirees' optimal level of renewable energy support, the above function has to be differentiated with respect to m_t:

$$\frac{\partial U^{old}}{\partial m_t} = -\frac{1}{c_t^2} < 0. \quad (18)$$

Since renewable energy support negatively affects the 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, each group in society has distinct preferences regarding the level of renewable energy support, which result in an intergenerational conflict between generations alive in the period t. 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** if $(1-\gamma)(1-\alpha-\beta) > \frac{(1+r_{t+1})m_t}{r_{t+1}s_t}$
Voting preferences regarding m_t	**= 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. However, Gradstein and Kaganovich (2004) states that since older individuals 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 the level of renewable energy support preferred by younger individuals. That is why using a majority voting mechanism in an OLG framework is problematic. Facing this problem, Gradstein and Kaganovich (2004) argue that political parties converge to platforms that maximize the aggregate welfare of the electorate. Thus, let us suppose a government which cares about the welfare of all living individuals by maximizing the aggregate utility function the period t:

$$U_t^* = (1-\mu)U_t^{old} + \mu U_t^{young}, \qquad (19)$$

where (1-μ) is equal to $L_{t-1}/(L_t+L_{t-1})$ and represents the share of older individuals in the total population. μ is equal to $L_t/(L_t+L_{t-1})$ and denotes the share of younger individuals in the total population.

The maximization problem corresponds to

$$\max U_t^* = (1-\mu)U_t^{old} + \mu U_t^{young}, \qquad (20)$$

subject to

$$c_t^2 = (1 + r_t)\, s_{t-1} - m_t \,,$$

$$c_t^1 = w_t - s_t - m_t \,,$$

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

$$r_{t+1} = \alpha\, p_{t+1} K_{t+1}^{\alpha-1} L_{t+1}^{\beta} E_{t+1}^{1-\alpha-\beta} \,,$$

$$E_{t+1} = FE_{t+1}^{\gamma} \left(\sigma\, m_t RE_{t+1}\right)^{1-\gamma} \,,$$

$$Env_{t+1} = Env_t - \omega c_t + \pi m_t \,.$$

Substituting the above constraints into (20) and building the first derivative of U_t^* with respect to m_t, the following first-order condition is obtained:

$$\frac{\partial U_t^*}{\partial m_t} = -(1-\mu)\frac{1}{c_t^2} + \mu\left[-\frac{1}{c_t^1} + \frac{1}{(1+\delta)}\left(\frac{(1-\gamma)(1-\alpha-\beta)\frac{s_t}{m_t} r_{t+1} - (1+r_{t+1})}{c_{t+1}^2}\right) + \frac{L_t}{L_t + L_{t-1}} \frac{1}{(1+\delta)} \frac{\pi}{Env_{t+1}}\right] = 0 \qquad (21)$$

The aggregate welfare is affected by an increase in m_t through five channels. On the one hand, an increase in m_t decreases the consumption of older and younger agents in the period t because of the trade-off between renewable energy support and consumption. On the other hand, in the long run, an increase in m_t improves environmental quality, but also has an ambiguous effect on consumption in the period t+1. These effects are faced by young individuals who benefit from future environmental improvements and face an unclear effect of renewable energy support on long-term consumption.

In order to choose an optimal level of m_t, negative and positive effects have to be balanced out, implying that $\partial U_t^* / \partial m_t = 0$. Since government takes into account the interests of both groups, the actual voting outcome is situated between the voting preferences of younger and older individuals. The key element, which influences the actual level of renewable energy support, is the proportion of old (1-μ) and young individuals (μ). A growth in the proportion of elderly individuals in the population increases the pressure on political 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 $\mu = L_t/(L_t+L_{t-1})$ grows and increases the political power of younger individuals, forcing the representative government to choose a higher level of renewable energy support (e.g. immigration could be such a mechanism, assuming that the average

age of immigrants is below that of the host country's population). This result goes in line with Tubb (2011) who states that aging increases the political pressure on the public planner to tilt the composition of public spending in favour of a transfer payment to the elderly.

4. Conclusion

This paper investigated the voting behaviour of different population groups regarding their renewable energy support. Based on the derived results of the overlapping generations model, it is possible to identify the following effects on individuals that are caused by renewable energy support: Due to a trade-off between renewable energy support and consumption, there is a negative consumption effect in the short-run. In the long-run, renewable energy support improves environmental quality. However, renewable energy support has an ambiguous effect on long-term consumption. On the one hand, there is a trade-off between renewable energy support and savings, so that an increase in renewable energy support has a negative effect on future consumption. On the other hand, renewable energy support has a positive impact on the amount of produced energy, which in the long run increases consumption. While the short-term effect influences both older and younger individuals, the long-term effects influence solely younger individuals. Following this line of argumentation old individuals will unambiguously lose from renewable energy support and vote for its minimum level. In the long run younger individuals might benefit from the positive environmental effect and an ambiguous consumption effect. Thus, based on the derived results, there is an intergenerational conflict between older and younger generations arising from different preferences regarding renewable energy support.

The limitation of the theoretical model is the assumption that there are no altruistic links between older and younger individuals. Incorporating the altruistic link between older and younger individuals would imply that children or grandchildren will inherit a better world, which also makes their parents better off - the benefit being a warm glow of satisfaction rather than direct benefits from improved environment or increased consumption. Although allowing altruism would increase the preferred level of renewable energy support, it would not influence the presence of the derived short- and long-term effects caused by renewable energy support. However, it should be acknowledged that incorporating altruism would indeed enrich the model. In order to address the assumption that the energy price level is assumed to be exogenous, the modelling of energy markets is another task for future research.

The theoretical results of this analysis could also be interesting from a policy perspective. Since older individuals unambiguously lose from renewable energy support and vote for its minimum level, information campaigns might be employed to address the fact that at least the descendants of elderly people would benefit from renewable energy. Furthermore, since positive long-term effects increase the level of renewable energy support amongst younger individuals, policy makers should increase the level of knowledge about and indeed perception of these effects amongst younger individuals by, for example, using awareness campaigns as well introducing environmental education into the school curricula.

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