

Steinkraus, Arne

Working Paper

Subsidizing human capital to overcome the green paradox: A demand-side approach

Economics Department Working Paper Series, No. 17

Provided in Cooperation with:

Technische Universität Braunschweig, Economics Department

Suggested Citation: Steinkraus, Arne (2016) : Subsidizing human capital to overcome the green paradox: A demand-side approach, Economics Department Working Paper Series, No. 17, Technische Universität Braunschweig, Institut für Volkswirtschaftslehre, Braunschweig

This Version is available at:

<https://hdl.handle.net/10419/146510>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



Technische
Universität
Braunschweig

Institut für
Volkswirtschaftslehre

Subsidizing Human Capital to Overcome the Green Paradox – A Demand-Side Approach

by
Arne Steinkraus

Economics Department Working Paper Series

No. 17

August 30, 2016

© Technische Universität Braunschweig,
Economics Department, 2016

Address

Institut für Volkswirtschaftslehre
Spielmannstraße 9
D38106 Braunschweig, Germany

Telephone

+49 531 391 2578

Website

<http://www.tu-braunschweig.de/vwl>

Fax

+49 531 391 2593

All rights reserved.

Any reproduction, publication and reprint in the form of a different publication, whether printed or produced electronically, in whole or in part, is permitted only with the explicit written authorisation of the TU Braunschweig, Economics Department, or the author(s).

The views expressed in this paper do not necessarily reflect those of the Economics Department or the TU Braunschweig.

The Working Paper Series seeks to disseminate economic research work by the TU Braunschweig Economics Department's staff and visitors. Papers by researchers not affiliated with the TU Braunschweig Economics Department may also be considered for publication to the extent that they have been presented at research seminars/workshops organised by the Department.

The working papers published in the Series constitute work in progress circulated to stimulate discussion and critical comments. Views expressed represent exclusively the authors' own opinions.

The Series is managed by the Director of the Economics Department, and an Editorial Board oversees the process of publication.

Subsidizing Human Capital to Overcome the Green Paradox – A Demand-Side Approach

Arne Steinkraus
TU Braunschweig

Abstract

This paper shifts the perspective of the recent green paradox literature towards the demand side. Based on a simple model, I show that a subsidy on input factors in a Cobb-Douglas production function may contribute substantially to postponing resource extraction into the future and, thereby, to limit the future costs of climate change. Specifically, indirect subsidies on human capital, such as investments in education, are plausible policy options to mitigate carbon dioxide emissions because it is robust to short-sighted incentives on the part of politicians and resource owners.

Keywords: Climate Change, Green Paradox, Subsidy, Demand-Side

JEL classification: Q38, Q54, Q58

Introduction

This paper makes an original contribution to the field of resource and environmental economics. It shifts the perspective of a recent strand of the green paradox literature towards the demand side by providing a simple model that analyses the intertemporal effect of subsidizing human capital as a (non-perfect) production input substitute for non-renewables.

Climate change has become one of the most severe problems facing mankind. Consequently, several policies have been discussed and introduced, although most of them were said to suffer from the green paradox. The term green paradox, stemming from Sinn (2008), describes policies that are intended to mitigate carbon dioxide (CO₂) but actually accelerate carbon production and CO₂ emissions in the short run because they only focus on the demand side and do not consider supply side effects. Specifically, policies that aim at emission savings far in the future (e.g., the Kyoto Protocol) provide incentives to resource owners to increase their current resource production. Therefore, during the last decade, much effort has been put into analysing the green paradox, as well as on the credibility and reliability of climate policies.

However, as already noted by DiMaria et al. (2013), the demand side of the resource market has been virtually ignored. Therefore, this study analyses the role of (non-perfect) input substitutes – resources and capital – in the production function on the demand side against the backdrop of climate change and the green paradox. I build a model in which resource owners and resource consumers strive to maximize their utility over time. Based on this model and by applying different numerical setups within a Vensim simulation, I show that even very low rates of time-varying and slightly increasing subsidies for human capital help reduce the total costs of climate change if resources, physical capital and human capital are considered as production inputs. This reduction in climate costs is achieved by an increase in the future marginal product of the resources that comes with postponed extraction and the flattening of the extraction path. Furthermore, I provide evidence that such a policy does not lead to a green paradox because the initial unit price of a resource increases and, thus, does not cause carbon leakage if this strategy is applied in only one part of the world. On the

contrary, a decreasing subsidy over time generates a green paradox because the ratio of the present to future marginal product of the resource increases.

The remainder of this paper is structured as follows: First, I provide a short overview of the relevant literature on the green paradox. Second, I describe the theoretical model and estimate the model using several input settings. Thereby, I show the effect of a subsidy on human capital on the extraction and price path, as well as on the avoided climate cost. Finally, I discuss the policy implications and state the main outcomes of this theoretical approach.

Overview of the literature

Among other policies, Sinn (2008) analyses the effect of an announcement of a carbon tax with a steeply increasing time path. He shows that the expectation of decreasing resource profits in the future induces resource owners to extract their dirty resources more rapidly in the present. This argument is in line with that of Sinclair (1994), who shows that a carbon tax must follow a decreasing time path. In addition to taxes on fossil fuels, subsidies on renewables have been subject to detailed analysis. Grafton et al. (2012) examine the way subsidies on renewable energy sources influence the extraction of non-renewables. They find that subsidies produce a green paradox if the supply curves of renewables are concave. Van Long (2013) examines the substitutability of renewables and non-renewables. He shows that technological improvements that increase substitutability produce higher present emissions because resource owners anticipate future shrinking demand. As noted by Hoel (2013), who analyses supply-side policies, the removal of high-cost reserves is accompanied by a flattening extraction path as long as a clean backstop technology is available. On the contrary, the removal of low-cost reserves from the extraction process may come with a rise in the extraction path and, thus, with an increase in early and total emissions. Hence, there is a possibility that even policies that directly limit the amount of reserves are subject to the occurrence of the green paradox.

Furthermore, technological innovations such as backstop technologies or carbon capture and storage (CCS), which have high potential to mitigate carbon emissions, have become subjects of the green paradox and related strands of literature. In a two-period model, Hoel and Jensen (2012) analyse the interdependence of renewable energy sources and CCS technologies under an imperfect climate policy. They find that, in terms of the green paradox, it is more desirable to see innovation on part of CCS technologies than on part of the renewables because resource owners are otherwise incentivised to increase their present production. This result is of high relevance because Steinkraus (2016) outlines that CCS technologies are already competitive with renewables even if a cradle-to-grave perspective is considered. Winter (2013, 2014) examines the effect of innovation regarding clean energy, as well as more efficient production technology and finds evidence for the so-called innovation green paradox because all kinds of innovations may increase the net damage resulting from global warming.

Despite a broad theoretical literature, DiMaria et al. (2013) find little empirical evidence regarding the green paradox because of constraints on the demand side, which are hard to overcome in the short run. Hence, they conclude that it is important to investigate the supply side and the demand side in an integrated model.

Model

It remains questionable whether influencing the price path of other input factors on the demand side, such as human capital, also leads to a green paradox or has the potential to cause sustainable, or at least a temporary decrease in, greenhouse gas emissions. One could think of the following ambiguous effect. An increasing subsidy on human capital leads to higher

inputs of human capital in the future. Consequently, the marginal product of the resource also increases. However, the price of the resource must still equal the marginal product and must increase with the relevant interest rate. Therefore, the future resource input either rises (in comparison to the no subsidy case) if the marginal product grows at a higher rate than the interest or decreases otherwise.

To analyse this effect, I proceed in two steps: First, I introduce a simple model that applies the Hotelling rule to the demand side. This demand side is supposed to represent a synthetic demand consisting of most resource-consuming industries. These industries produce final goods by means of a Cobb-Douglas function similar to that in Stiglitz (1974). Second, I use Vensim to estimate this model using different parameter settings. By doing so, I show the time path of resource extraction, as well as the price path for two different scenarios: no subsidy on human capital and a slightly increasing subsidy. Finally, I compare the extraction rates of both scenarios to calculate the amount of climate change costs that can be avoided by applying the subsidy.

Positive analysis

On the supply side, there are many resource owners j in a competitive market who are all price takers and strive to maximize their total utility U over time t :

$$\max \int_0^{\infty} U(C_j) e^{-(\rho \cdot t)} dt, \quad (1)$$

where C denotes consumption, and ρ is the social discount rate. The resource owners are constrained by the following conditions:

$$\dot{S}_j = -R_j \quad (2)$$

$$\dot{V}_j = p \cdot R_j - C_j + s \cdot V_j, \quad (3)$$

where S is the stock, and R is the depletion of the resource. V denotes the assets of j that yield an interest of s . For simplicity, I neglect extraction costs because the results are quite similar. Applying the standard Hamiltonian approach, the fundamental Hotelling rule follows. The relative change in resource prices \hat{p} must equal the relevant interest rate:

$$\hat{p} = s. \quad (4)$$

On the demand side, producers of final goods d also strive to maximize their utility according to equation (1). However, they face different constraints. First, their capital stock increases via production $F(K, H, R)$ and investments I but decreases by the sum of spending for consumption, input factors (w denotes the wage for human capital H) and capital costs (c is the weighted average of the cost of capital, which is not required to but may equal s). Second, investments increase liabilities and equity LE .

$$\dot{K}_d = F(K_d, H_d, R_d) + I - C_d - p \cdot R_d - w \cdot H_d - c \cdot LE_d \quad (5)$$

$$\dot{LE}_d = I_d \quad (6)$$

Based on these constraints the Hamiltonian yields the following textbook-like conditions for the optimal path:

$$\frac{\partial F}{\partial K} = c, \frac{\partial F}{\partial H} = w, \frac{\partial F}{\partial R} = p. \quad (7-9)$$

Considering a decreasing returns to scale, ($\alpha + \beta + \gamma < 1$), Cobb-Douglas production function, $F(K, H, R) = K^\alpha H^\beta R^\gamma$, the price path of equation (4), constant capital costs and the possibility of a time-varying subsidy $T(t)$ on the cost of human capital, ($w(t) = w_0 - T(t)$), the three following conditions describe the optimal paths for capital, human capital and resource consumption:

$$\alpha \hat{K} + \beta \hat{H} + (\gamma - 1) \hat{R} = s \quad (10)$$

$$\alpha \hat{K} + (\beta - 1) \hat{H} + \gamma \hat{R} = \hat{w} \quad (11)$$

$$(\alpha - 1)\hat{R} + \beta\hat{H} + \gamma\hat{R} = 0. \quad (12)$$

Solving equations (10-12) for \hat{R} yields:

$$\hat{R} = -\frac{s \cdot (1 - \alpha - \beta) + \beta \cdot \hat{w}}{1 - \alpha - \beta - \gamma}. \quad (13)$$

Although subsidizing (human) capital is not said to have an impact on long-term economic growth (Groth and Schou 2007), it seems to be a relevant impact factor on the path of resource extraction. On the one hand, it becomes obvious that an increasing tax or a decreasing subsidy on human capital has a deteriorating effect on climate change because a positive \hat{w} causes a steeper extraction path. On the other hand, a subsidy on human capital that follows a bounded growth function, such as $T(t) = w_0 - w_0 \cdot e^{-k \cdot t}$, comes with relative change in net wages \hat{w} of $-k$ and may contribute substantially to flattening the extraction path. As a positive side effect, \hat{R} becomes a constant variable. Based on the transversality condition and $\frac{dR}{ds} = -\hat{R}$, the initial resource production can easily be computed by:

$$R_0 = S_0 \cdot \hat{R}. \quad (14)$$

Thus, as long as $k < \frac{s(1-\alpha-\beta)}{\beta}$ holds, the initial resource production decreases as k increases.

Resource Extraction, Climate Costs Avoided and Price Path

Allen et al. (2009) assume that the maximum global temperature increase depends on the total amount of CO₂ equivalent emissions but not on the time path of those emissions. However, the costs of climate change are higher the earlier the maximum increase is reached and the more rapidly the increase occurs (Hoel 2012). Consequently, a suitable way to limit the costs of climate change is to postpone extraction far into the future. To calculate the extent to which a subsidy on human capital can influence the extraction path and thereby the costs of climate change, I estimate a Vensim model using several input configurations.

In a first step, I compare the impact of a very low subsidy with $k = 0.005$ (since the subsidy follows a bounded growth approach, $k = 0.005$ means that net costs of human capital decrease approximately 5 per cent within ten years) on the extraction path and the remaining storage stock to the no subsidy scenario for four different output elasticity combinations (see Figures 1A-4A and 1B-4B). In all simulations, the interest rate s and costs of human and other capital are set to 0.1. The initial resource stock is assumed to be 1000. Based on the simulation results, it becomes obvious that resource extraction is lower in the case of subsidies for the first two to three periods. Consequently, during the early periods, I observe a significantly higher resource stock in situ. This effect becomes even stronger when the output elasticity of human capital increases.

In a second step, I measure the effect of delayed extraction on climate costs, which can be seen as the external effect of resource production. To do so, I follow Allen et al. 2009 and Hoel 2012 and use an approach similar to Sinn 2008. I assume that each unit of extracted resource causes short-run costs of climate change amounting to 1 unit per period after it has been extracted. Therefore, the sum of avoided external climate costs equals the integral of the difference between the resource stock in the cases with and without subsidies. The results for the different elasticities are shown in Figures 1C-4C. Again, the higher the output elasticity of human capital, the more costs of climate change can be avoided by applying the subsidy.

However, these positive outcomes only occur if there is no carbon leakage linked to the subsidy. Carbon leakage is a phenomenon that gives rise to a green paradox and may emerge if only some countries in the world attempt to reduce their carbon emissions, e.g., by introducing a subsidy while other countries do not. Because of unilateral mitigation strategies, the world price of carbon decreases and undermines carbon reduction attempts by shifting the

fossil fuel consumption towards non-compliant countries. This effect is said to be stronger in case of export-driven markets supporting mitigation policies (see, e.g., Barker et al. 2007, Hoel 2013). To control for possible leakage, I more closely examine the initial price levels of the resource in both cases. Based on Figures 1D-4D – which show the price difference in the subsidy and no-subsidy cases – it becomes obvious that $p(t = 0)$, and thus, the price level in all following periods is higher if a subsidy is introduced. Therefore, I conclude that a demand policy, as mentioned above, does not suffer from carbon leakage even if it is adopted only in some countries. In addition, this argument is not valid exclusively from a global perspective. The initial price increase reduces resource consumption in other sectors that cannot be captured within the assumed production function.

How the subsidy should be funded remains an open question. Hence, I checked whether a time path of the subsidy suggested above comes with a positive net welfare effect. The net welfare effect is defined as follows: *Climate Costs Avoided + Production Surplus – Costs of Subsidy*. Based on a Monte Carlo simulation strategy and some sensitivity checks, I find that the net welfare effect is most sensitive to the costs of climate change. In addition, after approximately two periods, the subsidy's impact on the outcome of production becomes positive. In total, even for very low external climate costs, the net welfare effect is positive. Consequently, it can be argued that the subsidy is likely to be self-financing.

Conclusions and Policy Implications

Based on a simple model, I extended the shift of the recent green paradox literature towards policy opportunities on the demand side. I showed that subsidizing other input factors of the production function, such as human capital, has the potential to substantially flatten the resource extraction path. This finding results from the higher future marginal product of resources. Furthermore, costs of climate change can be reduced by postponed carbon dioxide emissions. In contrast to other carbon mitigation strategies that have been widely discussed, such as higher taxes on carbon, a subsidy on input factors does not produce a green paradox. Higher initial resource prices prevent other nations or sectors from increasing consumption and, thus, greenhouse gas emissions.

However, similar to other policies that aim to minimize the dangers and costs of climate change, an increasing time path of a subsidy on input factors has both strengths and shortcomings. First, a subsidy can be considered more effective than a tax on carbon because no one can expect to avoid receiving a subsidy, whereas resource owners and producers of final goods try to avoid taxes. Second, although subsidizing input factors may be a political tender point, subsidizing human capital as an input factor might resolve this issue. Specifically, indirect subsidies, such as investments in education, are honoured by people and reduce the costs of human capital because firms do not need to exert much effort to further educate their employees. This argument is highly relevant because my results suggest that the effect of a subsidy on the extraction path is more pronounced when the output elasticity of human capital is higher. Thus, high technology sectors with well-educated and highly skilled workers should receive subsidies for educational investments. Third, another problem that may occur in context of subsidies involves credibility. Politicians always have incentives to cut subsidies on input factors to relieve budgetary pressure. This incentive is intensified by the fact that resource extraction falls, especially right after the start of a subsidy. The later extraction rates cannot be distinguished between the subsidy and no-subsidy cases. This is a crucial point because a cut in the subsidy comes with a higher present marginal product of the resource and, thus, deteriorates the ratio between the future and present marginal product. If resource owners anticipate this behaviour, they will increase today's extraction and accelerate global warming. On the contrary, this problem can also be cured by an indirect subsidy, such as investment in education. The results of investments in education come with a time lag and

have long lasting effects. Hence, these features prevent side effects from short-sighted political decisions and prevent premature resource extraction due to higher future marginal products of resource inputs.

Based on the model and outlined results, it is obvious that there is considerable potential on the demand side to mitigate carbon dioxide emissions without creating a green paradox. However, policies must still be chosen and applied thoughtfully because the threshold between real green policies and paradox-inducing policies is very small. More detailed analyses of the demand side are needed to guide politicians along green side of the threshold.

Information about the author:

Arne Steinkraus (a.steinkraus@tu-braunschweig.de) is research assistant at TU Braunschweig, Institute of Economics, Carl-Friedrich-Gauß-Faculty, Spielmannstraße 9, 38106 Braunschweig, Germany.

Acknowledgements:

I would like to thank Sandra Achten, Dennis Ebeling and, especially, Christian Leßmann for providing helpful comments.

References

- Allen, M. R. et al. (2009). Warming caused by cumulative carbon emissions towards the trillionth tonne. *Nature*, 458(7242), 1163-1166.
- Barker, T., Junankar, S., Pollitt, H., & Summerton, P. (2007). Carbon leakage from unilateral environmental tax reforms in Europe, 1995–2005. *Energy Policy*, 35(12), 6281-6292.
- DiMaria, C., Lange, I. & van der Werf, E. (2013). Going Full Circle: Demand-Side Constraints to the green Paradox. *Climate Policy and Non-renewable Resources – The Green Paradox and Beyond*, CESifo Seminar Series, 225-251.
- Grafton, R. Q., Kompas, T., & Van Long, N. (2012). Substitution between biofuels and fossil fuels: Is there a green paradox?. *Journal of Environmental Economics and Management*, 64(3), 328-341.
- Groth, C., & Schou, P. (2007). Growth and non-renewable resources: The different roles of capital and resource taxes. *Journal of Environmental Economics and Management*, 53(1), 80-98.
- Hoel, M. (2011). The green paradox and greenhouse gas reducing investments. *International Review of Environmental and Resource Economics*, 5(4), 353-379.
- Hoel, M., & Jensen, S. (2012). Cutting costs of catching carbon—intertemporal effects under imperfect climate policy. *Resource and Energy Economics*, 34(4), 680-695.
- Hoel, M. (2013). Supply Side climate policy and the green paradox. *Climate Policy and Non-renewable Resources – The Green Paradox and Beyond*, CESifo Seminar Series, 21-41.
- Sinclair, P. J. (1994). On the optimum trend of fossil fuel taxation. *Oxford Economic Papers*, 869-877.
- Sinn, H. W. (2008). Public policies against global warming: a supply side approach. *International Tax and Public Finance*, 15(4), 360-394.
- Steinkraus, A. (2016). Does Carbon Capture and Storage Lock People into Fossil Fuel Use? – A Cradle-to-Grave Analysis. 39th IAEE Conference Proceedings.
- Stiglitz, J. (1974). Growth with exhaustible natural resources: efficient and optimal growth paths. *The review of economic studies*, 41, 123-137.
- Strand, J. (2007). Technology treaties and fossil-fuels extraction. *The Energy Journal*, 129-141.
- Van Long, N. (2013). The Green Paradox und Imperfect Substitutability. *Climate Policy and Non-renewable Resources – The Green Paradox and Beyond*, CESifo Seminar Series, 59-85.
- Winter, R. A. (2013). Innovation and the Green Paradox. *Climate Policy and Non-renewable Resources – The Green Paradox and Beyond*, CESifo Seminar Series, 121-150.
- Winter, R. A. (2014). Innovation and the dynamics of global warming. *Journal of Environmental Economics and management*, 68(1), 124-140.

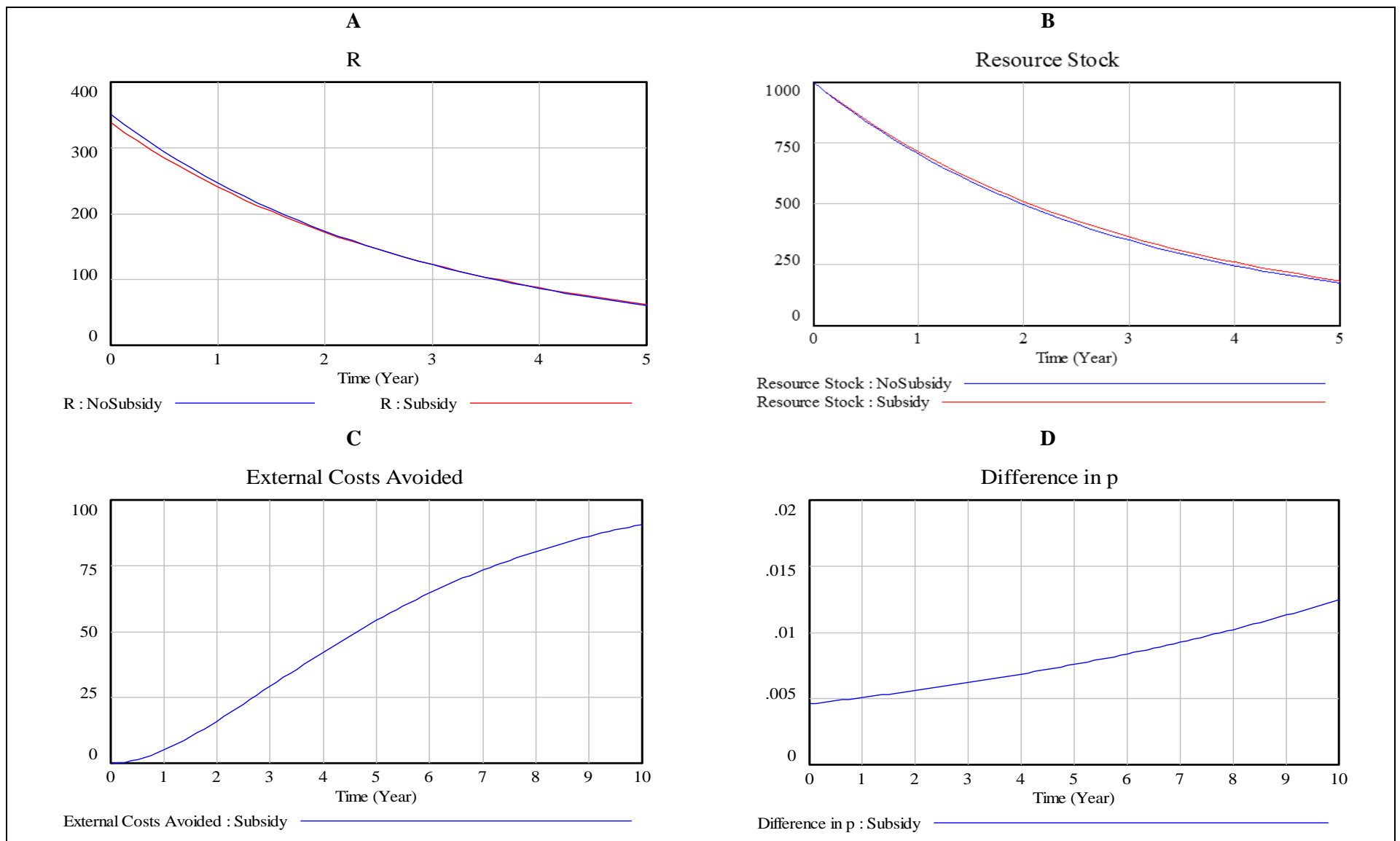


Figure 1: Simulation results with $\alpha = 0.4, \beta = \gamma = 0.25$. Source: Own calculations.

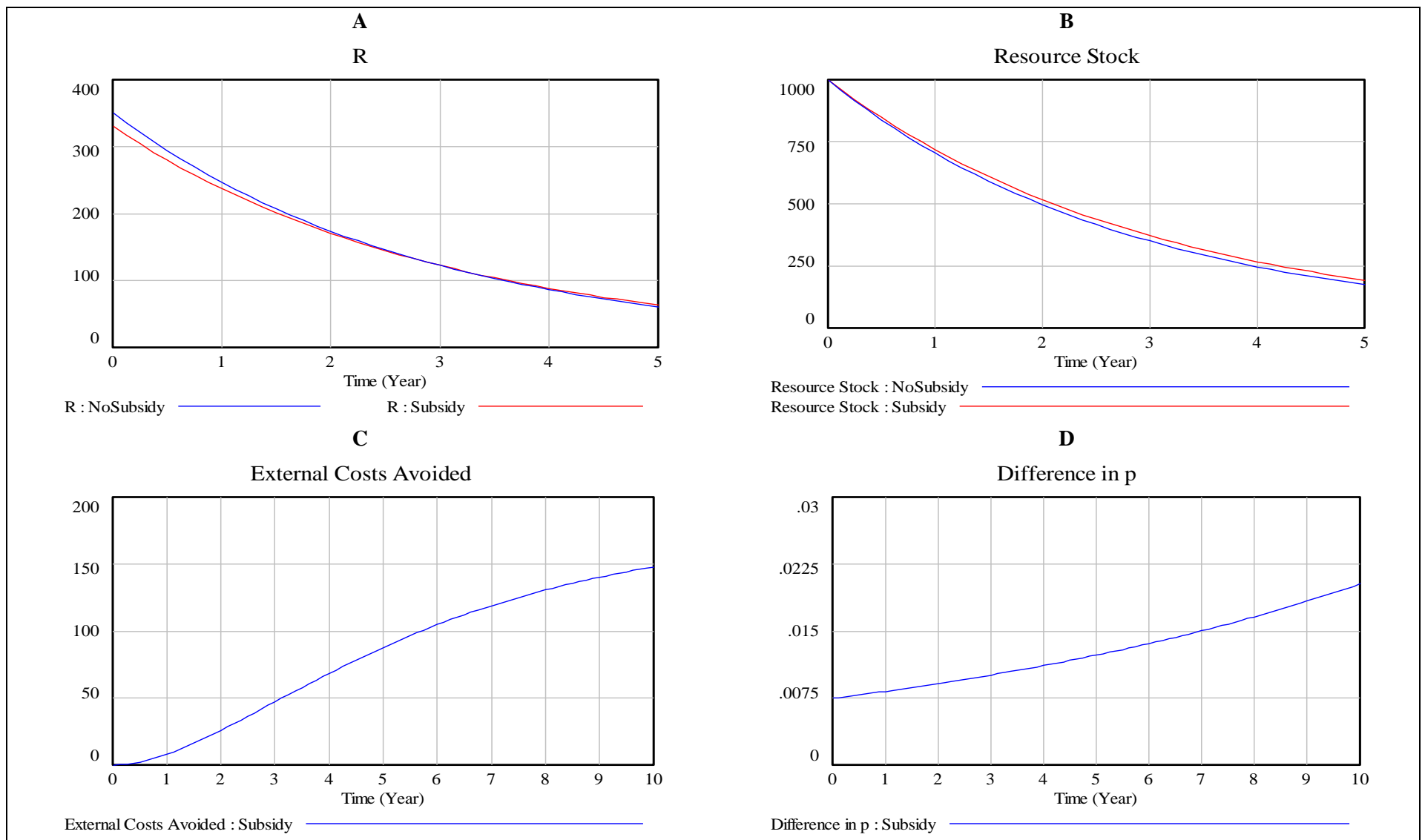


Figure 2: Simulation results with $\alpha = \gamma = 0.25, \beta = 0.4$. Source: Own calculations.

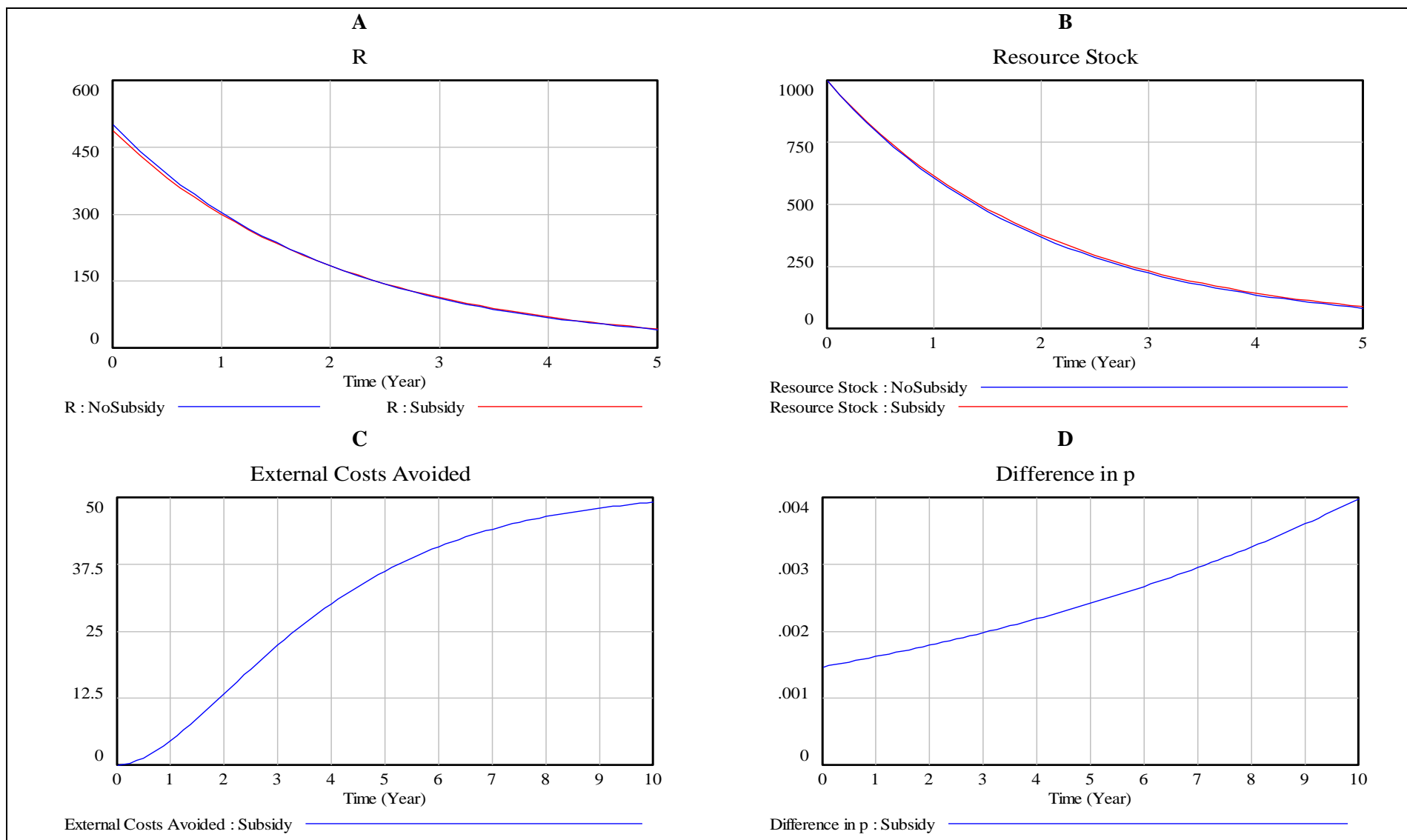


Figure 3: Simulation results with $\alpha = \beta = 0.25, \gamma = 0.4$. Source: Own calculations.

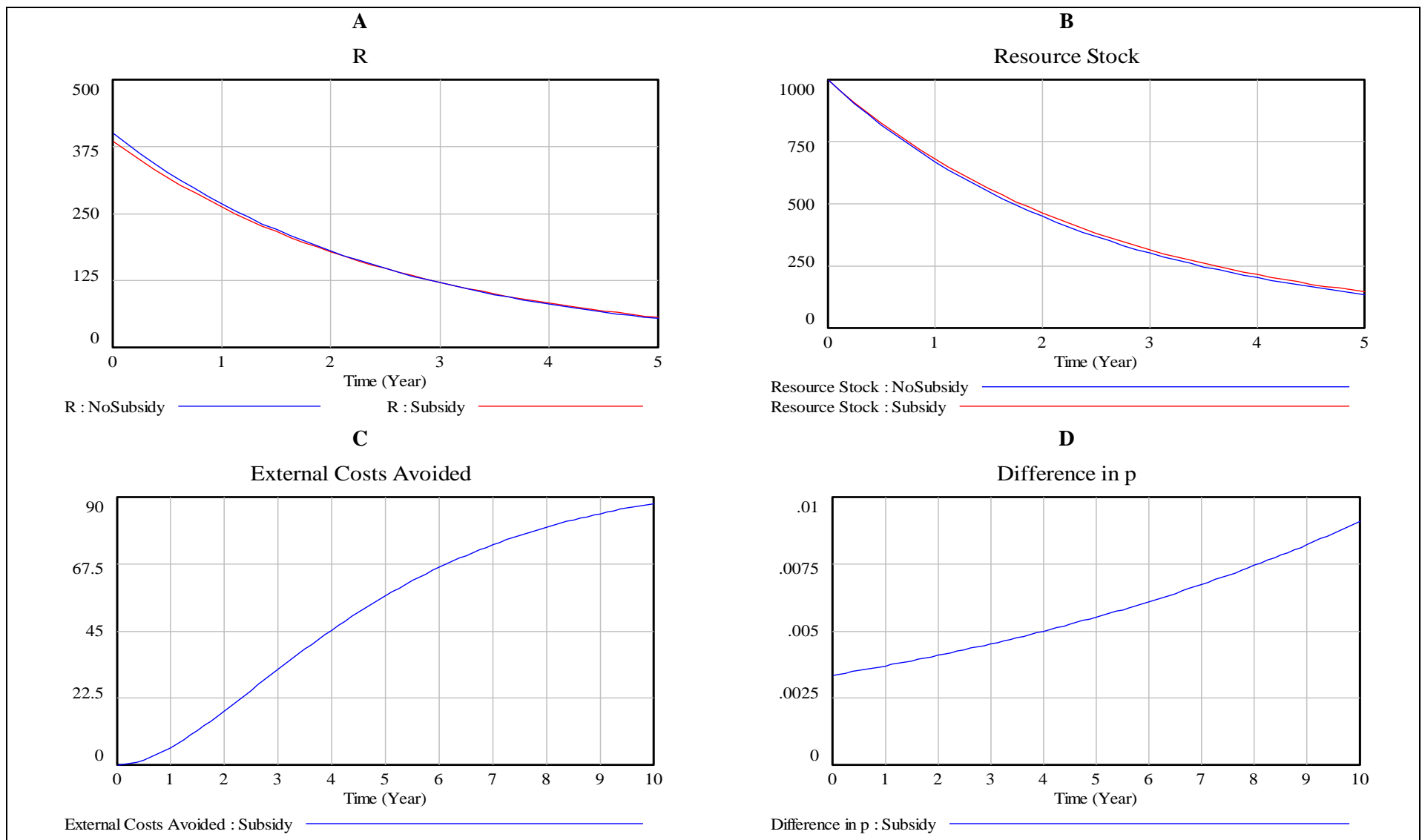


Figure 4: Simulation results with $\alpha = \beta = \gamma = 0.3$. Source: Own calculations.

TU Braunschweig, Economics Department, Working Paper Series

- 4 „Grandfather rights in the market for airport slots“
by Gernot Sieg, November 2008**
- 5 „Strategic Debt Management within the Stability and Growth Pact”
by Gernot Sieg and Ulrike Stegemann, April 2009**
- 6 „When to Regulate Airports: A Simple Rule”
by Uwe Kratzsch and Gernot Sieg, May 2009**
- 7 „Pakistan, Politics and Political Business Cycles”
by Irem Batool and Gernot Sieg, November 2009**
- 8 „Quality standards for passenger trains: Political majorities and environmental costs”
by Julia Rothbauer and Gernot Sieg, March 2010**
- 9 „Public Service Broadcasting of Sport, Shows and News as Economic Solution to the Voter’s Paradox of Rational Ignorance”
by Julia Rothbauer and Gernot Sieg, October 2010**
- 10 „A Full Participation Agreement On Global Emission Reduction Through Strategic Investments in R&D”
by Uwe Kratzsch, Gernot Sieg and Ulrike Stegemann, November 2010**
- 11 „An international agreement with full participation to tackle the stock of greenhouse gases”
by Uwe Kratzsch, Gernot Sieg and Ulrike Stegemann, July 2011**
- 12 „Welfare Effects of Subsidizing a Dead`End Network of Less Polluting Vehicles”
by Antje`Mareike Dietrich and Gernot Sieg, September 2011**
- 13 „Welfare Effects of Public Service Broadcasting in a Free`to`air TV Market”
by Julia Rothbauer and Gernot Sieg, September 2011**
- 14 “Coal and Gas – From Cradle to Grave with Carbon Capture and Storage
an Efficiency Analysis” by Arne Steinkraus, May 2016**
- 15 “Investigating the Carbon Leakage Effekt on the Environmental Kuznets
Curve Using Luminosity Data” by Arne Steinkraus, January 2016**
- 16 “Governmental platform intermediation to promote alternative fuel vehicles” by
Antje-Mareike Dietrich, May 2016**
- 17 “Subsidizing Human Capital to Overcome the Green Paradox – A Demand-Side
Approach” by Arne Steikraus, August 2016**

For a complete list of Working Papers published by TU Braunschweig,
Economics Department, please visit the Department’s website
(<http://www.tuFbraunschweig.de/vwl>)



©Technische Universität Braunschweig
Institut für Volkswirtschaftslehre
Telefon +49 531 391-2578
Telefax +49 531 391-2593
vwf@tu-braunschweig.de
www.tu-braunschweig.de/vwf